Navigating the Future: Digitalization, Sustainability, and International Business

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Preface

The contemporary challenges of the economies can be characterized worldwide by this phrase: green and digital transformation. While this transformation would be urgent due to climate change, the geopolitical, geoeconomic, and social obstacles are accumulating. In utilizing technological progress, the social acceptance of technologies is crucial. The current economic phenomena can be grasped from the aspect of global business in the framework of cross-country analyses. Global economic procedures and environmental issues entail a wide range of problems linked to sustainability and social responsibility.

This volume, "Navigating the Future: Digitalization, Sustainability, and International", collects studies which address these approaches. In the first part, the analyses focus on digitalization from the topic of autonomous technologies to digital marketing. The second part captures the macro-economic issues in a global context. The third part covers numerous areas of sustainability, from corporate social responsibility to waste management attitudes.

We hope readers will enjoy this rich selection of interesting studies and find insightful examinations.

Professor Beáta Farkas
Head of the Doctoral School in Economics

Chapter I

Digital Transformation and Technological Innovation

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Capturing autonomous technology acceptance with structured text and content analysis of social media comments

Miklós Lukovics

Today, the number of cities involved in the road tests of different autonomous vehicles is dynamically increasing. At the same time, it is becoming increasingly important to understand people's opinions about autonomous urban mobility. Although several social science studies address the acceptance of autonomous vehicles, most of the studies apply questionnaire methods. Furthermore, scarce information is available about how people formulate their opinion if there is no research framework, and they form their opinion spontaneously, especially in countries where the road test of autonomous vehicles is less common.
The main aim of the present study is to find out the free and spontaneous opinion of the Hungarian population regarding autonomous vehicles. The method is the analysis of Hungarian-language comments about autonomous vehicles on the most popular social media platforms (Facebook and YouTube): 1,690 comments of 10 posts in total are analyzed in the form of software-supported structured text and content analysis.

Keywords: autonomous urban mobility, comment analysis, self-driving car, autonomous urban delivery robot

1. Introduction

There are various estimations about whether autonomous vehicle-driven urban mobility will become a reality, and if yes, when it will be realized (Grindsted et al. 2022). Also, it is clear that the technological developments related to autonomous road vehicles have accelerated by now: the number of cities involved in public road testing and companies with road test permit is increasing (Zuti–Lukovics 2023). In January 2022, road tests took place in nearly 200 cities in the world, and in the state of California, up to 50 companies had road test permits while three of them also got permission to test cars without a steering wheel. The cars of Waymo offering robotaxi service have travelled over 7.14 million miles (about 11.5 million km) without a safety driver throughout the cities of the USA, having completed its 85% in the past one year. Thus, due to the speed of autonomous technology development, it is important to find out the public's opinion about autonomous vehicles, regarding which a large number of research results have been accumulated recently. The mostly questionnaire-based research papers identified which factors have higher and lower influence on technology acceptance (Keszey 2020). Wu et al. (2019) and Zhang et al. (2020) concluded that the ease of use perceived by the respondents does not play a significant role in the acceptance of autonomous technology. Koul and Eydgahi (2018), as well as Baccarella et al. (2020) found that perceived usefulness is the most important pillar of autonomous technology acceptance. Based on the results of Zhang et al. (2020), trust is a major factor of social acceptance. According to the findings of Acheampong and Cugurullo (2019), as well as of Panagiotopolous and Dimitrakopolous (2018),

subjective norms have an effect on perceived usefulness, perceived ease of use, and perceived safety. Nordhoff et al. (2020) found that hedonic motivation can be identified as the most important factor of autonomous technology acceptance. Hutchins and Hook (2017) showed that the majority of the respondents have concerns about autonomous vehicles: they questioned the safety of the vehicles, and they also expressed mistrust about the issue of legal responsibility and liability. König and Neumayr (2017), Liljamo et al. (2018), Audi–Ipsos (2019), and Havlíčková et al. (2019) identified markedly rejecting groups: women, elder people, people living in rural regions, and people with lower levels of education.

In Hungary, an increasing number of research results is published on social science issues regarding autonomous vehicles. The Hungarian researchers investigate self-driving cars' moral questions (Miskolczi et al. 2021), legal issues (Ambrus 2019, Kecskés 2020), relation with responsible innovation (Lukovics et al. 2018), effect on government budget and employment (Gyimesi 2019), effect on lifestyle and economy (Banyár 2019), relationship with cities (Lados–Tóth 2019, Smahó 2021), and social impacts and acceptance (Madarász–Szikora 2018, Szemerédi 2019, Majó-Petri–Huszár 2020, Csizmadia 2021, Páthy 2021, Nagy et al. 2022, Prónay et al. 2022, Palatinus et al. 2022, Lukovics et al. 2023). It is to be noted that the social science studies related to the social acceptance of autonomous vehicles are predominantly based on quantitative data which are collected with questionnaire surveys (Keszey 2020). At the same time, little is known about the opinions people form about autonomous vehicles if there is no research framework and they formulate their opinion spontaneously (Io et al. 2022). The spread of various social media platforms allows users to express their opinion publicly by publishing their ideas in the form of comments (Danner–Menapace 2020). They do it driven by their own motivation (i.e. without a researcher's elicitation), their publicly expressed opinion is not influenced by either a process or the effect of the researcher's physical or virtual presence (Branthwaite–Patterson 2011). The international literature includes some analyses on the social acceptance of autonomous vehicles conducted based on the analysis of social media comments (Kohl et al. 2017, Li et al. 2018, Liu et al. 2019, Pettigrew et al. 2019, Jefferson–McDonald 2019, Das et al. 2019, Io et al. 2022, Ding et al. 2021), but all of them analyze English-language comments, thus, scarce information is available about the opinion of Hungarian social media users. The main aim of the present study is to find out the free and spontaneous opinion of the Hungarian population regarding autonomous vehicles. To achieve this, an analysis is carried out on the Hungarian-language comments on the topic of autonomous vehicles on the most popular social media platforms (Facebook and YouTube), which is implemented in the form of software-supported structured text and content analysis. A total of 1,690 comments to 10 posts are studied.

2. Literature review

The increasing use of social media platforms allows people to express their opinions on social media (Cam et al. 2024), for example, on Facebook and YouTube. Social media has become widespread and important in terms of social networks and sharing opinion in the past years (Li et al. 2018). The millions of

entries and comments posted daily on Facebook, X, and YouTube are considered rich and informative data sources, which has attracted the attention of both academia and the industry (Ceron et al. 2014, Kulkarni–Rodd 2018). Comments are important sources of information about the users' emotions and opinion, which they express in the form of text (Porreca et al. 2020, Li et al. 2020, Chauhan–Meena 2019) or with the help of emojis (Tomihira et al. 2020). Comments enable the analysis of data to identify the opinions expressed in language, which can be revealed with difficulty otherwise (Palos-Sanchez et al. 2022). In this respect, understanding emotions in these opinions has become an important research topic, but the increasing quantity of these opinions makes manual processing very difficult, which has resulted in a need for automated processing (Cam et al. 2024). For this purpose, natural language processing and artificial intelligence techniques were applied to automatically analyze emotions (Nandi–Sharma 2021). The analysis of emotions is one of the most popular techniques in the computer-based analysis of people's thoughts and perceptions in a text (Lazarus et al. 2022). Several publications applied context analysis and data mining in different studies, for example, regarding online feedback on and satisfaction with hotels (Ríos-Martín et al. 2019, Saura et al. 2018), startups (Saura et al. 2019a), retail (Saura et al. 2019b), and disaster management (Khusna et al. 2023). Other articles present the role of social networks in studies which support recruitment measures in the development of user interface in mobile applications (Palos-Sanchez et al. 2018), especially in terms of the tourism sector (Palos-Sanchez et al. 2021). Furthermore, important research results were achieved from the analysis of comments related to cyber criminals and politicians (Lazarus et al. 2022), the analysis of comments related to American airlines (Rane–Kumar 2018), and the analysis of COVID-19 tweets (Kaur et al. 2021, Rustam et al. 2021, Rahman et al. 2021, Qorib et al. 2023, Osakwe et al. 2021). The latest advancements of autonomous vehicle technology have facilitated the emergence of autonomous vehicles in public interest, and autonomous vehicles have become a popular topic in social media (Li et al. 2018). Several extensive studies have been written to examine the social acceptance of, safety concerns about, and willingness to buy autonomous vehicles (Baccarela et al. 2020, Kovács–Lukovics, 2022, Cai et al. 2023). The quantitative data generated by the surveys describe the occasional concerns superficially rather than in depth (Pettigrew et al. 2019). Opinion mining based on data from social media and the latest techniques of text analysis offer new opportunities to address the disadvantages of traditional surveys (Io et al. 2022). Liu et al. (2019) emphasize that there is a limited number of studies which investigate people's subjective opinion about autonomous vehicles. In this context, Li et al. (2018) collected 50,000 comments from YouTube videos related to autonomous vehicles, highlighting that the study aimed to annotate the videos and the authors did not carry out detailed analyses. Das et al. (2019) analyzed the 15 most popular videos on YouTube related to autonomous vehicles, and the results suggested that the comments reflect a positive attitude. At the same time, the study used a small sample, and the analyzed comments were shaped by the videos. In terms of the analysis of social media, Kohl et al. (2017) conducted a long-term study to analyze tweets and categorized the tweets in different attitudes with the help of machine

learning. The results indicated a conservative attitude and showed that the acceptance of autonomous vehicles is still limited. Ding et al. (2021) rely on tweets and categorize emotions in the framework of a comprehensive model. The results show that the overall mood towards autonomous vehicles is positive, nevertheless, social media users may be emotionally biased about different autonomous vehicle terminologies. Pettigrew et al. (2019) collected people's opinions in a survey, and the results indicate that people focus on safety, while the safety of autonomous vehicles triggers mixed reactions. Jefferson and McDonald (2019) studied the tweets following the accident of the Tesla autopilot, and the results showed that people expect positive changes in the area of parking and environmental protection in the case of autonomous vehicles. Io et al. (2022) collected 10,374 comments related to autonomous vehicles from a microblog page, then they evaluated people's feelings and opinions. The results suggest that people's feelings are not only influenced by autonomous vehicles (e.g. their safety and comfort), but also by the effect of autonomous vehicles on society, such as unemployment and legislation.

3. Method and data

In order to achieve the research objective, primary research was conducted, implemented in the form of software-supported structured text and content analysis. During the process, Hungarian-language comments on Facebook and YouTube posts were analyzed. The social media posts involved in the study were selected based on the relevance of the topic and the number of comments. Specifically, I applied three criteria for post selection: the posts had to be about autonomous vehicles regardless of type (car, robot, truck, etc.), be in Hungarian, and have at least 50 comments. Due to the limited number of posts meeting these criteria, I relaxed the comment threshold for YouTube posts. This approach ensured that I included relevant and sufficient data for the analysis while addressing the scarcity of suitable posts. It was considered essential to include comments in the sample from the two most popular social media platforms, Facebook and YouTube, even though there is significantly less content available in Hungarian language on YouTube on the topic of autonomous vehicles. It was also considered important to see opinions about various types of vehicles, thus, the sample includes posts both about self-driving cars and autonomous urban delivery robots. The final data set included 10 posts and 1,690 comments in all, cf. Table 1.

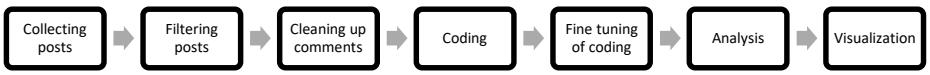
Table 1. Social media posts included in the analysis

Post title	Type	Author	Platform	Comment
Autonomous delivery robots will be tested in Debrecen	robot	Telex	Facebook	247
Level 4 autonomous driving may be closer than you think	car	Totalcar	Facebook	133
Mercedes gets new lights: turquoise is used when they go in a robot mode	car	Totalcar	Facebook	433
Would you pay 3.6 million more to let off the steering wheel?	car	Totalcar	Facebook	95
Self-driving cars: who drives last?	car	Totalcar	Facebook	70
Let's put things in order among self-driving cars	car	Bosch	Facebook	101
What is your opinion about autonomous delivery robots?	robot	EMFIE	Facebook	371
In what case would you replace your car with a self-driving one?	car	EMFIE	Facebook	83
Will self-driving cars be good for us?	car	Tech2.hu	YouTube	44
Will there ever be a self-driving car?	car	Büki Dani	YouTube	113
Total				**1,690**

Source: own construction

In the first step, the comments were cleaned and then processed with MaxQDA 2023 software, which carries out a data analysis and derives quantity information with the help of different metrics (Kuckartz–Rädiker 2019). For this purpose, coding was applied in the first step (Figure 1).

Figure 1. Logical framework of the primary study



Source: own construction

In the coding process, patterns were searched during the text analysis of the comments and based on them the original raw data were standardized with a predefined framework (Creswell 2013, Babbie 2016, Brait 2020). In this study, codes serve as an attribute, briefly summarizing the content, whether it is of any linguistic or visual nature (Saldaña 2013). By assigning the codes to the textual transcription of the comments, the contents of the comments were evaluated in a standard framework. The coding enabled to arrange the unstructured opinions on autonomous vehicles into a single structure, which contributed to exploring the patterns behind the comments. Over the course of coding, often several codes were assigned to a given coding unit, applying simultaneous coding (Saldaña 2013). When defining the codes, it was considered important to minimize the analyst's subjectivity, therefore, a framework which is accepted in wide professional circles was chosen. Consequently, the basis of the coding is formed by the four pillars of the AV Readiness Index elaborated by KPMG: (i) policy and legislation,

(ii) infrastructure, (iii) technology, and (iv) a user acceptance (KPMG 2018). They were completed with a code indicating safety, since the studies showed that people are worried about the safety of autonomous vehicles (AV) and the proper functioning of the technology (Jing et al. 2020, Kim et al. 2019, Rosell–Allen 2020, Dixon et al. 2020), which was clearly reflected in the comments as well. Also, the comments were coded based on their positive or negative attitudes.

The coding process was carried out manually in two steps, in MAXQDA software. In the first step, the seven codes derived from the literature were applied, i.e., the four pillars of KPMG, safety, and the positive or negative attitude. In the second step, the codes can be complemented by new codes and subcodes created during a deeper analysis of the texts (Saldaña 2013). In this case, a deeper analysis of the 1,690 comments required the inclusion of two new codes: the code of factual error and that of theft and criminal damage, thus the code system ultimately consisted of 9 codes:

1. Positive attitude
2. Negative attitude
3. Technology
4. Infrastructure
5. Policy and legislation
6. Social acceptance
7. Safety
8. Factual error
9. Theft and criminal damage as unemployment and legislation.

4. Results

In the process of coding, 1,424 codes in total were placed in the text system of 10 analyzed posts. They can be monitored both by post and overall with the help of the code matrix (Table 2). The code matrix shows the occurrence of the codes quantitatively, however, it does not analyze relationism between the codes. In the case of the code matrix, a heat map can be added on the resulting values. A scale ranging from blue to red indicates which word or code is frequent or less frequent in the system. It is conspicuous that the comments of the 10 analyzed posts are dominated by a negative attitude, 33.3% of all codes included in the entire system were negative. The number of comments with a negative value content (474) was 2.5 times the number of comments with a positive value content (190).

Table 2. Number of codes in the analyzed posts

Post / code	Vandalism, theft	Social acceptance	Legislation	Safety	Infrastructure	Technology	Factual error	Positive	Negative	Total
What is your opinion about autonomous delivery robots?	6	1			6	1	0	3	106	52
In what case would you replace your car with a self-driving one?		7					2		48	03
Would you pay 3.6 million more to let off the steering wheel?		8		3		0	4		49	28
Autonomous delivery robots will be tested in Debrecen	9				4	0		2	74	93
Mercedes gets new lights: turquoise is used when they go in a robot mode			1	3		2	7	7	45	62
Let's put things in order among self-driving cars.							0	2	28	3
Self-driving cars: who drives last?				4		9		6	21	6
Level 4 autonomous driving may be closer than you think		9	0	6		1	0	8	44	91
Will there ever be a SELF-DRIVING CAR?		5		3	6	9	2	1	46	77
Will self-driving cars be good for us?									13	9
Total	5	48	0	04	8	69	6	90	474	,424

Source: own construction

It is noteworthy that – although there are posts where the number of positive comments comes close to the number of negative comments – positive attitude is not dominant in the case of any of the posts. Following the attitude codes, technology (11.9%) and social acceptance (10.4%) codes were applied most frequently, in both cases there are posts where these aspects played a decisive role in the texts. It is to be noted that the issue of social acceptance has a stronger presence in YouTube comments proportionally, compared to Facebook. The two new codes (factual error, theft and criminal damage) both have 6.7% frequency of occurrence in the entire system, verifying the correctness of the decision to include them additionally. It should be highlighted that the criminal damage/theft code appeared exclusively in the case of posts related to autonomous delivery robots, and it strongly determined the comments of these posts. The legislation code has 6.3% in the whole system with a post where the discussion was strongly dominated by it. At the same time, the comments related to infrastructure were present only in 4.1% of the whole system, while three posts were found where the commenters did not discuss the topic of infrastructure at all. The code relations matrix reveals which code pairs occur frequently together within the same comment (i.e., the maximum distance = 0), therefore, it allows for understanding the complex relationship of the code pair occurrences. In the text system of the 10 analyzed posts, the negative attitude code moves strongly in line with the social acceptance code, i.e. the negative attitude of the commenters can be explained by the issues related to social acceptance in most cases within the same comment (Table 3). Considerable

technological concerns can be inferred explaining the negative attitude in the comments, where a large part makes an argument with the immaturity of autonomous technology. It is conspicuous that the technology code does not only move strongly in line with the negative attitude code, but also with the positive attitude code. It leads to an interesting situation where the technological aspect is present in the arguments of both the opponents and the supporters, the opponents claim that the technology is immature, while the supporters suggest that the technology is advanced. The same fragmentation occurs in terms of safety: the commenters forming a negative and positive attitude use safety risks vs. safety advantages as arguments, respectively.

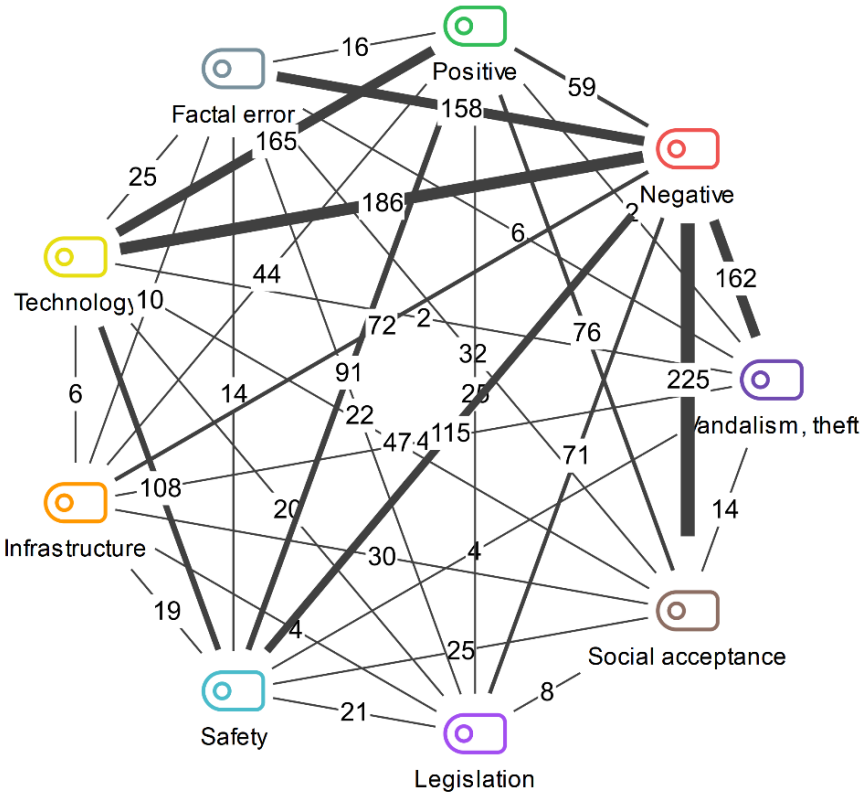
Table 3. Code relations matrix (maximum distance=0)

Code System	Vandalism, theft	Social acceptance	Legislation	Safety	Infrastructure	Technology	Factual error	Positive	Negative
Vandalism, theft	0	14	0	4	4	2	6	2	162
Social acceptance	14	0	8	25	30	47	32	76	225
Legislation	0	8	0	21	4	20	22	25	71
Safety	4	25	21	0	19	108	14	91	115
Infrastructure	4	30	4	19	0	6	10	44	72
Technology	2	47	20	108	6	0	25	165	186
Factual error	6	32	22	14	10	25	0	16	58
Positive	2	76	25	91	44	165	16	0	59
Negative	162	225	71	115	72	186	158	59	

Source: own construction

In many cases, the negative attitudes can be explained by the threat of criminal damage/theft, which is linked exclusively to autonomous delivery robots, but, interestingly, it is not associated with the idea of legislation in any case. There is significant co-movement between negative attitude and factual errors, which indicates that negative value judgements can be explained by obvious factual errors: for example, the technology will never be on a level where it can travel without a driver – the vehicles of Waymo have already travelled 10 million kilometers without a safety driver accident-free. The topic of technology and safety shows strong co-movement in the comments, i.e., the commenters argue in a way that they mention technology and safety within the same comment in many cases. If a visualization of the code relations matrix presented in Table 3 is created, the model of the text system composed based on the comments of the 10 posts is obtained (Figure 2). The model demonstrates the frequency of the co-occurrence of each code in the textual data. If two codes co-occur frequently, it indicates that the two codes are probably linked to each other or the same topic.

Figure 2. Code Co-occurrence Model (Code Proximity) of the 1,690 comments

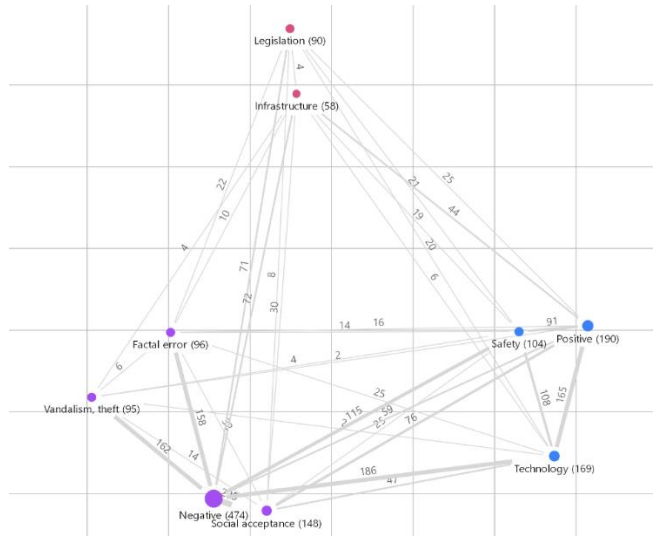


Source: own construction

Further connections can be revealed about the text system created from the comments of the 10 posts based on the code map of the 1,690 comments (Figure 3). The different codes are represented by circles, whose diameter is determined by the frequency of the occurrence of a given code. The line joining two codes demonstrates the frequency of the co-occurrence of the two given codes. The various colors of the code map show the clusters formed based on the distances, which indicates which codes' co-movement is the most significant within the entire text system created from the comments of the 10 posts. It results in 3 clusters:

- Cluster 1: negative attitude, factual error, social acceptance, criminal damage/theft
- Cluster 2: positive attitude, safety, technology
- Cluster 3: infrastructure, legislation

Figure 3. Code map of the 1,690 comments

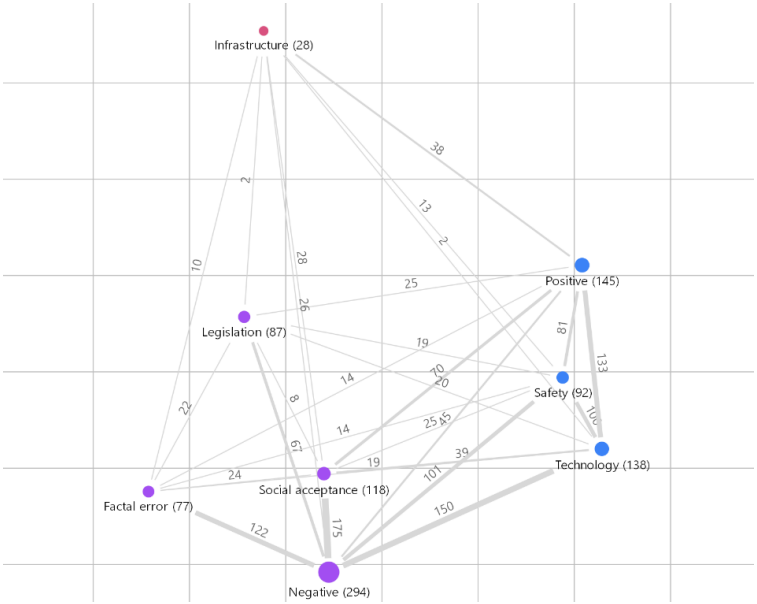


Source: own construction

It should be observed that if the entire system presented in Figure 3 is broken down and the two types of vehicles mentioned in the posts separately are analyzed, i.e. the comments discussing self-driving cars and autonomous delivery robots, a considerably different code structure and geometric representation is presented (Figure 4). If the comments of the posts which discuss self-driving cars (1,072 comments) are analyzed, it is seen that negative attitude is still dominant, which is fueled by social acceptance, technology, factual error, and safety risk, while the relative proportion of positive attitude increases, which is fueled by technology and safety in the same way as in the entire system. The risk of criminal damage/theft does not occur in any comment, thus, this code disappeared from the code map. At the same time, a substantial difference is the relative revaluation of the legislation code and its medium-strong relationship with negative attitude, which resulted in repositioning it from Cluster 3 to Cluster 1, while the cluster categorization of the other codes did not change. When only the 618 comments on the articles about autonomous delivery robots (Figure 5) are analyzed, it is seen that the strong negative attitude is highly fueled by criminal damage/theft, which appears in the comments in two ways: (i) on the one hand, the commenters merely express their concern that Hungarians steal the small-sized autonomous delivery robots, and, on the other hand, (ii) the commenters themselves express their negative attitudes by expecting criminal damage and theft if they encounter such a vehicle. Compared to the text system of self-driving cars, the relative revaluation of comments related to infrastructure is prominent: the commenters expressed their concerns about how the autonomous delivery robots travelling on pavement will be able to proceed on Hungarian streets, which are in poor condition in particularly many cases. The relationship of each type of comments (and, as a result, the codes) is rearranged significantly, resulting in the restructuring of the clusters: Cluster 1 includes legislation, social acceptance, infrastructure, safety, and

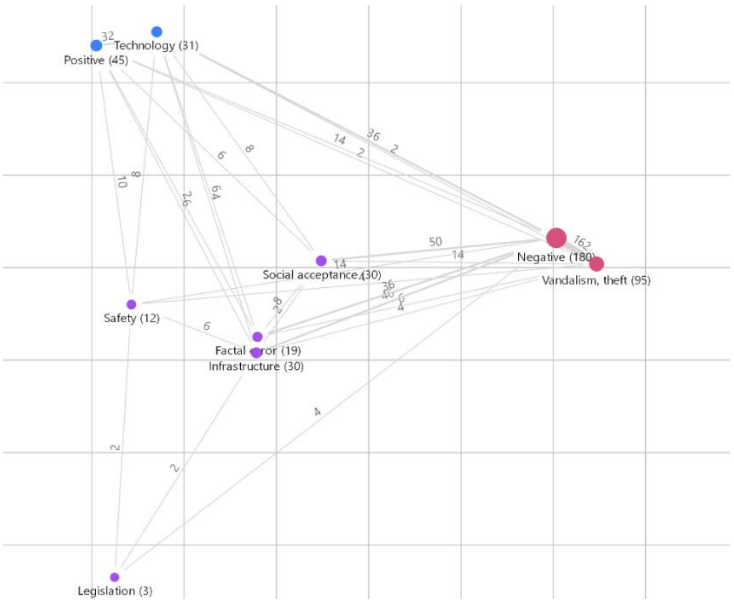
factual error, Cluster 2 consists of positive attitude and technology, while Cluster 3 includes negative attitude and criminal damage/theft.

Figure 4. Code map of the comments on self-driving cars



Source: own construction

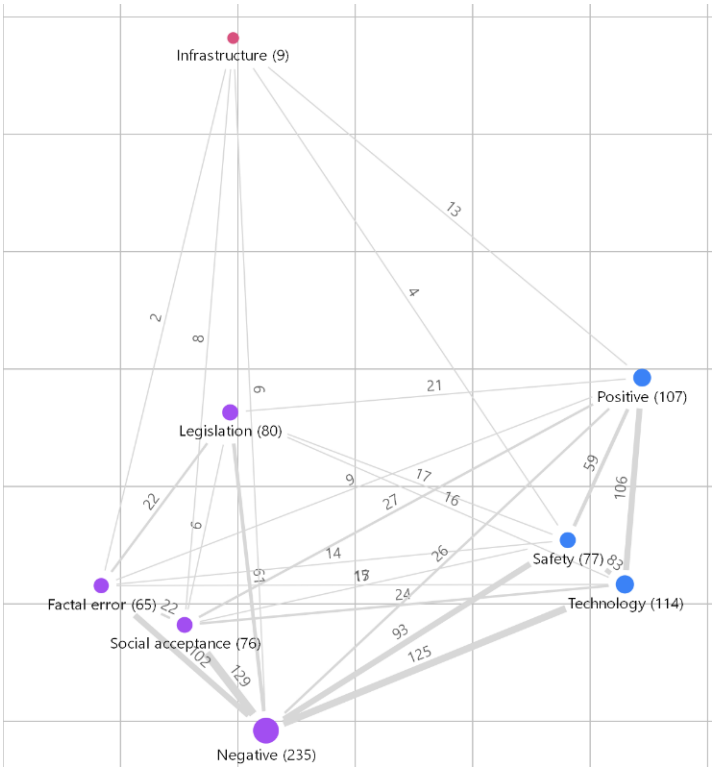
Figure 5. Code map of the comments on autonomous delivery robots



Source: own construction

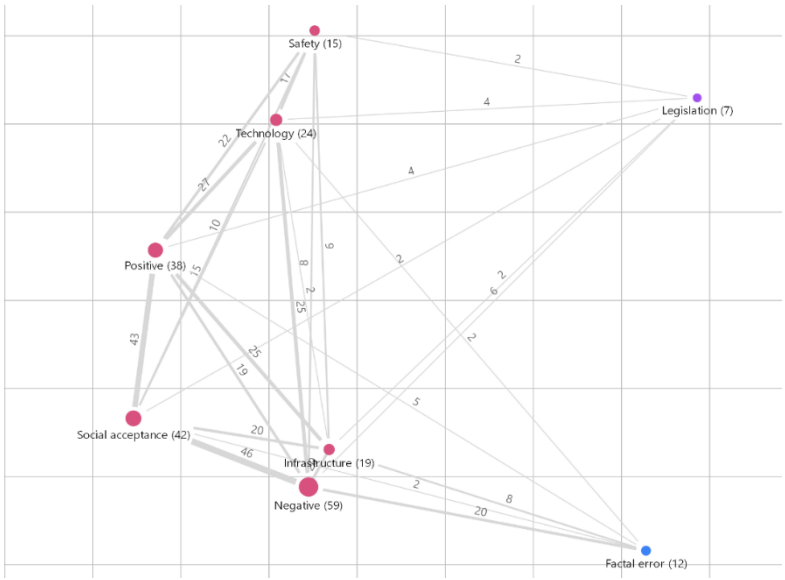
The study has also aimed to find out how the structures of the comments posted on the two most popular social media platforms included in the present study differ from each other. To examine this, first a thematic match needs to be identified. Since the Hungarian-language posts created on the topic of autonomous delivery robots on YouTube cannot be included in the analysis due to the low number of comments, a comparison was made with the comments of the posts about self-driving cars. Compared to the illustration in Figure 5, which features the comments of the posts about self-driving cars irrespective of the platform, there is no significant difference on the code map of Facebook comments: the dominant topics and codes, their relationship, and the members of the clusters are all identical (Figure 6). It is not surprising as the number of comments of Facebook posts considerably exceeds the number of comments posted on YouTube, which skews the results. At the same time, the completely different structure of the comments on self-driving cars placed on YouTube is quite interesting (Figure 7).

Figure 6. Code map of the comments on self-driving cars (Facebook)



Source: own construction

Figure 7. Code map of the comments on self-driving cars (YouTube)



Source: own construction

The negative comments are also dominant in the case of comments posted on YouTube, nevertheless, positive attitude is categorized in the same cluster as negative attitude only in this single case while they have strong co-movement with technology, social acceptance, safety, and infrastructure. It is also to be highlighted that the co-movement of factual errors with the other factors (including attitude codes) is relatively low, thus the code of factual errors is categorized in a separate cluster.

5. Discussion and summary

The present study has explored the patterns of the subjective opinion of the commenters of the selected 10 posts about autonomous vehicles. It is to be noted that the comments of all 10 analyzed posts are dominated by a negative attitude so much so that – although there are posts where the number of positive comments come close to the number of negative comments – a positive attitude is not dominant in the case of any post. The commenters' negative attitude was based on issues related to social acceptance in most cases, however, technological concerns were also significant in the comments, especially by referring to the immaturity of autonomous technology. Interestingly, the technological dimension is present in the arguments of both opponents and supporters, with the opponents claiming that the technology is immature while the supporters stating that it is advanced. The same fragmentation is observed in terms of safety: those expressing a negative or positive attitude both strongly argue for safety risks or advantages. There is also significant co-movement between negative attitude and factual errors, which indicates that negative value judgements can be explained by obvious factual errors. If these

results are compared with the results of the quantitative studies on the Hungarian population's technology acceptance of autonomous vehicles, the difference is visible – it is consistent with the findings of Branthwaite and Patterson (2011), as well as Io et al. (2022) suggesting that the analysis of comments can significantly differ from the results of structured questionnaire surveys due to the freedom of opinion. In fact, while the studies of Madarász–Szikora (2018), Majó-Petri–Huszár (2020), Csizmadia (2021), Páthy (2021), Nagy et al. (2022), and Prónay et al. (2022) did not record a strongly negative social attitude towards autonomous vehicles, the majority of the analyzed comments used a clearly rejecting tone. If the results are put in the context of international surveys of a similar topic found in the literature, it can be concluded that the results are radically different from the results of the analysis of English-language comments. While based on the results of Li et al. (2018), Das et al. (2019), Jefferson and McDonald (2019), Io et al. (2022), and Ding et al. (2021) the English-language comments reflect a positive attitude, the analyzed Hungarian-language comments show a clearly negative attitude. The results of Kohl et al. (2017) are closer to these results compared to the above-mentioned results because their findings indicate that the acceptance of autonomous vehicles is still limited, nevertheless, such a volume of negative attitudes cannot be observed as in the case of Hungarian-language comments.

The negative attitude of the Hungarian-language comments, which significantly differs from the positive and conservative attitude of the English-language comments, can be explained by the finding of Kovács and Lukovics (2022), suggesting that the post-socialist innovation environment itself has specificities which can also be seen in the social acceptance of autonomous vehicles. Furthermore, the considerable difference in attitude may be explained by the fact that several English-speaking commenters had the opportunity to encounter (or even travel on) the discussed autonomous vehicles in the streets. In contrast, there is only one comment based on the commenter's own experience among the Hungarian-language comments, others formed their subjective opinion based on their expectations. Despite this, a part of the results is in line with the results of the international literature: in the present text system, safety is one of the most important thematic areas and the duality (positive and negative) related to safety is evident, which was also shown by Pettigrew et al. (2019).

Overall, it can be concluded that due to the high number of factual errors, which is in strong co-movement with negative attitude, as well as the radically different beliefs about technology and safety, it is of key importance to raise public awareness about autonomous vehicles. Nevertheless, it requires patience since the analyzed texts imply that the commenters often prioritize their own beliefs over the information provided in the commented post. A solution for this can be the systematic reliance on credible data, increasing the quantity of information from validated sources, or if the author of the post replies to the comments containing factual errors with valid arguments. Also, it is a sensitive genre with serious psychological elements, which can be an excellent topic of a subsequent study.

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Role of digitalization and digital skills: The case of the agricultural sector

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The rate of digitalization significantly increases productivity within various economic sectors. Digitalization shapes the development of numerous sectors, however, there are sectors where digital transformation is lagging behind, like in the case of agriculture. Digitalization is influenced by capital, motivation, infrastructure, technology availability, and digital skills. Among all factors, in agriculture, one of the barriers to digitalization is the lack of digital skills.

For this reason, the aim of the study is twofold: it aims, first, to underscore the critical role of digitalization and to better understand the importance of digital skills, and, second, to reveal the obstacles of digitalization in the agricultural sector. In addition, the study examines the subskills of digital skills one by one, providing a comprehensive review of capabilities, thereby offering the reader a broader understanding of one of the primary influencers of digitalization.

Keywords: digitalization, digital skills, agriculture

1. Introduction

In the knowledge-based economy, information technology serves as a fundamental pillar (Vas 2009), therefore, it is almost indispensable to digitalize if one enterprise wants to enhance its operations in all economic sectors. In addition, it has been proved by several researchers experienced in this area of research that the productivity of business actors can be highly increased due to digitalization (Gray–Rumpe 2015, Isensee et al. 2020, Mammadli–Klivak 2020).

This is true for the Hungarian economic actors in all economic sectors. One sector in both Hungary and all over the world is highly affected by digitalization, namely, the agricultural sector. However, in this sector, as researchers concluded (Klerkx et al. 2019, Szőke–Kovács 2020), the speed of the digitalization process is not progressing as fast as in other sectors (such as the automotive or educational sectors).

In the meantime, there are several perils appearing all around the world, endangering global and local food production, for example, the climate crisis, wars, global food shortages, growing population, and the overall demand for food is rapidly increasing (Adams et al. 1998, Pereira 2017). Subsequently, the agricultural sector must keep pace with this increasing demand, otherwise further food shortages are inevitable. One solution to increase food production for the agricultural actors is the implementation of digital technologies. Digital technologies can help producers enhance productivity through various methods (Chandio et al. 2024, Nagy 2019, Gavrilova 2021, Bőgel 2018, Sung 2018, Berta 2018, Dajka–Oláh 2023). As a practical example based on Chandio et al. (2024) demonstrates, the internet can rapidly increase the dissemination of information online that is required by the labor in the field. This information dissemination process helps farmers increase their

productivity. Another example from Ozdogan et al. (2017) shows that digitalization increases food production through the utilization of drones. The drone technology operated by the users can cultivate the same amount of area in less time, or the drone technology can cultivate more area at the same time, both leading to higher productivity.

Digitalization can be increased in various ways, like increasing capital, motivation, infrastructure, the availability of technology, and digital skills, as stated by several researchers (Rupeika et al. 2022, Nallusamy et al. 2015, Van Dijk 2006). For this reason, the present study reveals, on the one hand, the most relevant factors, including the lack of digital skills, which hinder digital transformation in the agricultural sector, and, on the other hand, the most critical factors in terms of digitalization and particularly emphasizes the necessity of digital skills. The main research question is the following: what are the critical factors shaping digitalization, with a specific focus on the necessity of digital skills, and how do these factors impede the level of digitalization in the agricultural sector?

To answer this research question, first, the relevance and the elements that affect the level of digitalization will be highlighted. Since one of the main obstacles to digitalization is a lack digital skills, the paper describes the notion of digital skills in detail. Finally, the paper shows the already existing evidence related to digitalization in agriculture, a sector that has many challenges to face.

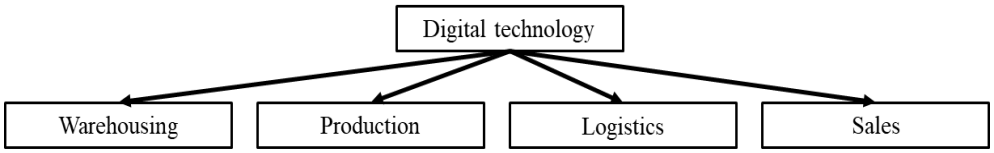
2. Relevance and elements of digitalization

To gain a deeper insight into the relevance of digitalization, first, it is necessary to describe what digitalization is from an economic perspective. In addition, it is essential to overview the economic impacts of digitalization, and the root causes of the lack of digitalization among the business actors. Therefore, I will provide a broader context of how digitalization shapes the economy and what factors hinder digitalization.

Researchers define digitalization in a diverse manner. The present study builds on the definition formulated by Gray and Rumpe (2015, p. 1) since this definition provides a clear understanding and examines digitalization from an economic perspective. According to this study, "digitalization in economic life is equal with the utilization of digital technologies (such as the internet, computers, smartphones) by economic actors to transform business (models) in a way that results in increased operational efficiency."

The effects of digital technologies on business actors are considerable. Teng et al. (2022) and Isensee et al. (2020) stated four key areas in the life of an average business actor that are being highly affected by the utilization of digital technologies in a positive way (Figure 1).

Figure 1. The four main areas affected by digitalization in the case of actors from the business sphere

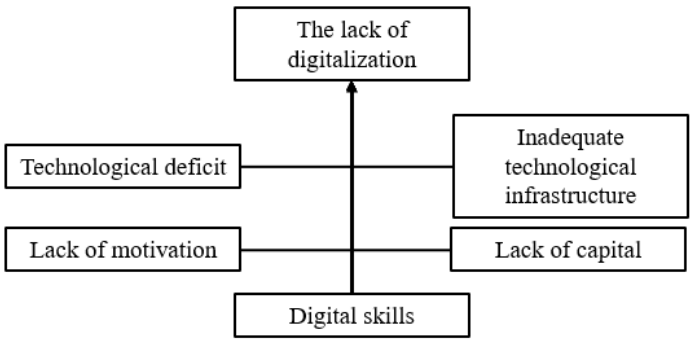


Source: own construction based on Teng et al. (2022) and Isensee et al. (2020)

Based on the studies by Teng et al. (2022) and Isensee et al. (2020) the following can be concluded. Warehousing, as a part of the operational functions of one business actor's life, is certainly being affected by digital technologies. For example, an enterprise resource planning (ERP) system being operated on a computer by the administrators can help the storage processes of a business become more transparent, thereby reducing storage costs, and helping track the available supplies accurately. Production operations can be similarly enhanced thanks to digitalization, because an ERP can once again help the production operations by monitoring the movements of the items in production, reducing the costs, and increasing the transparency in the production area. The logistics processes can be also enhanced due to the availability of digital technologies; online freight order websites and tracking modules can help spare resources for both the customer and service providers during the logistics operation. The sales department operations can be also increased with the help of digital technologies: webshops, email-based correspondence, and other utilizable tools can speed up the interaction between the customers and the webshop salespersons.

Despite this, it has been already proved that digital technologies are not available for all economic actors, for several reasons. To gain a better insight to the connection of digital technologies and economic science, we need to analyze these root causes, and I will do so based on the studies of Rupeika et al. (2022), Nallusamy et al. (2015), and Van Dijk (2006), which reveal the five main reasons why digitalization is missing in the case of several business actors (Figure 2).

Figure 2. The root causes of the lack of digitalization among business actors



Source: own construction based on Rupeika et al. (2022), Nallusamy et al. (2015), Deichmann et al. (2016), Mokthar et al. (2022), and Van Dijk (2006)

The first root cause which results from the lack of digitalization is the technological deficit. This means that the technology (e.g. internet, computers) is not present or is very expensive to access for the economic actors in the market in a particular country (for example, in some African countries), which hinders digitalization. The second root cause is the inadequate technological infrastructure that might be present at a given location. This means that although the technology for digitalization is accessible to market actors, their operation is not optimized, thus their efficiency is reduced, and they do not provide a return on investment for the company (for example, slow internet connection or outdated computers). The third root cause is the lack of capital. This is equivalent to the lack of money and investible funds. Due to a shortage of capital, actors are unable to purchase products of digital technology. The fourth root cause is the lack of motivation. This is alternatively phrased as internal resistance to change. From the perspective of business actors, there may be a lack of motivation towards digital technologies, or, in other words, all necessary conditions for the use of digital technology are present for the company, yet the actor is unwilling to apply the products of digitalized technology. The fifth and last root cause of the lack of digitalization is the lack of digital skills. The use of digital products is indispensable for users to have digital knowledge, such as how to use the internet and computers. The absence of digital skills can be an impediment to the efficient operation of the technology.

All the five root causes of the lack of digitalization determined by Rupeika et al. (2022), Nallusamy et al. (2015), and Van Dijk (2006) are important in the process of digital transformation. In the upcoming analysis, I focus on the role of digital skills in the digitalization of agriculture.

3. Digital skills

In this study, among the many factors determining digitalization, a special focus is on explaining what digital skills are, since they drive productivity and innovation, and foster inclusivity in the digital age. To properly execute a deep analysis of the aspects of digital skills, first, we need to define what digital skills mean. Digital skills (or digital capabilities) can be defined as a comprehensive set of competencies required for effective use and understanding of digital technology (Van Laar et al. 2017, Van Dijk–Van Deursen 2014). Digital skills consist of six subskills (Figure 3). Several studies have been examined to have these subskills properly determined, therefore we will have a better insight to the core elements of digital skills. We will determine the components of digital skills one by one in the next paragraphs.

Figure 3. The six subskills of the digital skill

Skill name	Definition	Reference
Operational skills	Technical competencies to use a computer (a.k.a. button knowledge)	Van Dijk and Van Deursen (2014), Van Deursen et al. (2014)
Formal skills	Associated with browsing and navigating digital technology (e.g. internet), and understanding its structure like menus and hyperlinks	Van Deursen–Van Dijk (2011)
Information skills	The ability to search, select, and evaluate information on digital media, is crucial in media with an abundance of sources and content like the Internet	Saikkonen–Kaarakainen (2021), Van Dijk–Van Deursen (2014)
Communication skills	Required for digital media that focus on communication, encompassing the use of email, instant messaging, social media, and online community participation	Siddiq et al. (2015), Van Dijk–Van Deursen (2014), Orjuela (2021)
Content creation skills	Increasingly vital in the era of Web 2.0, these skills involve creating user-generated content such as blogs, social media posts, and multimedia materials	Orjuela (2021), Van Dijk–Van Deursen (2014)
Strategic skills	The ability to use digital media as a tool for achieving personal or professional goals, involving critical thinking and decision-making in the digital space	Van Dijk–Van Deursen (2014)

Source: own construction based on the studies mentioned above

Based on the research of Van Dijk and Van Deursen (2014) and Van Deursen et al. (2014), operational skills can be defined as the technical competency required to use and operate digital technologies, such as computers. This basic skill, often referred to as "button knowledge," is essential for initiating the operation of digital devices. Mastery of operational skills is necessary not only for computers but also for a variety of other digital equipment including drones, monitors, docking stations, and more. Furthermore, this skill involves understanding the basic hardware and software functionalities, such as turning devices on and off, adjusting settings, and installing applications. It serves as the foundation upon which more complex tasks, like software troubleshooting and network configuration, are built. As digital technologies evolve, the scope of operational skills expands to include newer interfaces and connectivity options, highlighting the importance of continual learning and adaptation in the technologically driven economic world.

Formal skills, as identified in the studies of Van Deursen and Van Dijk (2011), are associated with the ability to browse, and navigate digital technologies, such as the Internet and cloud-based software, and understanding the structures within these technologies, like menus and hyperlinks. This skill involves the ability to efficiently locate, select, and utilize the various functions and features presented in digital interfaces. It extends to the comprehension of layout sources and visual hierarchies that guide users in interacting with complex digital environments, such as websites,

online platforms, and specialized software. Moreover, formal skills involve recognizing and interpreting common icons and symbols used in digital interfaces, which facilitate the use of software applications and internet navigation without extensive textual instructions. Individuals proficient in formal skills are better equipped to manage multiple windows or tabs, use search engines effectively, and follow navigation paths within software or websites. This competency is crucial for efficient digital literacy as it enhances the user's ability to adapt to new and unfamiliar technologies, and software quickly. Additionally, these skills are fundamental for avoiding common mistakes in digital environments, such as phishing scams and misleading links, by enabling users to distinguish reliable from unreliable digital content. As digital platforms evolve, the continuous development of formal skills remains vital for keeping pace with new digital formats and interactions.

According to Saikkonen and Kaarakainen (2021), information skills encompass the critical competencies needed to effectively search for, select, and evaluate information across various digital media. This skill set is particularly vital in environments like the Internet, which is characterized by a vast and ever-expanding array of sources and content. These skills not only include the ability to use search engines and databases with precision but also to distinguish the credibility and relevance of the information obtained. In their research, the authors emphasize the importance of critical thinking in the digital age, where information is abundant but variable in quality. Van Dijk and Van Deursen (2014) expand on this by highlighting that information skills also encompass the capacity to synthesize and integrate information from multiple digital platforms into cohesive knowledge. These researchers advocate for the development of these skills as part of a broader digital literacy initiatives, underscoring their significance in education, professional development, and personal development in navigating the digital landscape. As the digital divide continues to narrow, information skills become increasingly fundamental in enabling individuals to participate fully in the information society, bridging the gap between mere access to technology and the ability to leverage its full potential for personal and societal advancement.

According to studies by Siddiq et al. (2015), Van Dijk and Van Deursen (2014) and Orjuela (2021), communication skills in the realm of digitalization are diverse and involve more than just the ability to send and receive messages. They require proficiency in the use of various communication tools such as email, which demands an understanding of formal and informal styles, attention to detail, and the ability to transmit messages in a clear and coherent manner. Instant messaging, by contrast, often requires concise language and immediate reactions, with an emphasis on quick responses that adhere to the informal etiquettes of real-time digital conversations. When it comes to social media, communication skills involve crafting messages that are engaging and appropriate for the intended audience, understanding the cultural aspects of different platforms, and managing digital relationships. They include the understanding to navigate the rapidly changing trends and viral phenomena that characterize social media landscapes. Moreover, participation in online communities requires a set of communication skills that facilitate collaboration and contribution in forums, discussion groups, and other interactive platforms. This means not only sharing information but also providing feedback, fostering

discussions, and building relationships with others who share similar interests. Effective communication in digital media also includes being vigilant about the digital footprint that one leaves behind, understanding the permanence of online posts, and navigating the implications of public and private settings. It involves a sensitivity to context, audience, and the evolving norms of digital interactions, where misunderstandings can arise quickly due to the lack of non-verbal interactions. Therefore, digital communication skills are as much about interpersonal intelligence and empathy as they are about technical ability.

Orjuela (2020) and Van Dijk and Van Deursan (2014) concluded the following about content creation skills. These skills are a critical competency in digitalized life, where user-generated content is important in the digital landscape. These skills are not limited to the mere ability to produce text-based content like blogs; they also involve the creation of a diverse level of multimedia materials, including social media posts, videos, podcasts, infographics, and more. Effective content creation requires a high amount of creativity and technical know-how. Creators must be experts at using various tools and platforms to craft their content, whether that is video editing software for a YouTube channel, graphic design software for compelling visuals, or content management systems for maintaining a blog. A keen eye for design, the ability to tell a story, and an understanding of the principles of search engines are also part of this skill set. Moreover, the capacity to engage and grow an audience is integral to content creation skills in the digital environment. This involves understanding analytics to measure content performance, using feedback mechanisms to interact with the audience, and leveraging social media algorithms to maximize content reach and impact. Creating content also involves a strategic component; knowing when to post, what to post, and where to post is crucial for resonating with the intended audience. Content creators must also be aware of the ethical implications of their creations, ensuring that they respect copyright laws and contribute positively to digital discourse. With the spread of content creation tools, individuals now have the power to influence, educate, and entertain large audiences. As such, content creation skills are becoming increasingly important not just for personal expression, but also for professional marketing, education, advocacy, and even as a means of civic engagement.

Strategic skills in the context of digital media usage are essential for individuals aiming to achieve specific personal or professional objectives based on the study of Van Dijk and Van Deursen (2014). These skills extend beyond basic functionality and content creation to include a deep understanding of the digital environment and the ability to leverage it effectively. This skill set requires critical thinking to evaluate the most effective ways to reach an intended goal. For instance, someone with strategic digital skills might analyze which social media platform is most suitable for promoting a particular type of business or message, considering the platform's predominant user demographics and content format. Strategic skills also involve decision-making capabilities, such as determining the optimal time to post content for the best engagement or identifying which digital tools can streamline work processes. These skills include the capacity to set clear, measurable goals and to adjust strategies based on feedback and analytics data. In the professional sphere, strategic skills can translate into managing a brand's online presence, running targeted

advertising campaigns, or networking with industry professionals. For personal objectives, this could involve building a personal brand, engaging in online learning, or even managing one's digital identity and privacy. Ultimately, individuals with strong strategic skills in digitalization can make informed choices that align digital actions with desired outcomes, whether they're looking to grow a business, develop a personal brand, or simply use digital tools more effectively in their daily lives.

All the operational, formal, information, communication, content creation, and strategic subskills are vital for the improvement of digital skills. The improvement of any of these competencies can lead both to the enhancement of one's digital skills and the actors's productivity with the leverage of digital technologies. If a business actor is aspiring to increase its digital readiness, it is indispensable to enhance digital skills.

4. Digitalization in the agricultural sector

Digitalization has an impact on numerous sectors and can offer various benefits to the actors within those sectors, including the agricultural sector, which is tasked with providing solutions to numerous global challenges. In agriculture, digital technologies such as drones, GPS-based positioning, artificial intelligence, the Internet of things, satellite weather forecasting utilization, and automated systems are becoming widespread, contributing to increased productivity and efficiency (Nagy 2019, Gavrilova 2021, Bőgel 2018, Sung 2018, Berta 2018, Dajka–Oláh 2023). In addition, the digital products improve the quality of the operational processes of the agricultural actors, for example, humidity-, temperature- and soil moisture measurement methods, and crop health status monitoring methods (Sung 2018, Berta 2018). Other than that, the collective and systematic utilization of the digital products (like in the example of smart agriculture, or agriculture 4.0) can shape the whole methodologies of the agricultural operation itself (Zambon et al. 2019, Somosi–Számfira 2020, Bazsik et al. 2022). However, it is also known that despite the global spread of digital technologies in agriculture, it is one of the sectors where change cannot occur as rapidly as in other sectors, for example, the automotive industry or education sector (Szőke–Kovács 2020, Somosi–Számfira 2020, Bazsik et al. 2022).

Hungary, particularly the Southern Great Plain region, is one of the areas where agriculture is a promising sector thanks to its vast area of cultivatable land and economic potential. According to the Hungarian Central Statistical Office (KSH 2023), the Southern Great Plain region employs more than one quarter of the total agricultural employees in Hungary. Other than that, the agricultural sector contributes twice as much to the GDP compared to the EU average. In addition, the agricultural sector has a share with more than 10 billion EUR per year in the balance of export trade. However, compared with other developed countries, the country shows a significant lag in the speed of agricultural digital innovation (Szőke–Kovács 2020, Nagy 2019, Somosi–Számfira 2020). In Hungary, agricultural actors innovate much less in digital technologies and their spread is much slower compared to their counterparts in other developed countries (Szőke–Kovács 2020, Nagy 2019, Erdeiné 2020).

For Hungarian agricultural small and medium-sized enterprises, most of the products and services offered by digital technologies are available on the market, with few actors facing external obstructive factors. Yet the actors are not open enough to adopting these technologies, and the implementation of these digital technologies is not proceeding quickly enough, proving the lack of enhanced digitalization in agriculture (Szőke–Kovács 2020, Nezamova–Olentsova 2022). The most significant obstructive factor regarding digital innovation for actors in Hungarian agriculture is very similar compared to the data detailed in Figure 2.

Rupeika et al. (2022) offer an insightful analysis (Figure 2) of the factors hindering digitalization, positioning that the absence of necessary technological resources can significantly block the adoption of digital innovations among the agricultural actors. This phenomenon is significantly evident in the agricultural sector. The authors explain that in regions where technological development is insufficient, agricultural entities face substantial challenges in integrating advanced digital technologies into their operational frameworks. Specifically, in less developed countries, such as certain nations within Africa, there exists a definite deficit in the availability of essential technological tools and infrastructure. This scarcity not only restricts the direct application of digital technologies but also limits the potential for technological education and skill development among agricultural workers. Consequently, this lack of technological readiness undermines the ability of these regions to enhance agricultural productivity and efficiency through digital means. As a result, the gap in digital adoption between developed and developing regions continues to widen, highlighting the critical need for targeted technological investments and interventions to bridge this divide.

Nallusamy et al. (2015) identified insufficient capital (Figure 2) as a fundamental barrier to digitalization across various business sectors. This assertion is supported by Deichmann et al. (2016), who specifically highlight the agricultural sector as an area where this challenge is particularly frequent. The financial limitations faced by actors within the agricultural industry often stop them from acquiring advanced digital technologies that are crucial for enhancing productivity. Capital insufficiency restricts their ability to invest in new equipment and technologies, such as precision agriculture tools, automated systems, and data analytics software. Without the financial resources necessary to make these investments, agricultural producers are unable to leverage the benefits of digital technology, which can lead to increased yields, improved crop management, and greater overall efficiency. Consequently, the lack of capital not only hinders the immediate potential for technological adoption but also affects the long-term sustainability and competitiveness of farms. Addressing these financial barriers is essential to facilitate broader digital adoption and to foster economic growth within the agricultural sector.

Rupeika et al. (2022) asserted another fundamental blocking point to digitalization in the agricultural sector, which they identified as the inadequacy of existing technological infrastructure (Figure 2). They noted that the utilization of outdated technology models, which are not compatible with the demands of new digital technologies, alongside issues like slow internet connectivity, significantly hinders productivity enhancements in the agricultural sector. Such older systems, including outdated computers and other technological tools, lack the capability to

effectively support and integrate advanced digital solutions. Consequently, cutting-edge technologies such as drones, GPS, and remote sensors, which include humidity trackers critical for precision agriculture, remain underutilized. This underutilization comes from the older infrastructure's inability to process and transmit the large volumes of data these technologies generate, or to support the complex algorithms they employ. Therefore, without substantial upgrades to the technological infrastructure, the agricultural sector cannot fully leverage these innovations to increase production efficiency and crop yields. This situation underscores the urgent need for investment in modernizing technological frameworks to ensure that the agricultural industry can fully capitalize on the benefits of digital advancements.

Van Dijk (2006), Rupeika et al. (2022), and Deichmann et al. (2016) highlighted an additional significant barrier to the implementation of digital technologies: a lack of motivation (Figure 2). They assert that reluctance or resistance to learning and investing time in understanding digital technologies often leads enterprises to disregard the opportunities these technologies offer. This resistance is particularly pronounced in the agricultural sector, where the stakes for technological adaptation can be high. Furthermore, Deichmann et al. (2016) observed that this lack of motivation is especially dominant among older generation members within the agricultural community. These individuals often exhibit considerable hesitance, if not outright resistance, to adopting new digital tools, thereby creating a formidable obstacle in the digital transformation process. This resistance is not merely a refusal to adopt new technologies but often comes from a deeper skepticism toward the perceived complexity and the disruptive nature of digital innovations. Overcoming this generational divide is crucial for the effective integration of digital technologies into agricultural practices, necessitating targeted strategies that address these motivational barriers and foster a culture of continual learning and adaptation.

The low level of digital skills in the agricultural sector (Figure 4) is also present, which has multiple root causes.

Figure 4. The root causes of the lack of digital skills among the business actors in the agricultural sector

Root causes	Reference
Lower education level (elementary school or high school) Insufficient development of the agrarian university facilities No proper education for agricultural actors in technology	Hasan et al. (2022), Kale et al. (2016), Trukhachev–Apazhev (2019), Torres et al. (2020), Mokthar et al. (2022)

Source: own construction based on the studies mentioned above

Hasan et al. (2022), Kale et al. (2016), and Torres et al. (2020) collectively identified a significant deficiency in digital skills within the agricultural sector. As illustrated in Figure 5, this deficiency comes from multiple fundamental issues, the most prominent being the lower educational levels dominant among agricultural

workers. Typically, with their level of education being elementary or high school, these individuals often lack the necessary digital skills required to effectively employ and integrate digital technologies into agricultural operations (Trukhachev−Apazhev 2019, Torres et al. 2020, Mokthar et al. 2022). This gap in skills hinders their ability to leverage these technologies for improved productivity and efficiency. Further complicating this issue, Mokthar et al. (2022) highlighted the absence of proper educational programs for agricultural workers compared to other sectors. This discrepancy underscores a need for enhanced educational offerings that are specifically designed to meet the unique needs of the agricultural sector. Additionally, Trukhachev and Apazhev (2019) pointed out the scarcity of agrarian-focused educational institutions relative to other fields, which limits the opportunities for agricultural actors to receive specialized training. This educational shortfall means that for many in the agricultural sector, acquiring the necessary digital competencies is not just challenging but often unattainable. Addressing these educational and training deficiencies is crucial for equipping agricultural workers with the skills needed to capitalize on digital technologies, thereby enabling the sector to meet contemporary challenges and enhance its competitiveness.

5. Conclusion

The main aim of this study has been twofold. First, I have examined the relevance and elements of digitalization putting emphasis on the analysis of one of its components, namely, digital skills. I have evaluated the economic effects of digitalization in four main business spheres where digitalization significantly impacts productivity: warehousing, production, logistics, and sales processes. I have described the main root causes of digitalization among the business actors, which consist of five elements: technological deficit, lack of motivation, lack of capital, lack of inadequate technological infrastructure, and lack of proper digital skills. Subsequently, I have examined the core elements of digital skills, which consist of six subskills: operational, formal, information, communication, content creation, and strategic skills. Each subskill was thoroughly analyzed, providing with a broader vision about the core elements of the digital skill.

Second, I have examined the situation of digitalization in the agricultural sector. Digitalization has its impacts on the agricultural sector, which is facing numerous challenges around the world (climate crisis, ongoing conflicts, reduction of cultivable land, and increasing populations), and the agricultural sector needs to maintain its level of productivity if it wants to keep up the production levels with the increasing demands. The spreading of digitalization in the agricultural sector is progressing as in other sectors, but at a reduced rate, which can be traced back to the root causes of the following: the lack of technology, lack of adequate technological infrastructure, lack of capital, lack of motivation, and lack of digital skills. The lack of proper digital skills is one of the main root causes that could be enhanced to improve productivity. I have evaluated the main root causes of the lack of digital skills among the agricultural enterprises and the main reason can be led back to the lack of proper education among the agricultural business actors.

A future study's aim can be to deepen the research on the economic effects of digitalization and more emphasis on the analysis of digital skills in the aspect of economics. More specific focus should be put on the possible improvements, solutions, and recommendations for the digital skill-related problems of agriculture.

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The future of digital marketing? Artificial Intelligence and Augmented Reality

Adriana Mateášiková – Zdenka Kádeková – Ingrida Košičiarová

The Internet and digital technologies make consumers more informed and sophisticated nowadays, with a variety of rational and irrational factors influencing their shopping behavior. The present paper focuses on new digital trends, specifically artificial intelligence and augmented reality. The utilization of these trends in marketing communication within the food market is steadily increasing. The paper explores their influence on consumers' rational decision-making processes based on a questionnaire survey involving 764 respondents who are food consumers and use digital technologies. Statistical methods and techniques were used to evaluate the established hypotheses, such as the Chi-square test of independence, the Share test with known constant, and the Chi-square test of good agreement. Based on the results, some recommendations are suggested for improving digital marketing communication in the food market.

Keywords: digital marketing, AI, AR, rationality and irrationality in consumer shopping behavior.

1. Introduction

The present paper intends to underscore the significance of digital marketing, particularly the trends in digital marketing communication, and to evaluate their effect on consumer behavior, considering both rational and irrational factors in creating consumer preferences in the food market.

Dinker and Misra (2023) characterize digital marketing as promoting products or services using digital technologies. Marketers advertise products and services online through websites, blogs, social media, mobile applications, and other digital channels. Digital marketing integrates several channels and technologies through which a company explores marketing campaigns, content and strategies to understand what works and what does not in real time (Adler 2021).

Vysekalová and Mikeš (2018) state that the Internet has permeated our lives more than we realize, with the number of users continually rising. New modern technologies offer expanded communication possibilities. Nowadays, speed, the virtual world, and the need to be constantly online dominate (Vysekalová et al. 2020).

Chaffey and Ellis-Chadwick (2019) add that digital media and technologies are nothing new. We see significant development in digital marketing, aiming to discover new ways to communicate with customers. According to Shankar et al. (2022), the impact of digital communication has increased compared to traditional ways of communication, especially during the Covid-19 era. Sheremetyeva et al. (2021) suggest that the Internet has become the dominant marketing tool for companies, and the digitalization of marketing makes products and brands accessible to customers precisely when needed.

According to Bartanus (2021), the goal of digital marketing is maximum effectiveness of advertising messages targeted at a specific group of customers. Achieving this goal requires flexibility and the ability to react instantly to the current situation. Digital marketing focuses on a selected group of customers to obtain feedback and foster bilateral interaction between the company (seller) and the customer (Adler 2021).

Burešová (2022) outlines the following advantages of marketing in the online environment: unlimited availability, targeting desired customer segments, easy measurement of user response (tracking) and online tool effectiveness, flexibility, interactivity and two-way communication, price flexibility, and atypical and unique communication formats.

Veleva and Tsvetanova (2020) point out that digital marketing has several disadvantages. The main disadvantages include: negative reviews, lack of trust from customers and consumers, overcrowding of the online space with advertisements, unsuitability for all types of products, services, and companies, and high dependency on technologies.

Chaffey and Ellis-Chadwick (2019) explain various forms of digital marketing, such as search engine marketing, remarketing, social media marketing, influencer marketing, video marketing and content marketing. These forms have different goals and functions, therefore, not all are suitable for every marketers or industries. For example, in the accommodation sector, communication mainly takes place through websites and social networks, but it has been shown that social networks are more effective tools than websites (Lincényi–Bulanda 2023).

Kingsnorth (2022) suggests that pressure from digital technologies influences consumer behavior. Technological advancements such as smartphones and tablets significantly change consumer attitudes. On the other hand, it holds that no consumer can be labelled as entirely digital or, conversely, non-digital, as each of us falls somewhere on a digital spectrum. It is crucial to understand the unique nature of each individual and consider their desires and interests. According to Janouch (2020), modern marketing communication extensively utilizes insights from psychology because consumers are influenced by rational factors such as price, quality, availability, and functionality. However, significant impact is attributed to irrational factors, including emotions, impulses, and current trends.

Karabová (2021) explains that the customer's buying journey has become more complex in recent years. The customer responds to different stimuli at each purchase stage, is interested in different product information, spends time on different channels and has different motivations for choosing a particular brand. This complicates the buying journey, which influences purchasing behavior, and is described by the STDC marketing framework as follows:

SEE – the stage where people come into contact with the company or product for the first time. In this phase, it is essential to capture their interest and move them to the next stage;

THINK – at this stage, people are deciding whether they truly want to buy the product or if they can do without it; it is important to increase their awareness and remind them through appropriate methods via relevant channels;

DO – customers are deciding where to buy the product; this decision is influenced by various factors such as price, quality, service, and website speed, among other things, to which the seller should appeal;

CARE – Customers have already made purchases in the store, and it is the seller's task to take care of them and their shopping activities further (for example, offering them additional services).

Digital trends have a significant impact on the overall functioning of companies. They influence marketing, business philosophy and enterprise activities (Blazheska et al. 2020).

Májek (2023) argues that companies must strive to adopt new technologies and tools and develop marketing efforts to gain an edge over their competitors. Verma et al. (2021) state that artificial intelligence is considered a new technological trend with enormous potential for marketing transformation. Artificial intelligence is becoming increasingly popular in digital marketing (Májek 2023).

Slovíková (2023) states that this trend can improve content optimization, analyzing customer behavior or targeting in online advertising. However, the greatest risk is that artificial intelligence can be used to manipulate customers and intrude into their privacy.

Čiernik (2023) states that the market for foods produced with artificial intelligence will reach a value of $35 billion by 2028, according to analysts. Foods are already being designed now. For instance, Coca-Cola has created a new beverage in collaboration with artificial intelligence. It is designed to taste like a beverage from the year 3000. The Chinese ice cream manufacturer Zhong Xue Gao used artificial intelligence to design and create a new affordable ice cream launched in Shanghai in 2023. It is only available in the Chinese market.

Another digital trend is augmented reality. According to the VR Zone (2019), augmented reality is the projection or addition of a layer of digital content into the real physical environment in real time. Augmented reality bridges the real world with the virtual world. The real world is extended or enhanced with digital information. Advancements in augmented reality have led to an interest in its application in marketing strategy, giving rise to augmented reality marketing (Chylinski et al. 2020). Experts characterize it as a new strategic sub-discipline of marketing (Rauschnabel et al. 2022).

Berman and Pollack (2021) identify the advantages of augmented reality for customers as the high level of interactivity, high quality of customer support and service, and better integration between online and in-store shopping.

Berčík (2018) explains the implementation process of augmented reality in practice. It operates by scanning a predefined code through the camera of a device. Subsequently, the programmed object is displayed on the screen of a smartphone or tablet. In the food market, brands like Magnum have already utilized augmented reality. For instance, in Singapore, they launched the "Make My Magnum" campaign, which allows customers to design and create their own Magnum ice cream using augmented reality through their smartphones' cameras. Customers can purchase their creations at selected stores with a discount (Marketing-interactive.com 2018).

During the 2019 Singapore F1 event, Heineken launched a campaign where customers could win tickets to an exclusive pre-race party, tickets to the race and other prizes. The campaign operated on the principle of augmented reality. Participants were tasked to scan two bottles or glasses with the Heineken logo using an application. If the app recognized the logo as valid, it initiated a short F1-themed game. If the players succeeded, they won a prize (Just after midnight.com 2019).

2. Goals and research methodology

The present paper aims to highlight the importance of digital marketing, especially digital trends in marketing communication and determine their influence on consumer behavior in the context of rationality and irrationality in creating consumer preferences.

In connection with the aim of the paper, we have established the following hypotheses:

Hypothesis 1: We assume that more than 30% of respondents would use Magnum Company's AR application.

Hypothesis 2: We assume that there is a dependency between the age group of respondents and their opinions on food created by artificial intelligence.

We found out that customers in Singapore can create their own ice cream through the Magnum augmented reality-based application (Marketing-interactive.com 2018). We established the first hypothesis because we were interested in whether customers in Slovakia would use a similar application if they had the opportunity. We established the second hypothesis because we believe that the opinions of the older and younger generation on artificial intelligence differ, and, therefore, we decided to identify the possible differences.

Primary and secondary sources of information were collected and used to achieve the stated objective. Secondary data was obtained from studies and papers by domestic and foreign authors and WoS and SCOPUS databases.

Our study is based on a questionnaire survey. The questionnaire was processed in Google Forms, and the respondents were asked to participate in the study through personal social networks Facebook and Instagram and via e-mails. The questions focused on consumer's perceptions of digital marketing and trends, particularly in the food market. The final sample consisted of 764 respondents from the Slovak Republic who are food consumers and use digital technologies. We can see the sociodemographic characteristics of respondents in Table 1.

Table 1. Sociodemographic characteristics of the respondents

Characteristic	Category	Absolute frequency	Relative frequency
Gender	Female	409	53.5%
	Male	355	46.5%
Age group	Generation Z	277	36.3%
	Generation Y	210	27.5%
	Generation X	207	27.1%
	Baby boomers	70	9.2%
Residence	Cities	462	60.5%
	Countryside	302	39.5%
Education	Primary education	48	6.3%
	Secondary education without A-levels	79	10.3%
	Secondary education	323	42.3%
	Bachelor's degree	138	18.1%
	Master's degree	162	21.2%
	PhD	14	1.8%
Economic activity	Student	213	27.9%
	Self-employed	106	13.9%
	Employed	350	45.8%
	Unemployed	14	1.8%
	On maternity leave	29	3.8%
	Retiree/Disabled retiree	52	6.8%

Source: own construction

We further processed data from the questionnaire survey into tables and graphs and interpreted the results.

The first step was to verify the representativeness of the sample according to the gender of the respondents using the Chi-square test of good agreement. However, in order to conduct this test, we first had to obtain information about the current number of women and men in the Slovak Republic. We obtained this data from the website of the Statistical Office of the Slovak Republic.

The Chi-square test of good agreement tests nominal data within a single sample. It is used to determine whether empirical values are sufficiently different from theoretical ones that characterize the baseline dataset (Lyócsa et al. 2013).

The formulation of hypotheses looks as follows:

H_0: The sample is representative.

H_1: The sample is not representative.

We calculate the test statistic according to formula (1):

(1)

$$\chi^2 = \sum_{i=1}^{k} \frac{(E_i - T_i)^2}{T_i}$$

Where:
x2 – test statistic,
E_i – empirical frequencies,
T_i – theoretical frequencies.

In Microsoft Office Excel, using the CHIINV function at a significance level of $\alpha = 0.05$, we calculate the critical value and compare it with the test statistic. If the test statistic is less than the critical value, we do not reject H_0. However, if the opposite occurs, we reject H_0 and accept H_1 (Matejková et al. 2018).

Since we aimed for a deeper analysis of the results, the established hypotheses were tested using the Chi-square test of independence, which, according to Matejková et al. (2018), is a test for nominal data. Using this test, we investigate whether the differences between empirical and theoretical frequencies are only random (variables are not dependent) or statistically significant (variables are dependent). We formulate the null and alternative hypotheses as follows:

H_0: There are no differences (dependence) between qualitative characteristics.
H_1: There are differences (dependence) between qualitative characteristics.
We calculate the test statistic according to formula (2):

(2)

$$\chi^2 = \sum_{i=1}^{m}\sum_{j=1}^{k} \frac{(E_{ij} - T_{ij})^2}{T_{ij}}$$

Where:
x_2 – test statistic,
m – number of rows,
k – number of columns,
E_{ij} – empirical frequencies,
T_{ij} – theoretical frequencies

In Microsoft Office Excel, using the CHIINV function at the significance level $\alpha = 0.05$, we calculate the critical value and compare it with the test statistic. We accept the null hypothesis if the test statistic is less than the critical value. We accept the alternative hypothesis if the test statistic is greater than the critical value.

The authors add that if statistical dependence is found among the examined characteristics, it is necessary to determine its strength using Cramer's V coefficient. We will use formula (3) for calculation:

(3)

$$V = \sqrt{\frac{\chi^2}{n \cdot h}}$$

Where:
x_2 – test statistic,
n – number of observations (respondents),
h – interval range, calculated as min((m-1), (k-1)).

The coefficient can take values in the range from 0 to 1. The closer the value is to 1, the stronger the examined dependence.

The next test is the Share test with known constant (Right-tailed test). We use a Right-tailed test when deciding whether the parameter value is greater than expected (Math.sk 2017). The null hypothesis H_0: $\theta = \theta_0$ is posed against the alternative hypothesis H_1: $\theta > \theta_0$ (Statumeconomy.sk 2017).

We will use the formula (4) for calculation:

(4)

$$u = \frac{p - \pi_0}{\sigma_p} \quad \sigma_p = \sqrt{\frac{\pi(1-\pi)}{n-1}}$$

u – N (0,1) distribution
The test evaluation is as follows:
If $|u| < u_{1-\alpha}$, we do not reject H_0
If $|u| > u_{1-\alpha}$, we reject H_0 and accept H_1 (Matejková et al. 2018).

3. Results and Discussion

Our study was conducted to determine the importance of digital marketing and digital trends such as artificial intelligence and augmented reality in marketing communication and determine their influence on rational and irrational consumer behavior.

At first, we decided to verify the representativeness of the sample by the gender of respondents (Table 2). We used the Chi-square test of good agreement and established these hypotheses:

H_0: The sample is representative by the gender of respondents.
H_1: The sample is not representative by the gender of respondents.

Table 2. Chi-square test of good agreement

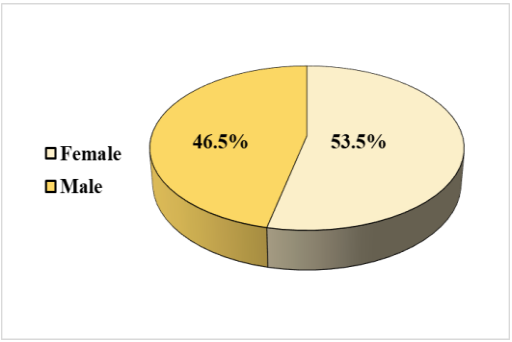
Source: own construction

Based on empirical and theoretical frequencies, we have determined a test

Gender	Baseline dataset	Empirical frequencies (Sample dataset)	Theoretical frequencies (Sample dataset)	$(E-T)^2/T$
Female	2,773,698	409	390.35	0.89
Male	2,655,094	355	373.65	0.93
Total	5,428,792	764	764	1.82

statistic. Its value is 1.82. The test statistic is smaller than the critical value. Therefore, we do not reject H_0, meaning the sample is representative by gender respondents. Sample representativeness is also demonstrated in Figure 1.

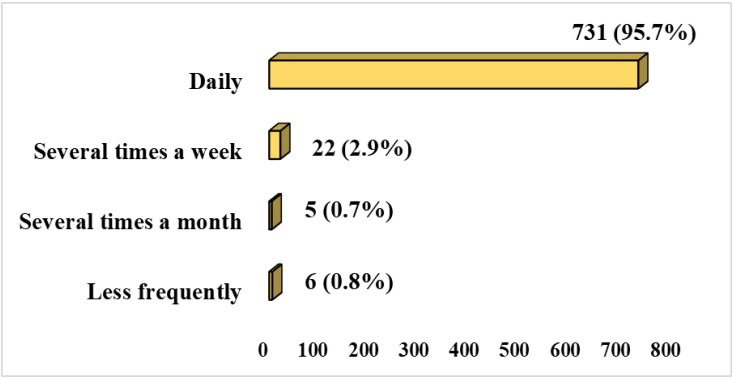
Figure 1. Gender of respondents



Source: own construction

The first part of our study focused on the online habits of the respondents. We asked them how often they use the Internet and digital technologies (Figure 2).

Figure 2. The use of internet and digital technologies



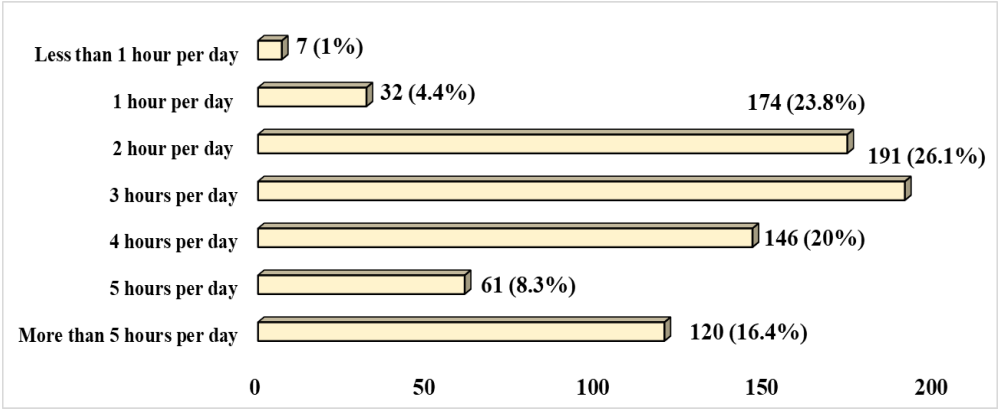
Source: own construction

Up to 95.7% of the 764 respondents said they use the Internet and digital technologies daily. We were also interested in the ways the Internet is utilized. The results indicate that respondents most frequently visit websites related to their interests (63.7%), surf on social networks and utilize them for communication with their family

and friends (57.3%). Additionally, it is worth noting that digital technologies and the Internet are considered work tools for 3.3% of respondents.

Among respondents who use the Internet daily (731), we examined the number of hours spent online per day (Figure 3).

Figure 3. Daily time spent online

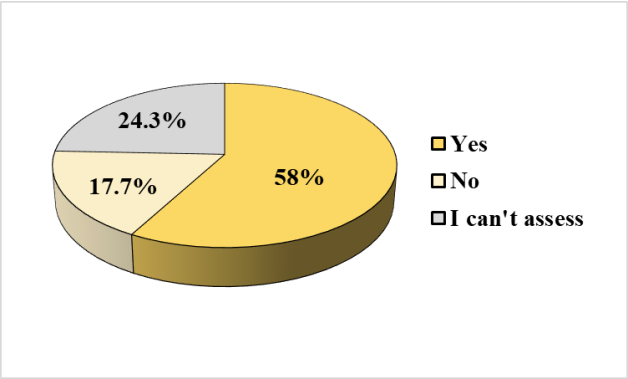


Source: own construction

Most respondents spend 3 hours online daily (26.1%). However, only 1% spend less than 1 hour online daily.

The most important question in the first part, pivotal for further research, was: "Do you think that the Internet and digital technologies influence your consumer behavior?" (Figure 4).

Figure 4. The influence of the internet and digital technologies on the customer Behavior



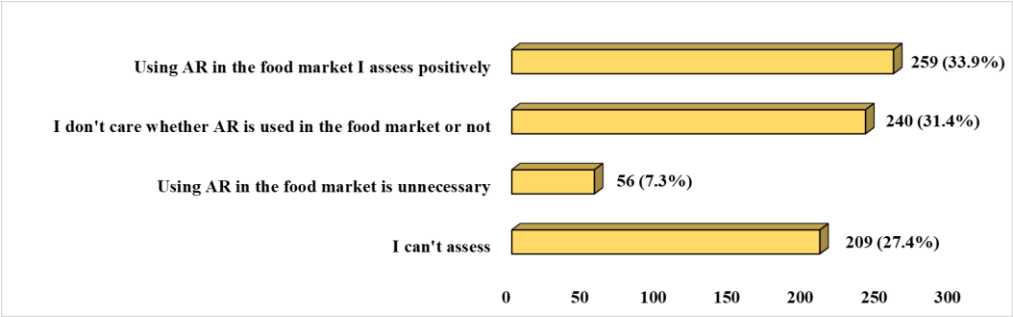
Source: own construction

A total of 58% of respondents know the impact of the Internet and digital technologies on consumer behavior. Under the influence of these factors, rational decision-making often shifts to irrational. On the other hand, 17.7% of respondents

do not believe that the Internet and digital technologies influence them, and 24.3% cannot assess the impact.

The next part of our study focused on today's popular digital trends, which are augmented reality and artificial intelligence. We investigated consumer opinions about implementing augmented reality in digital marketing within the food market (Figure 5).

Figure 5. AR as a marketing communication tool in the food market



Source: own construction

In Figure 5, we can see that 33.9% of respondents assess the use of AR in the food market positively, while only 7.3% consider it unnecessary.

In connection with this finding, we establish hypothesis 1: we assume that more than 30% of respondents would use Magnum Company's AR application.

Currently, this application is only accessible to customers in Singapore, and we were interested in whether Slovak consumers would utilize it if it became available in Slovakia. The Share test with known constant (Right-tailed test) was used to confirm or refute the assumption.

We have established a null and alternative hypothesis:

H_0: Less than 30% of respondents would use Magnum Company's AR application.

H_1: More than 30% of respondents would use Magnum Company's AR application.

The comparison between the test statistic and the critical value is in Table 3.

Table 3. Share test with known constant (Right-tailed test)

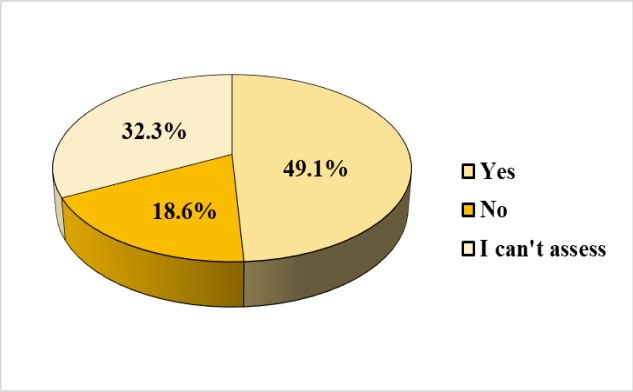
Test statistic |u|	>	**Critical value $u_{1-\alpha}$**
11.50	>	1.64

Source: own calculation

The test statistic is greater than the critical value, so we accept the alternative hypothesis. The first established hypothesis has been confirmed. Magnum Company's AR application would be used by more than 30% of respondents.

Figure 6 shows that up to 49.1% of all respondents would utilize the application.

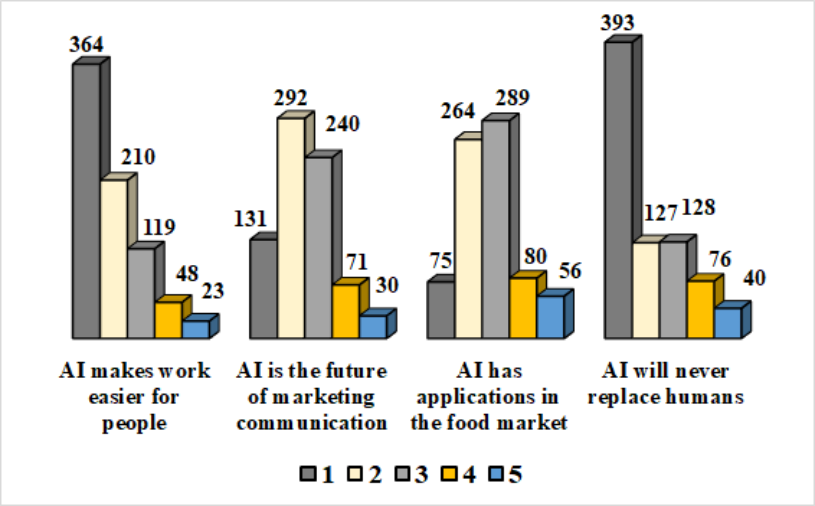
Figure 6. Magnum company's AR application



Source: own construction

Furthermore, we focused on artificial intelligence. Respondents evaluated several statements about artificial intelligence on a 5-point scale (1 – completely agree, 2 – somewhat agree, 3 – cannot assess, 4 – somewhat disagree, 5 – completely disagree) (Figure 7).

Figure 7. Artificial Intelligence



Source: own construction

A total of 364 out of 764 respondents completely agree that AI makes work easier for people, but at the same time, most respondents believe that AI will never replace humans. Many respondents also believe that AI represents the future of marketing communication and has applications in the food market. The relationship between the age group of respondents and their opinion on the fact that AI can create food was examined in the second hypothesis.

We assume that there is a dependency between the age group of respondents and their opinions on food created by artificial intelligence. This hypothesis was analyzed using the Chi-square test of independence.

We have established a null and alternative hypothesis:

H_0: There is no dependency between the age group of respondents and their opinions on food created by artificial intelligence.

H_1: There is a dependency between the age group of respondents and their opinions on food created by artificial intelligence.

Using a contingency table, we compared empirical and theoretical frequencies to determine the test characteristic. We then compared this characteristic with the critical value (Table 4).

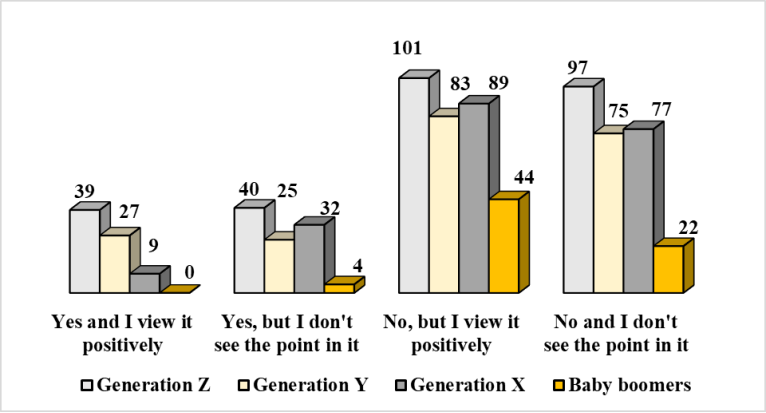
Table 4. Chi-Square test of independence

Test statistic	>	**Critical value**
34.85	>	16.92

Source: own calculation

The test statistic is greater than the critical value, so we accept the alternative hypothesis. The second established hypothesis has been confirmed. This means that there is a dependency between the age group of respondents and their opinion on food created by artificial intelligence. The Cramer's V coefficient was used to assess the strength of this dependency. Its value of 0.12 indicates a very weak dependency.

Figure 8. "Do you know that AI creates food? What do you think about it?"



Source: own construction

The Internet and digital technologies are part of our everyday life. This statement is supported by the results of our research, in which 95.7% of respondents stated that they are online daily.

Almost identical findings are presented by Krnáčová and Benkőová (2016); according to their study, as many as 96% of users utilize the Internet multiple times a day. Through the mentioned study, we also analyzed users' most frequent internet

activities. According to the findings of Krnáčová and Benkőová (2016), people mostly use the Internet for browsing social networks in Slovakia. Similar findings were confirmed based on our research, where social networks ranked second among activities.

Our next significant finding is that more than half of the respondents know the impact of the Internet and digital technologies on their consumer behavior. The impact of the Internet is also evidenced by the Digital Conzoomer survey conducted by the Mark BBDO agency in 2018, with a sample of 2000 Slovak consumers. One of the key findings of this survey is that the Internet has become a determinant in decision-making for more than a quarter of Slovak consumers (Mark BBDO.sk, 2018).

On the other hand, according to the study by Fedorko and Mihal (2017), respondents feel relatively uninfluenced by online advertising. This fact is surprising for us. As Nöjd et al. (2020) state, research shows that digital technologies and trends enhance customer experiences.

According to the results of our study, we can assert that AR is perceived positively by consumers as a tool for marketing communication. Its potential is mainly in applications that can help customers better understand the product and thus significantly ease purchasing.

Berman and Pollack (2021) found that an effective AR strategy allows consumers to skip steps in the typical purchase process by going from awareness directly to purchase and making a purchase decision online without going to the store.

Artificial intelligence is also the subject of study for many authors. Many people who participated in our study consider AI to be part of the future of marketing communication.

Lee (2020) examined the application of chatbots, currently the most well-known form of artificial intelligence. Chatbots are already effectively used today to provide useful information to customers, quickly resolve customer issues, and gather customer information suitable for marketing purposes.

According to a survey conducted by Median SK in 2023 with a sample of 1,003 respondents over 18, nearly half of the respondents believe that artificial intelligence sometimes helps, while at other times, it lacks a human touch (Trend.sk 2023). This opinion likely prevails in Slovak society today, as we presented similar results.

4. Conclusion

Our study has aimed to identify the impact of the Internet and digital technologies on consumer behavior, determine the significance of digital marketing as a tool of marketing communication, and also explore the importance of utilizing artificial intelligence and augmented reality in marketing communication in the food market in the context of rationality and irrationality in creating consumer preferences.

The increasing digitalization opens up new opportunities and challenges, becoming integral to our daily lives. The results of our research show that the majority of Slovaks we surveyed spend time online daily. They utilize digital technologies for

various activities. The Internet has become a determinant factor in purchasing decisions and can influence consumer behavior.

According to our results, consumers perceive AI and AR as marketing communication tools in the food market quite positively. Therefore, food retailers and grocery chains should use them more. We have the following recommendations to improve digital marketing communication in the food market in three ways.

First, in creating quality and interactive content on social networks. Since our findings have shown that social networks are among the most frequent internet activities, food retailers should focus on this tool and utilize it even more. Interactive content tailored to customer needs will help build a long-term relationship and trust between the retailer and the customer.

Second, in utilizing an AR-based application for food delivery e-shops and restaurants. Customers could create their meals according to their preferences and tastes, and thanks to the AR application, they would see what it looks like. Then, they would decide whether to order it or not.

And third, in the utilization of chatbots in grocery retail chains and the healthy nutrition segment. Retail chains could utilize chatbots to communicate with customers and inform them, for example, about current offers and discounts. E-commerce platforms specializing in healthy nutrition could utilize chatbots by allowing customers to provide information about the products they seek. The chatbot could then offer advice and suggest appropriate products. For example, if a customer aims to lose weight, the chatbot could offer weight loss advice while recommending the top weight loss products in the e-shop.

Our research has shown that artificial intelligence and augmented reality are the future of marketing communication. However, their potential in marketing has not yet been fully uncovered and utilized, and thus, in the coming years, they will undoubtedly become the subject of much more research.

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Chapter II

Global Business and Economic Synergies

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Trade facilitation and Global Value Chains harmony

Mahammad Kheyirkhabarli

In recent decades, the development and expansion of Global Value Chains (GVCs) have offered the production process an international scale, with an increasing number of countries contributing to the production of a single final product. The prominence of emerging economies in global value chains is on the rise, despite persisting disincentives that hinder the growth of international trade. Hence, to mitigate these impediments and foster international trade growth, the Aid for Trade initiative is launched. This study seeks to discern the nexus between the implementation of the Aid for Trade initiative in emerging economies and its prospective influence on the performance of these nations within global value chains. Existing literature expresses a positive outlook on the influence of aid for trade on global value chains, attributing this impact to the reduction of trade costs across various sectors involved in these chains.

Keywords: aid for trade, global value chains, emerging economies

1. Introduction

Over the past few decades, due to the increasing impact of globalization, certain phases of production that were previously localized have now become dispersed across different geographical locations. Global value chains (GVCs) denote a series of activities involved in manufacturing a product or delivering a service, ultimately sold to consumers. Each step contributes value to the final product, with at least two steps being conducted in different countries. When a company engages in at least one step within a GVC, it is considered part of the chain. With the rapid internationalization of production, new countries have been able to join GVCs, diminishing the dominance of major economies that previously controlled core positions. Consequently, more countries are now active participants in GVCs, with developing nations increasingly involved in various production stages. GVCs are increasingly seen as a potential avenue for emerging economies to achieve development, as highlighted in the research of Hanson (2012) on the integration of developing countries into the global economy and the rise of south-south trade within GVCs. Gereffi (2014) also underscores the expanding role of emerging economies in GVCs and the growing importance of GVCs for their economic and social welfare. Emerging economies, positioned between developing and developed nations, are subject to shifting categorizations as emerging markets, assessed periodically by various global financial organizations using diverse criteria. In line with the findings of Jangam and Rath (2021), there has been an increase in GVC involvement for emerging market economies from 34.8% in 1995 to 49.3% in 2011. However, participation in GVCs poses challenges for emerging economies. Aid for Trade serves as a key tool to address these challenges.

The Aid for Trade Initiative aims to bolster international trade in developing countries by addressing constraints through assistance and enhancement of trade-related factors. Introduced in December 2005 at the WTO Ministerial Conference in Hong Kong (Hallaert 2013), the initiative seeks to help developing nations build supply-side and trade-related infrastructure necessary to implement and benefit from WTO agreements, thereby expanding their trade opportunities. Emerging countries require technological and financial support to integrate and compete in foreign markets. Obstacles such as outdated or inadequate infrastructure, limited access to trade finance, compliance with diverse requirements, and complex border procedures pose costs for companies from emerging economies seeking to operate in foreign markets.

This paper examines the intersection between the implementation of the Aid for Trade initiative in emerging economies and its potential impact on these nations' performance within global value chains. Following this introduction, Section 2 reviews the existing literature on this topic, analyzing factors across three categories: Economic Infrastructure, Capacity Building, and Trade Policy and Regulations. Section 3 provides conclusions.

2. Literature Review

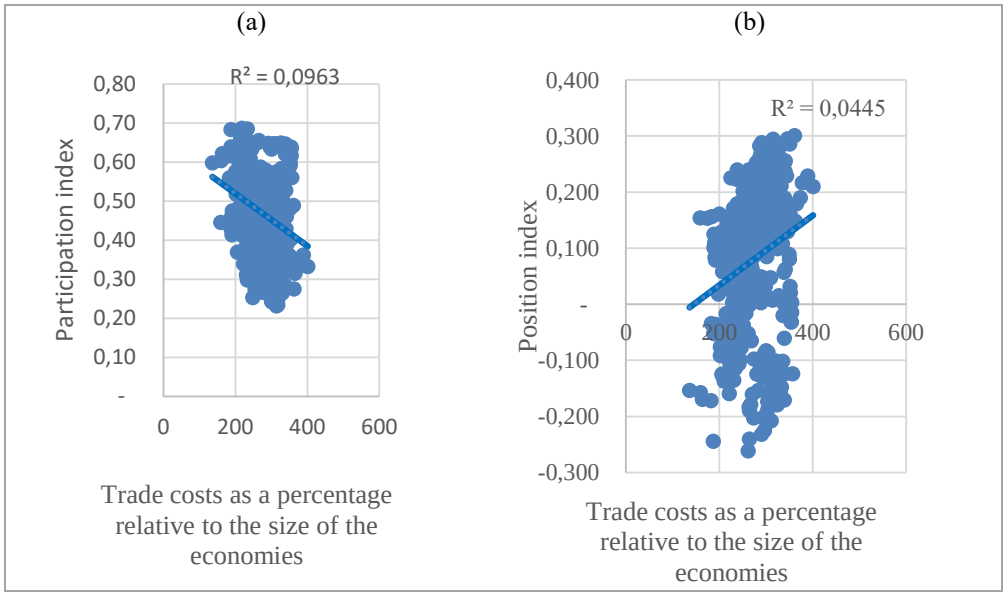
Global value chains emerged due to the deregulation and liberalization of international trade (Herr–Dünhaupt 2019). Several individuals might conflate the concepts of Global Value Chains and Global Supply Chains. The distinction between a value chain and a supply chain lies in their respective functions. A supply chain entails the coordination of all entities engaged in meeting customer demands, whereas a value chain comprises a series of interconnected operations utilized by a company to gain a competitive edge (Adewole–Struthers 2019). The GVC concept enjoys perception across various industries. The manufacture of goods such as transportation equipment and electrical devices is where the GVC concept is most well-known. However, the value chain approach may also be used to resource-based businesses. Aside from resource extraction, additional activities in the value chain encompass transportation and logistics. This type of conceptualization applies to the production of ores and minerals as well as agriculture. By taking part in GVCs, emerging economies may get access to new and often more profitable markets. This gives them the opportunity to add value to their own industries, create jobs, and raise income levels.

A country's participation in GVCs can be evaluated by adding its forward and backward linkages. The proportion of foreign value added in a nation's total exports is used to measure backward participation, whereas the proportion of domestic value contributed in exported intermediate products - which are then used by businesses in other nations for their exports – is used to measure forward participation. The GVC participation index specifies a preliminary understanding of a nation's total involvement in GVCs by aggregating these metrics and reflecting the degree of participation and its relative contribution in the global economy. However, merely examining a nation's relative participation rate is insufficient to comprehend how it participates in the networks of production (OECD/WTO 2015).

Countries' participation in high or low value-added activities matters as well. For a long time, economists have highlighted the advantages of international trade for economies, irrespective of the degree of added value connected to their product or field of specialization. Despite this, there is frequently a bias in favour of high value-added activities within GVCs in policy debates (Shepherd 2016). Low value-added activities, including assembly in manufacturing or commodity production in resource-based industries, are common points of entry into GVCs. Unlike in the manufacturing sector, rising through the ranks in resource-based value chains is typically more difficult (Shepherd 2016). In addition, OECD/WTO (2015) includes the structural attributes of nations, such as their size, location, and manufacturing proportion to GDP, as the primary factors influencing participation.

As illustrated in Figure 1, depicting the correlation between trade costs, sourced from the UNESCAP-World Bank dataset, and two key indices – the value chain participation index (a) and position index (b) sourced from the UNCTAD Database for the Aid for Trade recipient emerging economies for the available period of 1995-2018 – it becomes evident that trade costs play a substantial role in shaping value chain dynamics. Regarding the association between trade costs and the Participation Index (a), a clear negative correlation is evident, indicating that higher trade costs tend to correspond with lower levels of Global Value Chain (GVC) engagement in emerging economies. Conversely, the relationship between trade costs and the Position Index demonstrates a positive trend, suggesting that emerging economies with elevated trade costs are typically situated at the initial stages of production. According to Nyagadza et al. (2022), typical barriers that have been so evident in the emerging economies when it comes to employing the control, ownership, and supremacy of resources through the implementation of the 4IR technological dynamics encompass inadequate ICT infrastructure, radio frequency licensing, inadequate distribution of electricity in many rural areas of Africa, and development of skills, among others. Through their analysis of the Middle East and North Africa (MENA) region, Dovis and Zaki (2020) identified numerous significant barriers. The most pressing concerns are those related to political instability, insufficient electrical supply, restricted financial access, widespread corruption, high tax rates, and informal sector activities. Remarkably, these challenges are similar to those noted by businesses in other countries such as Latin America and the Caribbean and Eastern and East Asia and Pacific, where the main constraints include tax rates, competition from the informal sector and financial accessibility.

Figure 1. Trade costs and GVC participation/position indices in AfT recipient EEs, 1995–2018



Source: own construction

Note: Trade costs are shown in relation to (a) the value chain participation index and (b) the position index. Data are based on the UNESCAP-World Bank dataset for trade costs and the UNCTAD Database for GVC indices

Moreover, according to OECD/WTO (2015), economies' capacity to incorporate efficiently with the global economy is significantly impacted by the quality of transportation, telecommunications, and financial services, as well as border procedures, customs policies, and business and regulatory frameworks. Furthermore, Bamber et al. (2014) highlighted five aspects that influence developing nations' competitiveness with regard to GVCs: production capacity, infrastructure and services, business environment, trade and investment policy, and industry institutionalization. In general, economic infrastructure, building productive capacity and trade policy and regulation stand out prominently as primary barriers to GVC integration. Meanwhile, these elements represent focal points within the aid-for-trade initiative as well.

2.1. Economic Infrastructure

The arrangement of international trade is progressively centered on GVCs and can be enabled by enhancements in transportation, the revolution in information and telecommunications (ICT), and energy. The closeness to markets, which inevitably diminishes trade expenses, along with effective logistics and robust institutions, emerges as the primary catalysts for involvement in GVCs (Pathikonda–Farole 2017).

According to Mayer and Milberg (2013), the primary focus of infrastructure aid appears to be on transportation, which includes improvements to ports, railways,

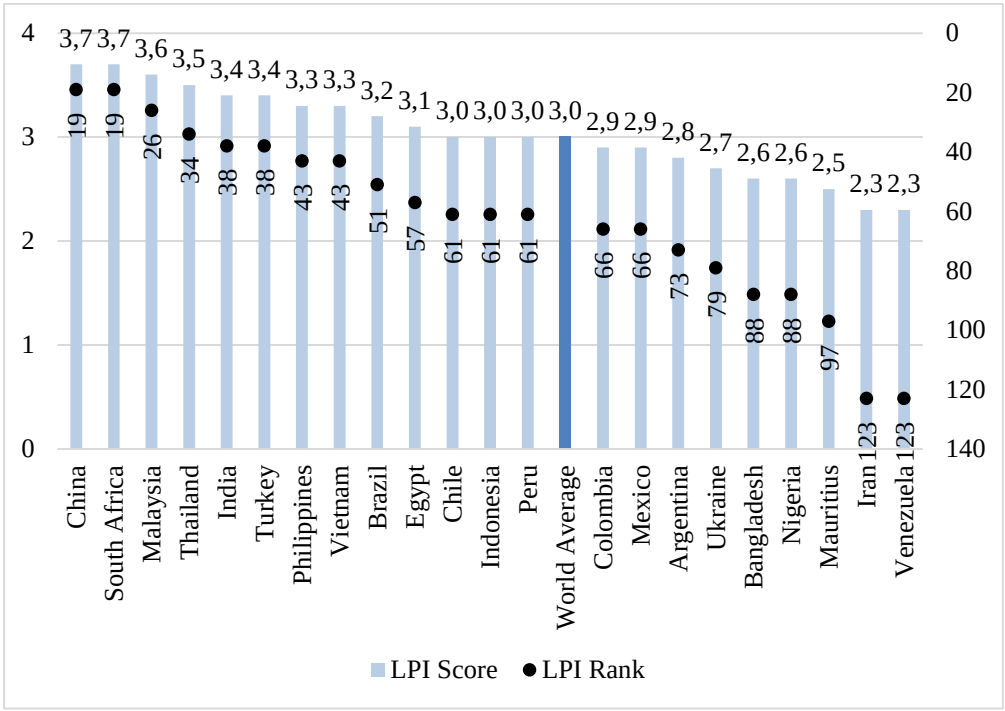
and road networks. Furthermore, a certain amount of the assistance in this category flows toward the development of electrical and communication infrastructure. Moreover, Bamber et al. (2014) emphasize the importance of infrastructure cost and quality, as well as the availability of border services. According to OECD/WTO (2015), improving trade facilitation and infrastructure quality is expected to have a substantial impact on global value chain integration. Poor infrastructure and inefficient border crossing processes might substantially raise the cost of product movement from point of origin to final location. Prolonged transit times caused by inadequate infrastructure decrease the efficiency of commodities movement to ports, while poor road conditions raise maintenance costs and decrease the lifespan of transportation vehicles. Furthermore, delays in customs processes for exports might impair product quality or result in the loss of perishable items (Bamber et al. 2014). Moreover, Lanz and Piermartini (2021) also emphasize that the importance of transportation infrastructure and simplified border processes in promoting international trade across supply chains cannot be ignored. Delays or inefficiencies in these areas increase inventory holding costs, impede quick reactions to moves in consumer demand, and limit the timely replacement of damaged parts. According to their results, robust transportation infrastructure provides a competitive advantage at the initial stages of production, known as upstream industries.

GVCs become impracticable in contexts with poor trade facilitation, such as those widespread in certain regions, since items, including components and parts, cannot be transported across borders quickly, reliably, and inexpensively (Shepherd 2016). Enhancing the trade facilitation and logistics framework emerges as a significant priority for emerging nations looking to increase their participation in GVCs. Investigating the upgrading experiences in cut flower GVC in East Africa, Keane (2019) highlights how insufficient logistical capacities might limit enterprises' capacity to adapt to diverse marketplaces and exploit prospects for advancement. Furthermore, Arvis et al. (2016) emphasize the critical importance of logistics performance in influencing a country's trade costs and, as a result, its ability to integrate into global value chains.

The Logistics Performance Index (LPI) is a significant measuring tool designed by the World Bank to assess the performance of logistics and trade facilitation measures in various nations (Arvis et al. 2023). This instrument provides insights into customs clearance efficiency, infrastructure quality, ease of shipping preparations, logistics service competency, tracking capabilities, and shipment timeliness. The LPI uses questionnaires of worldwide freight forwarders and logistics professionals to rate nations' logistical environment on a scale of 1 to 5, with higher ratings indicating greater performance. The LPI, which is widely used by policymakers, corporations, and researchers, assists in identifying areas where logistics infrastructure needs to be improved and allows for cross-country performance comparisons (Arvis et al. 2023). Figure 2 presents the Logistics Performance Index alongside the corresponding rankings of Aid for Trade recipient emerging economies, where data is available for the latest year, 2023, as sourced from the World Bank Database. The figure depicts variations in performance among selected countries. While the majority exhibit indexes higher than the world average, several emerging countries still perform below this benchmark. Notably, China and

South Africa lead with an LPI of 3.7, securing the 19th position out of 139 countries with available data. They are closely followed by Southeast Asian nations and Turkey. Conversely, Iran and Venezuela exhibit the lowest LPIs for 2023, standing at 2.3, and occupying the 123rd position in the ranking.

Figure 2. Logistics Performance Index and rankings in AfT recipient EEs, 2023



Source: own construction
Note: The Logistics Performance Index is shown on the left scale, while rankings are on the right scale. Data are based on the World Bank Database

In addition, the use of modern energy-saving technologies can also help developing countries improve the efficiency of their manufacturing processes (Yao et al. 2020). According to Dovis and Zaki (2020), electricity is a significant barrier for companies in the MENA region. Enhancing infrastructure, notably in the generation and distribution of electrical power, in that region would allow enterprises to specialize in more complex product lines, thanks to a steady and sustainable energy supply. Furthermore, by investigating thirty-six countries during the period of 1995-2014, Yao et al. (2021) found a positive correlation between energy efficiency and value-added trade.

Thus, economic infrastructure, including transportation, ICT, and energy, is vital for participation in GVCs. Funds in infrastructure aid are crucial for reducing trade costs and promoting GVC integration. Challenges like poor infrastructure hinder participation, emphasizing the need for improvements in logistics performance. Improving infrastructure, particularly in electricity generation and distribution, is

critical for enabling enterprises to thrive in GVCs. The positive relationship between energy efficiency and value-added trade underscores the importance of modern energy technologies in economic development and GVC participation.

2.2. Building Productive Capacity

Aid towards building productive capacity seems to be diverse, including cooperative aid, provision of infrastructure and equipment, as well as training efforts. Shepherd (2016) states that Aid for Trade programs allocate considerable funds towards developing productive capacities, emphasizing the importance of continuing this trend within a broader framework aimed at establishing policies for industry and human capital development, which will facilitate medium-term growth and progress. Furthermore, Bamber et al. (2014) also identify four broad elements that are critical to the growth of productive capacity in all industries: national innovation systems, standards, certification systems, and human capital. According to Nyagadza et al. (2022), capacity building is crucial for controlling support and regulations associated with strategic innovation. Furthermore, Lanz and Piermartini (2021) reveal that efficient institutions offer a competitive advantage in the later stages of the manufacturing process, which are often known as downstream activities.

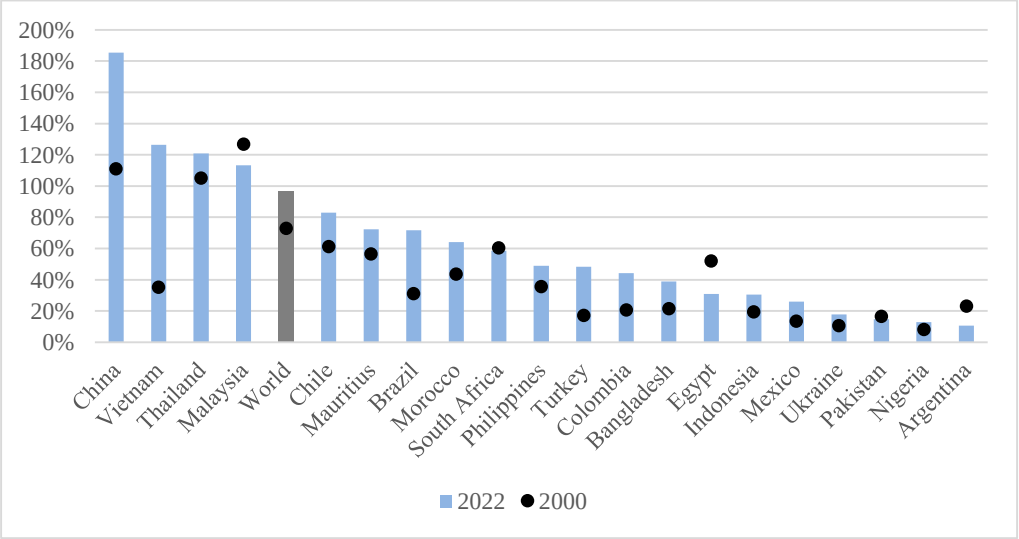
Agriculture is one of the most important sectors of the economy. Since aid organizations are already heavily involved in the agricultural sector, the importance of the sector to both developed and developing economies is demonstrated by the growing amount of funds that are allocated towards this area (Bamber et al. 2014). Farmers in emerging nations have better chances of obtaining inputs like fertilizers and seeds when trade costs in the agriculture industry are reduced. Consequently, this has the potential to boost productivity and encourage larger-scale manufacturing, which would assist the processing industries. Bamber et al. (2014) emphasize that the modern agriculture system has evolved into a sophisticated agro-foods system, led by major retail chains operating in international markets. Customers' demands for high-quality goods that adhere to precise requirements heighten supplier competitiveness as they compete to keep their places in supply chains.

Improving employee skills and productivity is crucial to raising their level of competitiveness not only in local economies but also in GVCs. First, aid might be provided to employees so they can increase their output by investing in technology and training, which will increase their efficiency and competitiveness along the value chain (Mayer–Milberg 2013). Similar to this, prioritizing aid efforts on the services sector – that is, on skill development and training programs – can increase a nation's involvement in GVCs and provide observable advantages including better R&D services, financial services, and marketing capacities (Banga 2013). Additionally, Mayer and Milberg (2013) stress that employee welfare and economic growth can be strengthened by aid programs that encourage the development of producers with backward links or that generate synergistic clusters of economic activity. Nonetheless, it is important to acknowledge that merely enhancing employee efficiency or bargaining power would not be adequate if global markets cannot be reached, underscoring the need of strategic industrial policy and market connections in aid initiatives. All of these statements have one thing in common: maximizing the benefits

of involvement in local and global economies, concentrated aid programs that aim to improve worker productivity, skills, and market connectedness is essential.

The access to financial resources has an important role in enabling the integration of individuals or businesses into GVCs. According to Bamber et al. (2014), financial resources, including bank funding, collateral, credit registries, and bankruptcy laws, are essential for investments to fulfil GVC requirements. Furthermore, Dovis and Zaki (2020) highlight that bank funding gives businesses the chance to grow and incorporate into GVCs, however, self-financing could have limitations in terms of quantity and sustainability. Figure 3 presents the domestic credit to the private sector by banks, represented as a percentage of gross domestic product (GDP), for the years 2000 and 2022, the latest available year, across emerging economies that are recipients of Aid for Trade, where data is available. The analysis highlights notable trends and variations in bank financing among these economies. Notably, China emerges as the most significant recipient of bank financing in 2022, followed by Vietnam, Thailand, and Malaysia, all of which surpass the global average. Conversely, Malaysia, South Africa, Egypt, Pakistan, and Argentina exhibit a decrease in bank financing from 2002 to 2022, contrasting with an overall increase observed in other countries. Vietnam stands out with the most significant surge, experiencing an exponential rise from approximately 35% in 2002 to 126% in 2022. According to El-Said et al. (2015) insufficient funds might limit small and medium-sized businesses' (SMEs') ability to engage in GVCs in a successful way. Thus, improving financial access may substantially increase the possibility that businesses will integrate into GVCs, supporting development and economic progress.

Figure 3. Bank credit to private sector (% of GDP) in AfT recipient EEs, 2000 vs. 2022



Source: own construction

Note: The percentage ratio of bank credit to the private sector to GDP is compared between 2000 and 2022. Data are based on the World Bank Database

We can notice that investment in agriculture is particularly crucial, as evidenced by the growing allocation of funds to this sector, which has the potential to enhance productivity and spur manufacturing growth. Improving employee skills and productivity is essential for competitiveness, with aid efforts focusing on technology adoption, training, and skill development in the services sector. Access to financial resources is also pivotal for integrating individuals and businesses into GVCs, with bank funding playing a significant role in enabling growth and integration. These aid programs collectively aim to maximize the benefits of participation in local and global economies by enhancing worker productivity, skills, and market connections.

2.3. Trade Policy and Regulation

A variety of studies emphasize how crucial trade facilitation and effective border crossings are to strengthening global value chains (GVCs) and advancing trade. The seamless operation of GVCs might be negatively impacted by inefficient border crossings that impede the prompt distribution of goods and services to their designated recipients (Bamber et al. 2014). Trade facilitation is becoming increasingly important for the smooth flow of products across borders as GVC operations expand. Hoekman and Shepherd (2015) state that enhanced trade facilitation helps businesses of all sizes by encouraging exports by lowering bottlenecks and logistical challenges. Furthermore, clearing up formal obstacles at borders promotes both importing and exporting economies while also facilitating integration into value chains. According to OECD/WTO (2015), certain policies that promote links within value chains and increase the overall efficiency of trade regulations include advance rulings, accelerated border procedures, and transparent import/export fees. Thus, encouraging economic growth, facilitating integration into GVCs, and helping businesses of all sizes throughout regions all depend on improving trade facilitation, lowering administrative barriers, and automating border operations.

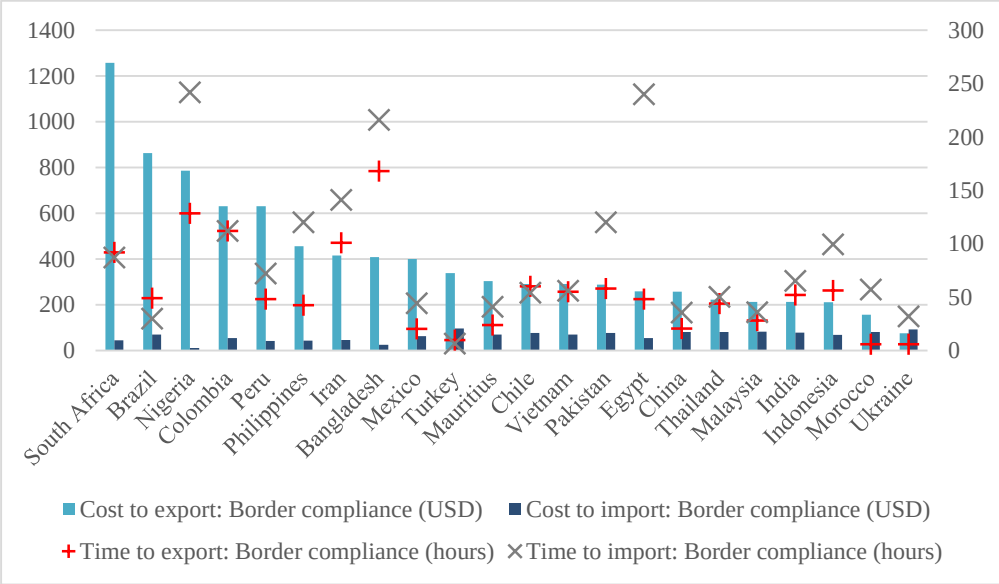
A number of factors, from the complexity of trade laws and regulations to the level of quality of a country's infrastructure, affect how businesses integrate into GVCs. The establishment of a national quality infrastructure, which includes certification, testing, standardization, and other associated activities that are essential for companies intending to engage in GVCs, is mainly the responsibility of the public sector (Shepherd 2016). Meanwhile, companies' feasibility of integration is highly dependent on the business environments in which they function; this is especially true in the MENA region, as demonstrated by Dovis and Zaki's (2020) research. According to them, a firm's possibility of integrating into GVCs is considerably hampered by elements like the number of procedures needed for fundamental company operations, lengthy procedures including managing insolvencies, and bureaucratic obstacles as paperwork requirements. Smaller businesses and companies in high tariff industries suffer additional difficulties that increase the obstacles to joining GVCs (Dovis−Zaki 2020).

According to OECD/WTO (2015), the increasing fragmentation of production in an international level highlights the need of an open, predictable, and transparent trade and investment policy, which calls for an encouraging atmosphere

for both domestic and foreign enterprises. On the other hand, a nation's competitiveness in international markets is diminished by tariffs, restrictions on imports, and ineffective border processes, which hinder both domestic manufacturers and foreign suppliers (Bamber et al., 2014 and OECD/WTO, 2015). Moreover, according to Keane (2019), a company's willingness to engage in intra-regional exports is highly influenced by institutional and governmental constraints, such as labour and customs laws. These factors are considered in the Aid for Trade Policy and Regulations channel. According to the finding of Wang and Xu (2018), there is a significant and positive relationship between the improvement of export quality and Aid for Trade Policy and Regulations. They emphasize that the impact of Aid for Trade is gradual, steadily increasing through cumulative impacts over time.

Figure 4 illustrates Doing Business indicators, including border compliance costs in USD and the time taken in hours to export and import for emerging economies that are recipients of Aid for Trade, based on the latest available data from 2019. The figure highlights significant variations in these indicators across countries. With the exception of Ukraine, a common trend is observed wherein border compliance costs for exports exceed those for imports. Among the countries analysed, South Africa, Brazil, Nigeria, Colombia, and Peru exhibit the highest border compliance costs for exports, while Ukraine demonstrates the lowest. Conversely, Turkey demonstrates the highest border compliance costs for imports, while Bangladesh records the lowest. In terms of the time required for border compliance for exports, Bangladesh exhibits the highest duration at 168 hours, followed by Nigeria at approximately 128 hours, while Ukraine and Morocco record the lowest duration at 6 hours each. Conversely, the longest durations for border compliance for imports are observed in Nigeria, Egypt, and Bangladesh, at 241, 240, and 216 hours respectively, whereas Turkey records the shortest duration at 6.5 hours. Overall, there is a significant amount of variance among the examined emerging economies with regard to the costs associated with border compliance and the time required to import and export goods, based on the data provided in the graph. Some nations exhibit comparatively cheap costs and effective procedures; however, others have notable obstacles, especially with extended processing timeframes and elevated costs associated with compliance. This implies that there could be chances for focused interventions and changes meant to simplify border processes and lower trade expenses, improving these nations' competitiveness in the international market.

Figure 4. Border compliance costs and time for trade in AfT recipient EEs, 2019



Source: own construction
Note: Border compliance costs (USD) are shown on the left scale, and time (hours) on the right scale. Data cover both export and import processes based on the World Bank Database

Thus, we can highlight the critical role of trade facilitation in bolstering global value chains and advancing trade. Enhanced trade facilitation promotes exports, lowers logistical challenges, and fosters integration into value chains. Factors like trade laws, infrastructure quality, and business environment complexity affect GVC integration. Institutional and governmental constraints, such as labor and customs laws, impact companies' willingness to engage in exports. The significant variations in border compliance costs and time required for exports and imports among emerging economies underscore the need for focused interventions to simplify border processes and enhance competitiveness in the international market.

3. Conclusion

The complex relationship between trade aid programs and emerging nations' incorporation into global value chains (GVCs) illustrates the complexity of modern international trade dynamics. This paper has presented an in-depth examination of the several aspects of this connection, shedding light on the possibilities and challenges associated with promoting growth in the economy globally.

A broader variety of nations have taken an active role in the global production of goods and services, which represents a significant shift from the traditional models of international trade that were caused by the introduction and spread of GVCs. The rise of GVCs is uninterrupted despite the ongoing obstacles and disincentives that are present in many emerging nations, which call for drastic steps to promote trade and economic expansion. Leading in carrying on these strategies is the Aid for Trade

initiative, a deliberate attempt to offer targeted support with its objectives of strengthening trade infrastructure, building productive capacity, and reforming trade laws and regulations.

It appears evident that developing infrastructure is essential to enable nations to engage in GVCs. In addition to lowering trade costs, funding in essential sectors like energy, information and communication technology (ICT), and transportation also improve logistical efficiency and encourage increased connectivity, which strengthens the integration of emerging economies into the vast networks of global chains. In addition, the development of production capacity is a crucial step towards GVC integration. This calls for an integrated approach that includes efforts to strengthen standards and certification programs, expand innovative ecosystems, and develop a trained labour force. Investing in these fundamental pillars will help emerging economies become more competitive and increase their capacity to create value in global value chains. Furthermore, the domain of trade policy and regulation has paramount importance in shaping the course of GVC integration. Improving the smooth flow of products and services across borders and increasing the operating efficiency of GVCs requires a number of initiatives, including simplifying border processes, lowering trade obstacles, and promoting openness in trade legislation.

Overall, the conclusions presented in this paper highlight the complex relationship that exists between trade assistance programs and the incorporation of emerging economies into global value chains. Trade aid initiatives have the potential to stimulate emerging economies' involvement in GVCs and promote inclusive growth on a global level by addressing infrastructure limitations, fostering productive capacities, and improving trade policy and regulatory frameworks. To achieve these goals, nevertheless, continued study into the complex dynamics of this connection and how best to maximize trade assistance measures in the context of GVC integration will be required.

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Split or steal or gift: Nash equilibria under altruistically extended payoffs

Zsófia Hajnal

Incentives for cooperation can come from different conceptual directions, beyond the "sticks and carrots" duality. This paper looks into potential, altruistic extensions of the payoff structure known from the prisoner's dilemma in game theory. The illustration of the payoff extensions happens through the derived game "split or steal". The notion of altruism has been frequently and increasingly channeled into game theory previously, yet no attempts were found where it affects the design of the payoff matrix directly and explicitly. The aim of this paper is to show that the original payoffs of the game "split or steal", and of the prisoner's dilemma more broadly, do not cover the full spectrum of human behavior in the strategic dimension of the situation, and that an altruistic adjustment, the "giving as a gift" option, gives space to corresponding incentives. The results are interpreted to be applicable to a number of real-life situations, complex, as well as competitive, both in the corporate and the governmental sphere.

Keywords: game theory, Nash equilibrium, altruism, gift giving, reward scheme

1. Introduction

The game "split or steal" is based on a prisoner's dilemma type payoff structure. In its conventional form, it gives rise to a situation with a 2-by-2 payoff table. Potential expansions have been studied, but the columns and rows therein focus on the inclusion of additional actors (up to indefinite, *n*), as well as on neutral reactions.

Through this paper, I aim to illustrate that the traditional "split or steal" game does not cover the entire spectrum of individuals' propensity to share, and rewards players in a partially distorted way, as compared to situations in real life. I focus on altruistically extended payoff schemes, in which I expand the number of options available to 3, with the possibility of giving as a gift, thus increasing the payoff table to nine (3x3) substantial cells.

The purpose is to support the stance that with a modified reward system, people's tendency to share and to give gifts would increase. In practical terms, this may provide ground for adjusting economic incentives and reward schemes. My research serves to prove the raison d'être of frameworks that give space to altruism, through simulational methods. Results may lead to rethinking the framework of rewards used in complex, and even competitive situations – both in the business and the public sphere. My approach and aims combined are unique, as reflected by searches conducted[1].

[1] On December 10, 2023. Google Scholar yields absolutely no results for "3 by 3 payoffs" (searched with quotation marks inclusive). As for "3 by 3 payoff", there are only 14 results, with only 9 of these mentioning Nash equilibria, or the name Nash in general. Each of the 9 remaining articles is either applying 3 by 3 payoffs in a highly specialized subcontext, is descriptive of existing phenomena in such contexts, or is general, but does not mention altruism.

Three central questions have been formulated: one concerning the payoff designs of "split or steal or gift" games (architecting the tables); the second about participant behaviors in games of such frameworks; and the third regarding the overall connection of extended payoffs with practice.

RQ1: What are the rules, ratios, or values (to be written in the additional five fields of the payoff table) in altruistically extended "split or steal or gift" games that are likely to increase participants' altruistic choices (shifting Nash equilibria toward the cell representing mutual gifting) whilst retaining the game nature of choices?

H1: I predict that the combinations in the additional payoff cells…
- H1a: … cannot be organized along a fixed sum,
- H1b: … have to reflect additional layers of tension and risk,
- H1c: … have to reflect that altruistic behaviors need to be rewarded, be worthwhile overall,
- H1d: … have to be calibrated so as to result in maximum payoff values in the case of both players choosing the "gift" option.

RQ2: Do individual, simulated players in the adjusted, altruistically extended payoff schemes of the "split or steal or gift" game behave more selflessly than in the standard "split or steal" version of the game?

H2a (null-hypothesis): No, they do not.
H2b: Yes, they do.

Both RQ1 and RQ2 are methodological in nature, thus their validation is primarily addressed within the methodology section. RQ2 is the part that the simulations will focus on.

RQ3: In what ways is an altruistically extended payoff scheme more realistic than the split or steal game?
H3: In practice, selflessness is rewarded beyond fixed sum structures, which can be witnessed both in the corporate and the governmental sphere.

My paper is structured as follows. Section 2 provides the theoretical background. Section 3 describes the concrete framework, the tools, and the conduct of the methodology. Section 4 summarizes results, which are then broadly discussed in Section 5. Section 6 describes further research opportunities, and section 7 concludes the paper.

2. Theoretical Background

In the formulation of Daskalakis et al., "Game Theory is about the strategic behavior of rational agents.", and games are "thought experiments modeling various situations of conflict" (2009, p. 89). More broadly: "In game theory, a game may be any situation in which there are interdependent decisions, and the players are all the decision-making

entities" (Elridge 2023). Aligning with these definitions, the subsections look into the strategic aspects of equilibria, into how and in what context the "split or steal" game has been examined thus far, as well as into altruistic extensions of games, a procedure not independent of the altruistic extensions of human behavioral models. For the compilation of works for the review, a mixed technique of Google Scholar searches and collection through reference lists of the works already listed has been used.

2.1. The Nash Equilibrium

The notion of the game forks off into two distinct categories: cooperative and non-cooperative games. Cooperative games are characterized by possibilities: "In a cooperative game, players may work together by forming groups, so-called coalitions, and may take joint actions so as to realize their goals better than if they were on their own" (Rothe 2021, p. 15073). For non-cooperative games, the emphasis is on the constraints: "A game is non-cooperative as long as no mechanism exists for the players to make binding agreements with one another" (Elridge 2023).

For non-cooperative games, there exists a situation in which the individual players cannot improve their expected outcome by changing their own strategy (Elridge 2023). This is called the *Nash equilibrium*, named after the late American mathematician John Forbes Nash Jr., who introduced its definition and characteristics in his seminal 1950 article titled "Equilibrium points in *n*-person games". The Nash equilibrium can be a single cell in a given payoff structure, however, alternatively, "[i]t is possible for there to be multiple Nash equilibria to a given problem" (Elridge 2023).

From the many non-cooperative games known and described to date, the choice for applying and testing altruistic extensions in payoffs has fallen here upon the structure of the widely researched and discussed as the "prisoner's dilemma". The game theoretic model stems from 1950, developed in the frame of an experiment by the mathematicians Melvin Dresher and Merrill Flood, with the criminal narrative having been added by Albert Tucker, Nash's thesis advisor (Holt–Roth 2004, p. 4000).

The prisoner's dilemma[2] is one of the widest known instruments in game theory, with the first comprehensive empirical work dating back to 1965 (Rapoport et al. as referenced in Capraro–Perc 2021, p. 3). Within the prisoner's dilemma model, and according to a self-interested and rational model of the individual, without the chance to communicate, both prisoners will prefer the option of confession to the option of silence, this being the Nash equilibrium.

[2] The background narrative is of two prisoners who have been arrested for the same crime. Individually, both care more about their personal freedom than about the welfare of their accomplice. The prosecutor offers each of them, separately, the choice to confess (i.e. defect, in the context of the game) or to remain silent (i.e. cooperate, in the context of the game). If one confesses and the other remains silent, the one who confessed goes free immediately, while the other serves a longer (e.g. 10 year) prison sentence. If both confess, both will have to serve a moderate (e.g. 5 year) prison sentence. In the case of both of them remaining silent, the prison sentences will both be relatively short (e.g. 2 years). "The 'dilemma' faced by the prisoners here is that, whatever the other does, each is better off confessing than remaining silent. But the outcome obtained when both confess is worse for each than the outcome they would have obtained had both remained silent" (Kuhn 2019).

The reason this underlying structure will be of use in this study is twofold. For one, "[…] the puzzle illustrates a conflict between individual and group rationality" (Kuhn 2019). The reason is that "[…] if the payoffs are not assumed to represent self-interest, a group whose members rationally pursue any goals may all meet less success than if they had not rationally pursued their goals individually" (Kuhn 2019). Second, the dilemma highlights "[…] a choice between selfish behavior and socially desirable altruism" (Kuhn 2019). The individual versus the group, as well as selfishness versus altruism are notions separated by economically permeable boundaries – different interpretations of individual behavior, with different contexts (in terms of emphases and extension) allow the model of the agent to pass from one side of these two dimensions to the other.

2.2. "Split or steal" games as experiments in economics

One of the many variations in applying or "translating" the prisoner's dilemma is the game called "split or steal". A reward is to be shared equally, taken entirely by one of the two players, or to be lost completely, depending on the participants' choices. The mechanism and reward structure (in terms of ordinality) is analogous to that of the prisoner's dilemma.

Sticking to the rational, self-interested model of agents, it is easy to see the following: "The dominant strategy in this game is to always pick steal, since this maximizes profit if the other picks split and doesn't matter if they steal. The Nash Equilibrium in this game is for both players to walk home with nothing" (Cornell University 2014.

Beside analogous laboratory experiments, the first wider appearance that the game made can be dated to the early 2000's, when the entertainment industry began utilizing its mechanism. Best known for this was the British television show *Golden Balls*, running from June 2007 to December 2009 (van den Assem et al. 2012, p. 4). Van den Assem et al. provide a succinct description of the part of the show that is relevant to this paper: "In the final stage of Golden Balls, contestants make a choice on whether or not to cooperate in a variant of the famous prisoner's dilemma. In particular, the two final contestants independently have to decide whether they want to 'split' or 'steal' the jackpot. If both contestants choose split, they share the jackpot equally. If one chooses split and the other chooses steal, the one who steals takes the jackpot and the other gets nothing. If they both steal, both go home empty-handed" (van den Assem et al. 2012, p. 3).

The (online) video game named *Split or Steal* is an iterated version of the phenomenon, involving real players interacting with each other, and collecting "karma", based on the trustworthiness of the behaviors they exhibit. The game design contains elements of inter-player and global communication too, resulting ultimately in "an absurd alchemy that combines social engineering, free-to-play incentives, and idle-game satisfaction that scratches some itch at the back of your brain" (Feldman 2020). As of 2020, split choices in this game were reported to be around 81% high (Feldman 2020), a figure substantially higher than detected through televised game shows (as will be discussed below).

One of the seminal works in approaching the "split or steal" game as an economic experiment is the above-mentioned 2012 article "Split or Steal? Cooperative behavior when the stakes are large", authored by Martijn J. van den Assem, Dennie van Dolder, and Richard H. Thaler. They state that the factor determining their choice falling upon a

television show to study the phenomenon is primarily the size of potential rewards, which is remarkably bigger than the common values used in laboratory experiments, and is also varying within a higher range (van den Assem et al. 2012, p. 2). However, they note an important difference between the "original" prisoner's dilemma and the final stage of *Golden Balls*: "Where in the classic form of the prisoner's dilemma defecting strictly dominates cooperating, here defecting only weakly dominates cooperating: choosing steal always does at least as well, and sometimes better than choosing split" (van den Assem et al. 2012, p. 3). The average cooperation rate turns out to be 53% (van den Assem et al. 2012, p. 4), lower than in the above-mentioned online game. The main conclusion of the article is the influential nature of context on attitudes (van den Assem et al. 2012, p. 16).

By a slight contrast with the van den Assem article, a 2009 paper reported a rate of 48% for cooperation in the *Golden Balls* show (Coffey 2009, p. 2), albeit the data in this paper is restricted to coming from episodes broadcast in 2007 (Coffey 2009, p. 7). Cooperation has been measured along identical and different genders, as well as similar and more distant age groups. Coffey's paper contrasts with van den Assem et al. (2012) also in reporting men's cooperation rate to be higher than that of women (Coffey 2009, p. 2). The paper highlights important parallels with the classical prisoner's dilemma, such as the simultaneous nature of decisions to be made, but emphasizes important differences too, such as the zero-sum nature of "split or steal", which cannot be said about the standard prisoner's dilemma (Coffey 2009, p. 6).

Behavioral aspects have been taken into account heavily by Darai and Grätz, in their working paper "Golden balls: A prisoner's dilemma experiment" (2010). In the late 2010's the split or steal element of *Golden Balls* has attracted even further scientific inquiry, going into specific details regarding pre-decision communication between contestants (Turmunkh et al. 2017, p. 1), and regarding a peculiar strategy of lying in one distinct episode, that had counterintuitive results of cooperation (Brams–Mor 2019).

2.3. Altruistic extensions in game theory

When speaking of altruistic extensions in the context of game theory, the process or phenomenon can be detected at two different but interconnected points in the literature. For one, works that examine individuals displaying altruistic behavior in standard game structures, and which thereby aim to broaden the economic understanding of humans. Second, the design of the classical game structures can be adjusted, so as to allow for altruistic behaviors to show explicitly. In the current subsection, I survey academic works in these two groups. This paper unifies the two strands in subsequent sections, in that both the preliminary assumption about individuals, as well as the game design have the notion of altruism included.

In 1993, the American behavioral economist Matthew Rabin published the article "Incorporating fairness into game theory and economics", wherein he explores intersections of fairness equilibria (outcomes reflecting reciprocal motivations) and Nash equilibria. Through stylized facts, Rabin develops a framework to incorporate retributive and altruistic emotions into economic models, which he illustrates through the games *battle of the sexes*, the *prisoner's dilemma*, and the *chicken* game. The payoff structures of these games require no alteration for the purpose of the paper though.

The economist David K. Levine's 1997 article "Modeling altruism and spitefulness in experiments" was among the earlier pieces of its kind. Levine tested his theory of altruism through a series of games, ranging from an *ultimatum experiment* to a *public goods game*, including a *competitive auction* and a *centipede game*. In terms of initial assumptions, his article relates to and relies upon the work of Rabin. As in many of the referenced articles, the author begins by conceptualizing altruism within a broad perspective. Throughout the chapters describing the experiments, as well as through a series of propositions, Levine supports his model of altruism in quantitative terms.

In a *Nature* review article in 2003, the Swiss economists Ernst Fehr and Urs Fischbacher emphasized the curious observation that "[d]epending on the environment, a minority of altruists can force a majority of selfish individuals to cooperate or, conversely, a few egoists can induce a large number of altruists to defect" (p. 785). They review results from classical games such as the ultimatum game, the dictator game, the prisoner's dilemma, and the public goods game, pushing their review to the limitations of altruism even, in the understanding of the given time period. Game theoretical models have not been altered at their core in their article either, but the interpretations provide the behavioral (and not the psychological) study of altruism with more space.

In his 2010 article "Mixed feelings: Theories of and evidence on giving", James Konow uses the dictator game framework in an experimental study to examine internal motivations for, as well as institutional effects on giving. He reports the results through a mixed interpretation of the categories of unconditional and conditional altruism. The dictator game is used in different variations, however, the differences in the game design serve the assessment of behavior in different contexts and relations, and represent no substantial changes or extensions to the structure of the game.

Roughly from the mid-2010s, one may observe the element of rationality being applied in studies that concern themselves with altruism's game theoretic analysis and interpretation. In their 2016 dictionary entry, Andreoni et al. highlight the rationality element, as well as the difficulty of capturing altruism, with the concept of *warm-glow giving* being a confounder in the process. The authors review a series of classical laboratory experiments of game theory: the prisoner's dilemma, the public goods game, dictator games, and trust games. In each of these, they "adopt the convention of using Nash equilibrium to refer to the prediction that holds if all subjects are rational money-maximizers" (Andreoni et al. 2016). What they reveal (through reviews) is that altruism is not a necessary condition of cooperation in the prisoner's dilemma, that in the public goods game, "with a dominant strategy of giving zero, any error or variance in the data could mistakenly be viewed as altruism" (Andreoni et al. 2016), that deliberate giving is not identical to altruism, that a "lack of social distance" between the researcher and the "dictator" may explain seemingly non-selfish behavior in the dictator game, and that in trust games with positive outcomes, motivation is reciprocal, and not altruistic (Andreoni et al. 2016).

The economists and regular co-authors Ingela Alger and Jörgen W. Weibull ask in their 2017 article "Strategic behavior of moralists and altruists" "whether altruism and morality help improve the material welfare properties of equilibria in strategic interactions" (p. 18). They get different responses depending on the conditions: the type of the game (public goods games vs. two-by-two games are tested), the length (static or repeated), and whether the focus is on altruistic, moral, or self-interested strategies (classes

of preferences) – which the authors clearly distinguish from the start. The authors point to the highly ambiguous relationship between the classes of preferences and welfare outcomes.

The article "Rational altruism" (Tóbiás 2023) is a peculiar example of treating altruism as endogenous to choices. The author explores the possibilities of pre-agreed degrees of altruism in the prisoner's dilemma, and shows that the strictly dominant strategy (both players defecting) shifts as a result of allowing players to internalize the outcome of their opponents, in other words: to care about the other (Tóbiás 2023, p. 51).

As for methods of incorporating altruism in the game design directly, the German computer scientist Jörg Rothe has provided a prompt summary in 2021, mainly with the purpose of bettering real-world applications of AI simulations in the context of altruistic behavior (p. 15070). Rothe observes that "[f]rom the early beginnings of (non-cooperative) game theory due to von Neumann and Morgenstern (1944), a player (or agent) in a game has been viewed as a homo economicus […]" (Rothe 2021, p. 15070) This perspective, however, as we saw in the works cited above, has been shifting. Not only has altruistic behavior been detected and used as an explanation in – mainly non-cooperative (Rothe 2021, p. 15071) – games, researchers have also aimed at changing games so as to introduce altruism into models of game theory directly.

Examples include interpreting altruism in utility functions, studying the efficiency of altruistic behavior (Rothe 2021, p. 15071; similar to the approach of Alger and Weibull 2017, above); assuming existing levels of altruism for players and looking for Nash equilibria under such conditions (in line with Tóbiás 2023); calculating minimum and optimum numbers of predefined altruists for certain desired outcomes (Rothe 2021, p. 15072); observing altruistic extensions of players' preferences (Rothe 2021, p. 15073); and studying stability under altruistic extensions (Rothe 2021, p. 15074). None of the examples listed cover the option of altruism in the explicit and augmentative manner in which it is used in the present paper.

As a cautionary, clarifying, as well as contextual note, the following statements ought to be added to the review of altruistic extensions within game theory: "In light of rewards, the notion of altruism remains a controversial one. It is not to be interpreted as an act between individuals, for that would shift the process toward reciprocal exchange. It is an opportunity and procedure intrinsic to the system in its entirety, moving it – in the ideal case – towards a state of equilibrium." (B. Hámori, personal communication, December 19, 2023, own translation from Hungarian).

3. Methodology

When designing payoff tables for the specific purpose of incentivizing altruism within games, a number of dimensions and conditions have to be taken into account. The baseline condition is to have a workable definition of altruism itself.

The altruistic extensions in game theory have no uniform underlying description of the concept in common, despite the relative nature of altruism – as compared to self-interested behavior – being evident. For the current game theoretic context, I am relying on the definition provided by Capraro: "A player may prefer to renounce to part of her gain in order to favor another player" (2013, p. 8).

Three-by-three (3x3) payoff tables have been used before in game theory, albeit for different purposes from mine. One may find them as tools of illustration for the so-called saddlepoint: "the outcome that rational players would choose in a two-person constant-sum game" (Brams–Davis 2023). The commonly known rock-paper-scissors game is a special case, without a saddlepoint (Duersch et al. 2010), yet a classic example itself for the 3x3 payoff structure for two players. Prisoner's dilemma payoff structures have also been extended to 3x3 payoff tables to include the option, the third move of "neither" (beside "cooperate and "defect"), or of an "opt-out", in the same manner – this latter version being labelled "optional PD" (Kuhn 2019).

In the paragraphs below, I have documented the thought process of designing *split or steal or gift* payoff tables, i.e. the way I arrived at the individual values in the cells, in the set of the sample tables.

For the sake of simplicity and clarity, the draft payoff designs will be for symmetric games only. Both participants face the same conditions, the same payoff structure, and have to make their decisions at the very same time, without prior communication.

The zero-sum (or fixed sum) vs. variable sum question is interrelated with the tensions of the game, for it is in variable sum games that the players have both common and opposed interests (Brams–Davis 2023). Certain areas of the payoff tables (such as the first three cells of the classical "split or steal" structure) may be described as internal zero-sum sections, but with the introduction of the additional "gift" layer, the ratio of the internal zero-sum area to the whole is about to decrease.

Whilst the tension, the dilemma nature of the game, is to be retained, there may arise a tension between this retention and designing payoffs so as to "steer" players into socially desirable outcomes. According to Kuhn (2019), "universal cooperation is the most socially desirable outcome". The table has to be "tweaked", so as to contain possibilities and to generate inclinations towards mutual altruism, even if that scenario cannot coincide with the dominant Nash equilibrium. To a certain extent, the attractive option to the individual player, leading to a Nash equilibrium – which tends to be located in the lower right corner, the absolutely non-cooperative section of the payoff table – may be counterbalanced by Pareto efficiency[3] in the cooperative, or even fully altruistic (both choose to "gift") equilibrium.

As for the power of the aforementioned tweaks: an incremental change in the payoffs may make the dominant strategy "trickle" towards the more cooperative outcomes, whilst keeping the dilemma nature and structure of the game. If we understand the trickling dynamically, it can stand for a potential *virtuous circle* of *backward reasoning*, more specifically, of *backward induction*.

I expect this positive mechanism to follow mainly from the structure of the payoffs itself, not only from the – realistically speaking – inherent altruism of the individual players. "In standard treatments, game theory assumes rationality and common

[3] A quick definition: "A state of affairs is Pareto-optimal (or Pareto-efficient) if and only if there is no alternative state that would make some people better off without making anyone worse off" (Ingham 2023.

knowledge" (Kuhn 2019). The simulations will be standard treatments also in that players take the other players' (likely and rational) strategies into account.

Without fixed-sum adherence, and with the intention to make choices trickle "northwest", i.e. becoming more cooperative, then altruistic, the payoffs have to be designed with rewards overall increasing (or potential losses overall decreasing) towards the upper left, the altruistic corner of the payoff table.

The altruistic choice (in light of the potential strategies of the partner) must appear either risky but potentially more rewarding, or more safe but probably resulting in lower level rewards for any concrete choice, than in the cells "southeast". This retains the tension. For the sake of clarity and simplicity, however, the differences between the payoff values here should be as low as possible, reflecting ordinality only.

According to the statements above, four payoff tables (see Tables 1 to 4 below) designed are about to follow. The first value in the cells is always the reward for player A (rows), the second for player B (columns). The core part, i.e. "split or steal" rewards have not been changed – the values in those cells are highlighted.

Table 1. The first payoff version for "split or steal or gift"

	B gifts	B splits	B steals
A gifts	2; 2	1; 2	0; 2
A splits	2; 1	1; 1	0; 2
A steals	2; 0	2; 0	0; 0

Source: own construction

Table 2. The second payoff version for "split or steal or gift"

	B gifts	B splits	B steals
A gifts	1; 1	0; 2	0; 2
A splits	2; 0	1; 1	0; 2
A steals	2; 0	2; 0	0; 0

Source: own construction

Table 3. The third payoff version for "split or steal or gift"

	B gifts	B splits	B steals
A gifts	2; 2	1; 3	0; 4
A splits	3; 1	1; 1	0; 2
A steals	4; 0	2; 0	0; 0

Source: own construction

Table 4. The fourth payoff version for "split or steal or gift"

	B gifts	B splits	B steals
A gifts	0; 0	2; 1	2; 0
A splits	1; 2	1; 1	0; 2
A steals	0; 2	2; 0	0; 0

Source: own construction

In my first payoff proposal (Table 1) for the "split or steal or gift" game, I have followed the logic that altruism generally brings higher rewards "to the table", here – literally. A coincidence of "gift" choices doubles the total amount of rewards. This is in line with an excerpt from the originally Swedish saying "shared joy is double joy". If one of the players gifts but the other one "only" splits, that is still a better outcome overall than just splitting mutually, or than any of the combinations involving a "steal" choice. Tension is retained by leaving the steal option "attractive" as it was, through the maximum payoff value for the player who steals, in case the other one chooses to gift.

In my second payoff proposal (Table 2) I have architected the table so as for it to remain fixed-sum (except for the last cell), with the sum value being 2. The design also incorporates a higher level of sacrifice that the player who chooses to gift is willing to make, by making mutual gifting equally rewarding to mutual splitting, yet numerically completely unrewarding if the other participant chooses any other option but to gift.

The next version (Table 3) turns the above explanation on its head. Here I raised individual and overall rewards to the maximum level of 4. Both players are better off if the other one gifts, and they split or steal, but by "just" splitting they can leave (or reward) their partner with at least 2. If, however, both players opt for this compromise of splitting, they will be worse off than they would have been with a mutual "gift" choice. The table could be described as a direct or linear extension to the original game, for it applies the very same algorithm.

Altruism can be rewarded in a more ambiguous way, too, in the cases that the other player does not exhibit such behavior. This is depicted in Table 4, where the mutual "gift" choice is just as disadvantageous as if both players were to steal, yet if one player gifts and the other splits or steals, the former one will earn a reward of 2.

From my initial RQ1 related subhypotheses (H1a, H1b, H1c, and H1d) the first three apply, that is, the payoffs (taking the whole table into account) cannot be organized along a fixed sum (H1a), have to reflect additional layers of tension and risk (H1b), and have to reflect that altruistic behaviors have to be rewarded in most cases (H1c). The fourth subhypothesis (H1d) has to be rejected, for – as illustrated in Tables 2 to 4 – mutual altruism does not have to be the cell of maximal payoffs.

It should be added that in the design of payoffs, cardinality matters heavily (Chmura et al. 2015, p. 4), along with the ordinality aspects explored here. Cardinality would gain higher importance when moving from theory and simulations to practice (potentially through behavioral experiments), a move the lack of which is a limitation to the present paper.

The fact that I did not come up with more altruistically extended payoff schemes does not mean that they are not possible, it only designates my personal limitations in creating explicable "split or steal or gift" extensions. These limitations are set and/or supported by logic and intuition, and it might be the topic of yet another paper how to prove the exhaustion of the system in terms of explicably extended altruistic payoff options.

As for the calculations of Nash equilibria, it is reasonable to embed them into a digital computational tool, for finding Nash equilibria is a task of high complexity (Sugiyama et al. 2021, 1). Sugiyama et al. name and describe three of the existing main game theory programs which can be used for Nash equilibrium computation: Gambit,

Game Theory Explorer (Antonov–von Stengel 2020), and GamePlan (Langlois n.d., Sugiyama et al. 2021, pp. 3-5), each with their own advantages and disadvantages.

The introductory pages of the above mentioned software have been looked at carefully, and Game Theory Explorer (GTE), as well as Gambit (Savani–Turocy 2023) have been chosen – due to their accessibility, clear display, and ease of use – to calculate the Nash equilibria for the four payoff schemes outlined. Through searches and functional filtering, I selected the mathematical resource page Zweig Media's "Finite mathematics utility: game theory tool" (Waner 2007) as an additional computational tool to be applied too.

My choice of testing method, simulations, can be interpreted as a bow to "the long relationship between Game Theory and Computer Science" (Daskalakis et al. 2009, p. 89). In the interpretation of my results for practical uses, however, the limitation in the factors included in the simulation will have to be taken into account.

Looking at options (interactive game theory tool collection pages, mathematical modeling software, specialized game theory software packages) that are available,[4] I have ultimately opted to work in the Python programming language for my simulation purposes. Other options were also excluded based on license fees, a lack (or a smaller degree) of user-friendliness, and the restrictedness in terms of the number of strategies (where only two-by-two matrices were available).

4. Results[5]

In order to distill general and comparative results from my software-assisted analyses, I constructed a summary table, with the four payoff versions as columns, and the four software tools as rows, see Table 5 below.

Table 5. Comparing results for the four payoff versions, in the four tools

	first payoff version	second payoff version	third payoff version	fourth payoff version
GTE output – the number of "extreme equilibria" (EE) and "connected component" (cc) lines	nr of EE: 6 nr of cc lines: 3	nr of EE: 4 nr of cc lines: 2	nr of EE: 5 nr of cc lines: 2	nr of EE: 7 nr of cc lines: 6
Gambit output – game tree probabilities – likeliest choice	steal	steal	steal	gift
Zweig Media output – the optimal strategy cells	gift – gift	gift – gift	gift – gift	split – gift gift – split
Python simulation results – final average payoffs	1.10875	0.8838	1.4475	0.8908

Source: own construction

[4] And following a brief email exchange with Dr. Péter Csóka, Corvinus University of Budapest, whose PhD student has indirectly advised me to use the Python coding environment, for which advice I remain grateful.

[5] The concrete illustration of inputs into the programs, and the more detailed results they have given will be made available upon request from the author.

Overall, the altruistic extensions have made the games more complex in terms of options and of Nash equilibria, with the fourth payoff table version yielding the highest number of "extreme equilibria" and "connected component" lines, suggesting the most challenging computation for Nash equilibria. The fourth version also stuck out in terms of the likelihood of choices, as depicted in the game trees, for it was the only version with gifting being likelier than stealing, according to the Gambit program. Moreover, the optimal strategy cells have been split, and have shifted in this version to "split – gift" and "gift – split" cells, by contrast to "gift – gift" ones in all others. The uniqueness and potential attractiveness of this table, however, has faded out in the simulations, where it has yielded low average payoffs. In regard of the simulations, the third payoff version appeared to be the most rewarding design.

Based on the results from these programs, Nash equilibria through altruistic extensions have spread more probabilistically, which has blurred the outcomes, potentially increasing payoffs in the long run (for repeated rounds in the first and third versions), but not driving choices unambiguously towards permanent "gift – gift" scenarios. This would only weakly reject my H2a (null) hypothesis, with the answer to RQ2 remaining uncertain, and up for further exploration.

5. Discussion

The boundaries between primarily and narrowly self-interested value systems and views of the interdependent and altruistically rewarding social structures can initially be difficult to overcome, from an individual perspective, and are initially "invisible", i.e. difficult to detect in an individual from the viewpoint of others, too. This makes it a challenge to encourage the spread of altruistic behaviors, and this is why modern systems, in all of their major social spheres, can benefit from systemic tweaks that contribute to it.

In my third research question I have contemplated the potential ways in which an altruistically extended payoff scheme is more realistic than the split or steal game. The following paragraphs aim to reflect upon the corresponding hypothesis, in light of the broader analysis conducted in the paper.

As indicated earlier, real life rewards in game-like situations are non-zero-sum, not even fixed sum, rather multidimensional, with short- and long-term rewards differing, and hard to assess in the present moment. Even if one were to visualize all the dimensions and structures involved in organic and genuine decision-making, players with general human-level comprehension and modes of perception might encounter obstacles in interpreting or taking in all the information.

Seeing beyond the materialistic veils of actual rewards, beyond "split or steal", and recognizing the additional option and rewarding strategy of "giving as a gift" in reality takes time, education, reflection, and experience – in the form of life-changing events at times. Prior to such recognitions, the lack of insight provides an explanation for the high frequency of individuals choosing to stick to the fixed (or even zero) sum areas in strategic decision making, and not to be selfless. In reality, true insights on altruism are difficult to obtain, and selfless heuristics are even harder to develop and to sustain. Once a system has shifted to more altruistic patterns, it crystallizes that "[t]here are no immediate winners or losers; the usage of mixed or randomized strategies is inadequate; and cooperation often replaces competition" (Zeleny 1975, p. 180). The process of spreading consciously

altruistic behaviors can be accelerated by encouraging them, by incorporating the rewards of altruistic choices into decisions visibly and in an articulate manner.

My intentions with the subsequent two subsections is to provide tools for shifting toward cooperative and altruistic balances. I do not claim to have covered the whole spectrum of social functioning with the selection of these major spheres, nor to offer ultimate solutions for the multidimensional networks and issues societies are interwoven with. My goal is to open the intellectual gate of enhancing social structures with smart and ethical mechanisms an inch wider then it is at present.

5.1. Implications for the corporate sphere

In this subsection, when writing about the private, corporate sector of the economy, I shift from general insights, through asymmetric and symmetric situations of individual agents, to the implications for networks and large actors.

The corporate sphere, in general, is considered to be a mostly competitive environment. The major role of competition, however, is in no direct contradiction with potential emergences of reciprocal and altruistic behaviors. The opportunities for such behaviors provide a soft, underlying ethical fabric. As Camerer writes, "reciprocity can be very important, even in competitive environments in which moral hazard is predicted" (2003, p. 96, footnote 26). Increasing the number of opportunities for altruistic behavior to be realized at one company, establishing a culture of giving through – in Camerer's terminology – "homegrown intrinsic incentives" (2003, p. 97) in a sufficiently transparent environment is likely to fuel the spread of such acts, instead of their exploitation.

The altruistically extended payoff schemes can awaken individual players' altruism and unite economic agents against the payoff scheme, the payoff structure of the system itself. And "[g]enerally, the more two players' interests coincide, the more important and advantageous communication becomes" (Davis–Brams 2024). Communication contributes to the transparency of the system, thus making it safer and more welcoming for altruistic action, in a virtuous circle. The altruistic extension, however, also adds layers of complexity, and as per Davis and Brams, "[f]or games in which the players have both common and conflicting interests–in other words, in most variable-sum games, whether cooperative or noncooperative–what constitutes a solution is much harder to define and make persuasive" (Davis–Brams 2024).

Considering the financial aspects of the corporate sphere, altruistically extended payoff schemes hold analytic potential as tools for behavioral finance, for interacting with investor behavior both in active and external ways. Resulting insights could be grouped under and add to the context of financial non-linearity.

Asymmetric situations include transactions on the commodity and the labor markets. They can be contract negotiations between an individual and a business (Elridge 2023), or structures with a clearinghouse design. A concrete and specific example would be maintenance and repair contracts in the mining industry, for which strategy profiles and outcomes have already been illustrated in three-by-three payoff matrices (Pak 2007, p. 29). Also, labor market Nash equilibria may have the potential to be made more favorable through altruistic extensions. As Holt and Roth describe, "one important factor in whether such a labor market clearinghouse succeeds or fails is whether the clearinghouse is designed so that it is a Nash equilibrium for applicants and employers to

participate in a way that produces a matching of workers to jobs that is stable, in the sense that no employer and applicant who are not matched to one another would both prefer to be" (2004, p. 4001).

Asymmetry is involved in most of the transactions individuals make. Many of these transactions, as well as an increasing proportion of economic activity now takes place in the digital realm. Ever since strategic behavior has become relevant to the design of computer platforms (Daskalakis et al. 2009, p. 89), new options have opened up for charitable giving, too. During a simple online banking transaction, in an intermediary step, the customer is asked whether they wish to "support to a good cause" (OTP 2024). If the options of donating were provided in an altruistically extended payoff scheme, customer incentives to contribute may strengthen. An example in the asymmetric context would be if customers were willing to pay higher fees under the promise that their providers invest an even greater amount into charitable causes.

For symmetric situations, a classic example would be the oligopolistic race, when larger "firms selling similar products may undercut each other's price until price is driven down to cost" (Holt–Roth 2004, p. 4000). Providing a third option to firms, in the form of a market institution, augmenting the competition thereby, may divert efforts and incentives towards altruistic and worthwhile endeavors. Similar augmentations could influence the economics of auctions, and the Nash equilibria of the auction rules (Holt–Roth 2004, p. 4001).

In private economic networks, incorporating altruism in the design of market institutions has the potential of three positive effects. For one, the positive atmosphere, and the trust levels raised can induce cost effectiveness: "network trust, tied into the system of market economy selfishness, is not only capable of strengthening individuals' will to run risks, but lead[s] to an unmistakable decrease of costs in market transactions" (Hámori 2014, p. 219) Second, the altruistic institutions and behaviors may spread conveniently, independently of the sector or of the industry: "Reciprocally altruistic networks of various sizes […] function effectively in most spheres of [the] economy" (Hámori 2014, p. 222). Third, the incorporation of altruistic incentives fosters trust, which is a personal and a market virtue at the same time: "Another significant difference between traditional exchanges and reciprocal altruism is that the lifeblood of the latter is trust, while the former relationship, actuated by self-interest, is inherently distrustful" (Hámori 2014, p. 222).

Altruistic behaviors differ between micro and macro levels, and presumably even in-between. "[A]gents of larger scale, like firms or countries, which may have to publicly deliberate before acting, may be more transparent than we are" (Kuhn 2019). They may thus have, and they may require to be incentivized to apply more sophisticated conditional strategies (Kuhn 2019).

5.2. Implications for the governmental sphere

Zooming out, to the governmental, or even to the societal level, one may draw parallels to altruistic payoff table extensions in a historical, longitudinal context too. On the one hand, extending the payoff table likens to labor division and an ever more complex economic institutional system. On the other, the increase in players' numbers would liken population

growth and integration processes (e.g. the European Union accession negotiations and procedures).

Remaining with the general and the historical intergenerational conflicts, struggles over financial assets, as well as the presently "invisible" intergenerational tension over natural resources and the environment can be inserted into the *split or steal or gift* frame. The financial aspect, regarding taxes and the public pension system, is a conflict with both sides having a present-day agency and potential impact through the political system. It is a sequential battle though, where the generation in the paying position will find itself on the receiving end, in a few decades' time.

The phenomenon is highly dependent on demographic expectations, which may give an impression of injustice in the pensions' context, and translate into an intergenerational moral hazard, an erosion of the pension system. Meanwhile, however, the validity of the statement that "a good society is wherein the oldest and youngest fare well" (J. Veress, personal communication, own translation, February 19, 2024) is hardly disputable, especially in a long-term, historical context.

The micro-, or individual level intertemporal economics of the longitudinal distribution of resources over one person's lifetime, the battles between one's past self, present self, and future self are a special type of a strategic game, where rational self-interest clashes with cognitive boundaries, expectations, uncertainties, loss aversion, and biases.

When discussing international or supranational incentive schemes, it is rather punishment than reward coming first to mind. International organizations and regionally integrated communities set legal limits upon themselves, and agree on quotas, in areas such as environment protection, migration, and military arms build-up. In terms of global spaces, international negotiation and regulation results in how nations, and groups of nations relate to, and utilize the spheres for satellites, outer space, the geographical poles, the high seas, the seabed beneath, airspace, the atmosphere, and cyberspace (Groenendijk 2024). Stemming from the anarchic state of the international community, both punishments and rewards are challenging to execute though. The *split or steal or gift* structures that groups of countries could impose on themselves would sometimes need to be inverse versions of the four payoff tables designed for this paper, because it is responsibilities and burdens being dealt with, and not financial rewards. These payoff schemes could then be enforced through smart contracts, adding a layer of validation to the agreements.

In terms of arms races, I do not see an option or space for altruism within purely bilateral relations. Isolated bilateral relations, however, can hardly be observed in the real world. Layers and dimensions of economic, geopolitical, as well as cultural interests connect states all over the globe, and it is these interdependencies to rely upon when trying to minimize national arms build-up. The virtuous trust-transparency circles hold in the global context too, making multilevel, multilateral international discourse crucial to global security.

Within a democratic nation, in present-day democratic systems, democracy itself may be described with, and modeled in *split or steal or gift* structures, albeit in a linear, rather than simultaneous manner. The split element is the agreement to the terms and the respect for rules and laws of the political system. The steal element is the fight for democratic power – there are only so many votes to be gained. In simplified terms, the

voting is zero-sum. The gift element is the act of concession – the acceptance of the other party's win. Ceteris paribus – assuming the collectively self-interested and reasonable judgement of the electorate, conceding to the electoral defeat may bring benefits to the opposition even, in the form of being governed by a more capable former contestant for the next political term.

There are political and policy situations, "common social choices" (Kuhn 2019) where the rate of participation itself challenges the system, also described as volunteer dilemmas (Kuhn 2019). Three classical examples are voting (from the electorate's perspective), vaccination, and the protection of the environment. Whenever an individual prioritizes their own personal benefits and comfort over the collective outcomes targeted, such as a high voter turnout, effective levels of vaccination, and sufficient efforts to save the natural world, their behavior aligns with the *steal* option. If they comply – vote, take on the vaccine, and make environment-friendly choices – they can be considered to have opted for *split*. The thoughts playing out in those minds could be illustrated as follows: "When we are at the threshold of adequate cooperation […], I am better off cooperating" (Kuhn 2019). If an individual goes out of their way to get others involved as well, and to raise public awareness – those individuals are the *givers* in society.

A more peripheral example of communities encountering social choices would be risk sharing networks. "[R]isk-sharing networks based on specific forms of reciprocal altruism strengthen […] people's inclination to take risks under circumstances where real risks are extremely high as a consequence of underdeveloped institutional framework" (Hámori 2014, p. 219). In this scenario we see individual behavior being pushed by extreme situations, in an institutionally defective environment, and being secured by altruistic patterns of a shadow network. Whilst – at present – the positive content, the trustful side of informal relationships cannot and should not replace regulation, and professional, ethical conduct in most developed societies, it may augment contracts, transactions, and processes.

6. An outlook

The research topic I put under the magnifying glass has several open ends and points of inspiration that can be elaborated on further. From the countless potential directions and future research opportunities for the theme of altruistically extended payoff schemes I highlight four different options in this paper.

For one, game theoretical proof could be provided on the exhaustion of the system, i.e. whether the sketched payoff schemes cover all reasonable possibilities for three-by-three structures, whether they are a comprehensive set of explicably extended altruistic payoff options (as indicated in subsection 3.1).

Second, my research methods could be seen as an analogy, or a preparation for leveling the scheme up to an *n*-person, multi-player game. It could prove surprising on a whole new level of complexities "to model interaction, coordination, collaboration, and collective decision-making among the agents in a multiagent system" (Rothe, 2021: 15070) with 3-by-3 payoff structures.

Third, the algorithm of extending payoff schemes with layers in an explicable manner could be generalized. This would make the game transformable not just to *n*-player, but *n*-layer versions, potentially aligning with degrees of altruism in the

dimensions and complexities of real life. If an algorithm for designing payoff structures with ever increasing players and layers were figured out, that could contribute to calculating pure and mixed Nash equilibria, potentially extending an existing process through artificially intelligent assistance. If $n > 3$ for the layers (i.e., the payoff matrix is larger than three-by-three), the illustration through real world examples becomes increasingly difficult. The models could still be applicable when paralleled with psychological dimensions, especially that the payoffs have a theoretical possibility to exist. Payoffs for subsequent n values can be designed so as to obtain the closest to the desired Nash equilibria.

Fourth, the results in this paper could be experimented on behaviorally, specifically with the three-by-three, altruistically extended payoff schemes sketched. This could either illustrate or reduce and simplify the "mental complexity" involved in games with altruistic elements, as Camerer had described (2003, p. 17). According to him, and based on the behavioral testing of simpler schemes, "[t]he experimental results suggest that it is easy to create an experimental theory world in which moral hazard is solved by norms of reciprocation" (Camerer 2003, p. 99).

7. Summary and concluding remarks

In this paper, I have embarked upon an exploration of altruistically extended payoff structures, specifically to prisoner's dilemma style "split or steal" games. Upon adding the option of "giving as a gift" to the table, I have dived into the circumstances and consequences through three main questions, on the development and design of the payoffs, the resulting agent behavior, and the relation of these structures to reality.

I have zoomed in on and reviewed the literature in a systematic manner, starting from the basic concepts of games and Nash equilibria, moving through works that have utilized "split or steal" games as behavioral economic experiments, and closing with the relevant altruistic extensions in game theory that have been explored and analyzed already.

My methodology had two main phases. First, the development of the altruistically extended payoff structures. It was at this point that observed and described the thought process, answering my first research question on payoff matrix design, with one out of the four sub-hypotheses being rejected. Second, after introducing the available and the chosen software, for each of the four payoff tables established I have conducted a fourfold analysis (Nash equilibrium calculations through Game Theory Explorer, game tree probabilities with Gambit, optimal outcome calculations through Zweig Media's tool, and a simulation of ten thousand rounds being played in Python). Calculation and simulation results have been summarized in the frame of a comparative analysis.

In the sections of discussion and practical implications I have shifted from theory to practice, and mostly to a larger scale. The topics were also illustrations to how incentives for cooperation can come from different conceptual directions, beyond the *sticks and carrots* duality. As regards the corporate sphere, I have moved from general insights, through asymmetric and symmetric situations of individual agents, to the implications for networks and large actors. In the governmental sector, I have discussed historical and geopolitical macro movements, intergenerational conflicts, arms buildup,

elections, vaccination issues, environmental problems, as well as risk sharing shadow-networks.

In a final main section, I have outlined four groups of possibilities for future research, potentially branching off from this paper. The noble pursuit of developing technologies and organizing principles by which individual behaviors are driven into more altruistic directions can be augmented by specific incentive scheme designs. Progress is ultimately likely to be achieved by their combination.

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The business cycles synchronization in three monetary unions: EMU, WAEMU and CAEMC

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International monetary cooperation is, according to theory, seen as the final stage of economic integration. The example of non-European unions shows that it is possible to function within a monetary union and derive benefits from it without first creating a common market or customs union. The aim of this paper is to assess the degree of synchronization of business cycles in three monetary unions: EMU, WAEMU and CAEMC. The study used annual time series illustrating the dynamics of real GDP, which were subjected to the decomposition procedure (Hodrick–Prescott filter). Cycle convergence was examined using spectral analysis. As a result of the conducted research, it can be concluded that the cycles of the EMU countries are more synchronized than the cycles of the WAEMU and CAEMC countries. Cooperation in monetary terms is not enough to achieve a relatively high level of cycle synchronization.

Keywords: monetary union, EMU, WAEMU, CAEMC, business cycles synchronization

1. Introduction

International monetary cooperation is, according to theory, seen as the final stage of economic integration. The example of non-European monetary unions, such as West African Economic and Monetary Union (WAEMU) and Central African Economic and Monetary Community (CAEMC), shows that it is possible to achieve benefits from using the same means of payment without first creating a common market or customs union.

African monetary unions are characterized by a different integration path, which results from historical conditions. Unlike the European economic integration process that preceded the creation of the European Monetary Union (EMU), the WAEMU and CAEMC countries operated for several decades without any formal mechanisms aimed at the convergence of economies and macroeconomic policies. Despite some benefits resulting from cooperation in the field of money, these unions struggle with many social and political problems, and the convergence criteria were formulated only in response to real threats to the integrity of the union.

In monetary unions, regardless of the economic integration path, the key element is the synchronization of business cycles, which determines the adequacy of the common monetary policy. It is also one of the indicators enabling the assessment of real convergence. For this reason, it is justified to assess the degree of synchronization of business cycles in three monetary unions: EMU, WAEMU and CAEMC. This is the aim of the research in this paper. The research question was formulated as follows: Does cooperation in the field of money without the prior creation of a customs union and a common market enable a high degree of synchronization of business cycles?

The present paper has the following structure. After this introduction, the business cycles synchronization as a part of Optimal Currency Area Theory is discussed, followed by an overview of the monetary integration of three monetary unions in practice. After

explaining the materials and methods, the results of research on business cycle synchronization for three monetary unions WAEMU, CAEMC and EMU, are presented. The article ends with the results and conclusions.

2. Optimal Currency Area Theory with a particular emphasis on business cycles synchronization

The theoretical basis for the creation of a monetary union is the concept of an optimal currency area. The Optimal Currency Area (OCA) Theory indicates the criteria that the economies of countries should meet in order for the monetary union they create to be optimal (Kotliński–Warżała 2020). The general criterion for assessing the ability of a given country to participate in the monetary union is the low susceptibility of the economy to asymmetric shocks and the development of appropriate mechanisms to absorb these shocks (Pronobis 2008).

The Theory of Optimal Currency Areas focuses on the possibility of asymmetric shocks occurring and on identifying mechanisms that allow for their absorption. The group of factors reducing the risk that the country will be affected by an asymmetric shock includes: the degree of production diversification, a similar level of inflation, convergence of business cycles and similarity of the structure of economies. Factors contributing to the absorption of shocks include: mobility of production factors, price and wage flexibility, and fiscal and financial integration (Markowski 2023, Drossart-Demond 2022, Nkwatoh 2019, Kotliński–Warżała 2013, Mognelli 2002).

Under the conditions of a single monetary policy within the monetary union, it is impossible to accommodate economic shocks through exchange rate adjustments or adjustments to national interest rates (Markowski–Warżała 2023). Therefore, the asymmetry of economic shocks is perceived as a key obstacle to the creation of a monetary union by a given group of countries. The asymmetry of disruptions is manifested primarily in the uneven course of business cycles in individual countries (Wojnicka 2002).

Losing monetary policy autonomy is more costly if there is a risk of cyclical inconsistency. The common monetary policy may be inappropriate in relation to the needs of a given country if the business cycle of this economy is shifted in relation to other countries included in the monetary union. In this case, the potential costs of participating in the monetary union are related to the possibility of procyclicality of the common monetary policy. The risk of inappropriateness of the cyclical common monetary policy does not exist when business cycles are synchronized. In addition to shifting the business cycle, the frequency of business fluctuations, the type of shocks affecting the economy, different reactions to shocks and different depths of the cycle phases are also important (Kotliński–Warżała 2013).

On the other hand, differences in economic conditions in individual partner countries may be a countercyclical factor. This will be the case when domestic demand and exports are substitute components of aggregate demand. In the event of a domestic recession and a simultaneous improvement in the economic situation in the partner country, the decline in domestic demand could be replaced by exports.

Thus, the decline in domestic production would be mitigated and exports would act as a stabilizer of the economic situation.

In the 1990s, attention was drawn to the fact that joining the currency area itself could trigger a significant impulse for trade expansion, which in turn could result in more correlated business cycles. This means that a given country may be more willing to meet the criteria for a currency area ex post rather than ex ante. This concept was called the endogeneity hypothesis, and the whole trend clearly reduces the importance of costs and emphasizing the benefits of monetary integration – the New Optimal Currency Area Theory (Markowski 2023). The benefits of a currency union can be obtained in the way that the distances between countries could be narrowed down by lowering transaction costs, removing market segmentation, eliminating exchange rate volatility, and rising price transparency. It thereby promotes trade among monetary union members. The benefits also involve the insulation from speculation bubbles (Nguyen et al. 2020). Therefore, the very fact of creating a single-currency area triggers processes that automatically create an optimal currency area in the economic sense (Frankel–Rose 1998). Even if the countries were not an optimal currency area at the time of joining the monetary union, business cycles are synchronized during its duration.

In this perspective, international integration processes are even motivated by the desire to protect countries against the unfavorable impact of economic fluctuations and crises. According to these arguments, over time, the synchronization of business cycles among monetary union members should increase.

3. Monetary integration in practice

This section of the paper discusses the three monetary unions under consideration (EMU, WAEMU, and CAEMC/CEMAC) regarding their members, history, rules, institutions, and monetary policy, with particular emphasis on different integration paths, and differences among them.

3.1. European Economic and Monetary Union

The European Economic and Monetary Union (EMU) represents the third and final stage of full economic and monetary union for the member states of the European Union (EU), including Austria, Belgium, Croatia, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia, and Spain[1].

The process of monetary integration in Europe was preceded by trade integration and the construction of a common market. In the 1950s, after the successful liberalization of trade on the coal, steel and iron markets, the member countries decided to deepen economic cooperation, which was inaugurated with the signing of the Treaties of Rome (1957), establishing the European Economic

[1] Only 20 of the 27 members of the European Union have adopted the common currency and pursue a common monetary policy.

Community (EEC) and the European Atomic Energy Community (Euratom). The basis for European cooperation was to be the customs union, which was finally created in 1968. These events initiated the process of economic interpenetration and merging of European countries, which resulted in increased dependence also in other areas. In the 1970s, after the period called "Eurosclerosis", consideration began to be given to how to incorporate confederal thought into the idea of a "practical federation", which was based on the gradual achievement of legal and political connections. The European Community began to be perceived as a unique structure combining the federal trend with intergovernmental cooperation (Zielińska-Głębocka 1999). As a result of these observations, new initiatives were launched to promote economic integration in Europe. In terms of monetary integration, the European Monetary System (EMS) was created in 1978, based on the European Monetary Unit (ECU). This mechanism facilitated further integration initiatives. In 1985, the European Commission was obliged to prepare a calendar of projects aimed at creating a common market. The basis for its establishment was the Single European Act, signed in 1986. The common market, enabling the free movement of capital, goods and services, became a reality at the beginning of 1993.

The monetary union in Europe is the successor to the above-mentioned European Monetary System. The legal, institutional, and monetary parts of European integration were established in the Maastricht Treaty (1992), following the recommendations of the Delors Report (1989), as highlighted by Eichengreen et al. (1993) and Haug et al. (2000).

Moreover, as part of the Maastricht Treaty (1992), four "nominal convergence" requirements were established for the monetary and fiscal components, which a member state had to fulfill to be eligible to join the EMU. These were: (a) no currency devaluation in the two years before union entry; (b) inflation rate no more than 1.5 percentage point above the average of the three lowest-inflation countries; (c) long-term interest rate no more than 2 percentage point above the average of the three lowest-inflation countries; and (d) government debt and deficits not more than 3% and 60% of GDP, respectively. Further, the EMU, also known as the Eurozone, is a wide umbrella that has implemented several policies targeted at free trade and economic convergence among its member nations. Three stages went into creating the EMU, the third of which started the transition from previous national currencies to the shared euro currency (Hodson et al. 2022). All of the original EU member states have finished this, except Denmark and the United Kingdom, which chose not to accept the euro. After the Brexit referendum in 2020, the United Kingdom subsequently departed the European Union.

It can be emphasized that the EMU is based on the idea of convergence, which refers to both the convergence of European countries to preserve the distinctive European model and the convergence of member states toward the highest levels of wealth (Juncker et al. 2015). According to Juncker et al. (2015), important aspects of economic policy continue to be national, even while monetary policy is centralized in the EMU. Ensuring that citizens and businesses can adjust to and benefit from changing demands, trends, and difficulties, as well as modernizing economic structures and welfare systems, are all in the common and self-interest of all members. Every member has an equal stake in the others moving at a comparable pace. This is

especially important in the European Monetary Union (EMU), where labor mobility is restricted and large-scale fiscal transfers between member states are not anticipated.

It can be indicated that EMU is administered by some designated institutions which include the European Central Bank (ECB), the European System of Central Banks (ESCB), the Economic and Financial Committee, the Eurogroup, and the Economic and Financial Affairs Council (Ecofin) (Jost 2023). These institutions are largely responsible for establishing the European monetary policy, rules governing the issuing of the euro, and price stability in the EU. Furthermore, the EMU is governed by a set of rules and regulations that are established to ensure economic stability, convergence, and coordination among its member states. These comprise the following:

1. Treaty on the functioning of the European Union (TFEU): The TFEU is one of the primary treaties governing the European Union (EU) and provides the legal framework for the EMU. It sets out the objectives, principles, and institutional framework of the EMU.
2. Maastricht Treaty: The Maastricht Treaty, formally known as the Treaty on the European Union (TEU), established the EMU in 1992. It laid down the conditions and criteria for the adoption of the euro as a common currency and the formation of the European Central Bank (ECB). The Maastricht Treaty also established convergence criteria, known as the "Maastricht criteria," which member states must meet to join the EMU.
3. Stability and growth pact (SGP): The SGP is a set of rules aimed at ensuring fiscal discipline and coordination among member states. It sets limits on government deficits and debt levels to promote fiscal stability. The SGP requires member states to maintain their budget deficits below 3% of GDP and their public debt below 60% of GDP.
4. European semester: The European Semester is an annual cycle of economic policy coordination among EU member states. It aims to ensure the coordination of economic policies, fiscal policies, and structural reforms to strengthen economic performance and convergence. The European Semester involves the monitoring, assessment, and coordination of member states' economic and fiscal policies by the European Commission and the Council of the European Union.
5. Macroeconomic imbalance procedure (MIP): The MIP is a framework established to identify and address macroeconomic imbalances within the euro area. It aims to prevent and correct imbalances that could pose risks to the stability and functioning of the EMU. The MIP monitors indicators such as current account balances, housing prices, private and public debt, and unemployment rates to identify potential imbalances and trigger corrective actions.
6. Banking union: The banking union is a framework established to ensure the stability of the banking sector within the euro area. It consists of three pillars: a Single Supervisory Mechanism (SSM), a Single Resolution Mechanism (SRM), and a common deposit insurance scheme (EDIS). The SSM, operated by the ECB, oversees the prudential supervision of banks.

The SRM provides a framework for the orderly resolution of failing banks, and EDIS aims to establish a common deposit insurance scheme to protect depositors.

It is worth emphasizing that monetary policy plays a crucial role in shaping the economic performance of countries. In the context of the European Economic and Monetary Union (EMU), a common monetary policy is followed and this monetary policy is formulated and implemented by the European Central Bank (ECB) for the euro area member states (Ardakani et al. 2024, The European Central Bank 2021). The EMU aims to promote economic integration and stability among its member countries. However, the integration paths among member states have varied, leading to different challenges and dynamics in the implementation of monetary policy (Pagliari–Young 2014). It is important to explore the different integration paths within the EMU and their implications for monetary policy.

It should be noted that the functioning monetary policy is predicated on maintaining the equality of interest rates in the EMU interbank market, which is a uniform position throughout the monetary union. The formulation of monetary policy has been centralized in this instance, leading to the harmonization of instruments and techniques and the uniformity of monetary policy signals across nations (Enoch–Quintyn 1996). This has also created enough opportunities for arbitrage across the EMU, allowing for the rapid and uniform transmission of interest rate changes throughout the monetary union. Additionally, the integration paths among members of the EMU have varied, leading to different challenges for the implementation of monetary policy. The core-periphery divide, varying degrees of economic convergence, and differences in the effectiveness of monetary policy transmission channels have all shaped the dynamics of monetary policy within the euro area. The ECB has responded to these challenges through unconventional measures and initiatives such as the Banking Union and the Capital Markets Union. As the EMU continues to evolve, addressing these integration paths and challenges will remain important for ensuring the stability and effectiveness of monetary policy.

3.2. West African Economic and Monetary Union (WAEMU)

The West African Economic and Monetary Union (WAEMU) is a regional organization that seeks to promote economic integration and monetary cooperation among its member states.

The currency grouping in West Africa was created as an economic consequence of French colonialism. In the second half of the 20th century, the colonial franc was established there as the currency in monetary circulation. The CFA franc was created by the French colonial authorities in December 1945 following France's ratification of the Bretton Woods Accords. According to the declarations of the French authorities, the creation of a new currency was a kind of act of magnanimity in order to spare the French colonies from the strong devaluation that the French franc was subjected to.

Dating back to 1962, WAEMU is one of the oldest sub-regional unions and also one of the currency unions in the world today (Kebalo–Zouri 2022, Kireyev

2015). The WAEMU consists of eight low-income countries, namely, Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal, and Togo. WAEMU was established in 1994, through the signing of the Treaty of Dakar. However, its origins can be traced back to the West African Monetary Union (WAMU), which aimed to promote economic integration among its member states through the establishment of a common currency and a central bank. Over time, WAMU evolved into WAEMU, with a broader mandate to foster economic and monetary cooperation (Hernández-Catá–François 1998). Thus, WAEMU shares a common currency, the CFA franc, which is pegged to the euro. The CFA franc is issued by the Central Bank of West African States (BCEAO), which is the central bank of the WAEMU.

Moreover, the WAEMU operates based on a set of rules and institutions designed to facilitate economic integration and monetary cooperation and the members are required to abide by these rules. The main institutions responsible for running the affairs of the union are the following: The West African Monetary Union Commission (WAMU Commission), which is the executive body of WAEMU and is responsible for implementing the decisions of the Council of Ministers and the WAEMU Heads of State; The Council of Ministers, which is the highest decision-making body of WAEMU and consists of the ministers in charge of economic and financial affairs from each member state; The central bank of WAEMU (BCEAO), responsible for issuing the CFA franc, pegged to the euro at a fixed exchange rate, conducting a single regional monetary policy, pooling foreign exchange reserves of members, supervising the banking system, and maintaining price stability; and The Convergence, Stability, Growth, and Solidarity Pact, which sets out the fiscal and monetary policy framework for member states (Diop 2010). The pact includes convergence criteria related to budget deficits, public debt, inflation, and external reserves, which member states are expected to meet.

Further, as indicated early on, WAEMU has a common monetary policy managed by the BCEAO and for that matter, the monetary policy decisions are made by the Monetary Policy Committee, which consists of representatives from the BCEAO and the national central banks of member states. The BCEAO uses various instruments, such as open market operations and reserve requirements, to manage liquidity and stabilize the CFA franc (Hernández-Catá–François 1998). It can be stated that members of WAEMU have diverse integration paths and these paths can be broadly categorized into two groups: (a) Francophone countries, including Benin, Burkina Faso, Côte d'Ivoire, Mali, Niger, Senegal, and Togo, which have a deeper level of integration within WAEMU and a common currency, the CFA franc, as well as adhere closely to the rules and institutions of the union; and (b) Guinea-Bissau, a former Portuguese colony which joined WAEMU in 1997 but has not fully adopted the CFA franc as its currency and maintains its own currency, the West African peso. Guinea-Bissau has a more limited level of integration within the WAEMU compared to the francophone countries.

3.3. Central African Economic and Monetary Community (CAEMC/CEMAC)

The Central African Economic and Monetary Union (CAEMC), also known as the Economic and Monetary Community of Central Africa (CEMAC), is also a regional

organization in Central Africa that has the aim of promoting economic integration and monetary cooperation among its member states. Like WAEMU, its roots can be traced to French colonialism and the creation of the franc zone in Africa. The CAEMC is made up of six member states, namely, Cameroon, Central African Republic, Chad, Republic of Congo, Equatorial Guinea, and Gabon. These countries also share a common currency, the Central African CFA franc, which is pegged to the euro at a fixed exchange rate. Moreover, CAEMC was established in 1994, with the signing of the Treaty of N'Djamena. This organization was created as a successor to the Central African Customs and Economic Union (UDEAC), which was established in 1964 to promote economic cooperation among its member states (Melo–Ngwenya 2018).

Later, UDEAC grew into CAEMC with a broader mandate to foster economic and monetary integration. Just like WAEMU, CAEMC/CEMAC is governed by rules and some designated institutions. These institutions include the Conference of Heads of State and Government, which is the highest decision-making body of CAEMC and consists of the heads of state and government of member countries; The Commission of the Economic and Monetary Community of Central Africa (CEMAC Commission), which is the executive body of CAEMC, responsible for implementing the decisions of the Conference of Heads of State and Government; The Central African States Development Bank (BDEAC), which plays a crucial role in financing development projects within the CAEMC region; and The Bank of Central African States (BEAC) also known as the Banque des États de l'Afrique Centrale (Manu 2016). The BEAC is the central bank of CAEMC and is responsible for issuing and managing the Central African CFA franc, conducting monetary policy, and maintaining price stability. In addition, the BEAC is granted the authority to establish a common monetary policy, keep and oversee member states' foreign reserves, and issue a single currency, the CFA franc (de Zamaróczy et al. 2018).

Within the CFA franc zone, there are no restrictions on capital flows and CEMAC works under a fixed exchange rate regime. The CFA franc is freely convertible at the set exchange rate and is fixed to the euro. Here, the BEAC makes monetary policy decisions through the Monetary Policy Committee, which includes representatives from the BEAC and the national central banks of member states. The BEAC uses various instruments, such as open market operations and reserve requirements, to manage liquidity and stabilize the Central African CFA franc. However, it can be indicated that the monetary policy of member countries is influenced by the monetary policy of the Eurozone, as the CEMAC countries do not have control over their monetary policy. It can be emphasized that CAEMC member states have followed different paths of integration within the union as was seen in the case of WAEMU. These paths can be said to be in two directions:

(a) Francophone countries such as Cameroon, Central African Republic, Chad, and the Republic of Congo have a deeper level of integration within CAEMC. Thus, these countries have adopted the Central African CFA franc as their currency and adhere closely to the rules and institutions of the union;
(b) Equatorial Guinea and Gabon, which were former Portuguese and French colonies, respectively, have a more limited level of integration within

CAEMC. These countries have not fully adopted the Central African CFA franc and maintain their currencies, the Central African ekwele and the Central African franc, respectively. Also, these countries have their monetary policies and a different level of adherence to the rules and institutions of CAEMC.

To sum up, it can be indicated that these three monetary unions have some level of similarities in terms of the conduct of monetary policy. Due to the use of a single currency among the member states within the respective unions, monetary authorities from the national central banks surrender their control to the central banks of the unions – that is, the unions' central banks that are in charge of the chosen currency receive complete control over monetary policy and exchange rates from the monetary authorities. Also, even though WAEMU and CAEMC use the CFA franc, it is pegged to the euro. Here, it can be stressed that the use of the CFA franc and euro by WAEMU and CAEMC probably occurred due to historical ties to former colonial masters or a currency reform intended to restore macroeconomic stability (van Riet 2024, Staehr 2015).

However, there are differences associated with them. At the integration level, the EMU has a higher level of economic and monetary integration among its member states which involves coordination of fiscal, monetary, and economic policies and a unified central bank. In the case of WAEMU, the member states have different integration paths and it aims to achieve economic integration and monetary stability within the West African region through the use of a common currency and coordination of monetary policies. The CAEMC/CEMAC also has a disparate way of integration.

It can be concluded that African monetary unions are characterized by a different integration path, which results from historical conditions. Unlike the European economic integration process that preceded the creation of the European Monetary Union (EMU), the WAEMU and CAEMC countries operated for several decades without any formal mechanisms aimed at the convergence of economies and macroeconomic policies. Despite some benefits resulting from cooperation in the monetary field, these unions struggle with many social and political problems. Moreover, the convergence criteria were formulated only in response to real threats to the integrity of the union (Młodkowski 2007).

These differences constitute an argument for empirical verification of the degree of synchronization of business cycles in the countries belonging to the three mentioned unions. An interesting issue is the answer to the question whether cooperation in the field of money without the support of formal mechanisms aimed at economic convergence allows to achieve a relatively high level of synchronization of fluctuations in economic activity, such as in the European monetary union

4. Materials and methods

This study assumes the annual dynamics of real GDP as the raw time series. The selected concept of separating the cyclical component is the growth method, and the identification of the growth cycles combines "cyclical" and "growth" aspects of

dynamics (Hübner et al. 1994, pp. 18-20). It allows to identify cyclical fluctuations even when the economy is characterized by a long period of uninterrupted growth.

Due to the use of annual data, the seasonal adjustment procedure was not necessary[2]. The cyclical component was extracted from the time series using the Hodrick–Prescott filter (1997). It is a high-pass filter, which means that it "passes" fluctuations with frequencies higher than those selected by the researcher (Adamowicz et al. 2008, p. 18; Łuczyński 2013, p. 270). Although this filter was created within the new classical economics and methodologically corresponds to the interpretation of the Lucas cycle (Beck 2017, p. 6), it should not be treated as a theory, but as a universal tool and a standard econometric procedure (Kasperowicz 2010, p. 69).

The starting point in using the HP filter is the assumption that the time series consists of two components: a trend and a cyclical component. The filter takes the form of the sum of squares of the time series increments. The trend is estimated by solving the following function (Kufel et al., 2014: 42; Beck, 2017: 7):

$$min\left[\sum_{t=1}^{T}(y_t - g_t)^2 + \lambda \sum_{t=3}^{T}(\Delta^2 g_t)^2\right]$$

Where: g_t is a trend and λ is the so-called smoothing parameter.

The only component of the equation that must be determined by the researcher is parameter λ (Beck 2017, p. 7). The smoothing parameter was set according to the suggestion of M.O. Ravn and H. Uhlig (2001, p. 1), who proposed that this value of annual data should be 100.

The reference series were business cycles of entire monetary unions, to which the variability of national cycles was related. The convergence of fluctuations was measured using spectral analysis – the coherence coefficient and cross-correlations. The coherence coefficient allows to determine the strength of convergence between time series within a predetermined fluctuation range. The value of this coefficient indicates the extent to which cyclical fluctuations of the empirical series of variable X are able to explain cyclical fluctuations of the reference series:

$$K_{yx}^2 = \frac{c_{yx}(\omega)^2 + q_{yx}(\omega)^2}{f_x(\omega) * f_y(\omega)}$$

$$0 \leq K_{yx}^2(\omega) \leq 1 \ \ for \ \ \omega \in [-\pi;\ \pi].$$

[2] Typically, higher-frequency data is preferred when examining business cycle synchronization. However, such data are difficult to access for African countries or are incomplete. Another solution is to carry out the disaggregation procedure of annual data. However, this raises doubts regarding the comparability of estimated data (for WAEMU and CAEMC) with real data (for EMU). Therefore, it was decided to use long time series representing annual data in this work.

Where: $c_{yx}(\omega)$is a co-spectrum (real part cross-spectrum), $q_{yx}(\omega)$ is quadrature spectrum (negative imaginary part of the cross-spectrum), and $\omega = 2\pi/N$ is a frequency of harmonic components.

Coherence is therefore a measure of the R^2 fit in a regression of the dependent variable against the independent variable for a given frequency. The value of the coefficient ranges from 0 to 1. The closer the coherence value is to unity, the more interdependent the series under study (Burzała 2009).

Cross-correlation, on the other hand, is a function of the value of the Pearson correlation coefficient of two time series shifted by Δt relative to each other depending on the value of Δt. The study also calculated the number of additional cycles of a given country relative to the reference series.

The time range of the research is 1981–2022. The starting date results from the implementation of the ECU (European Currency Unit), i.e. the accounting unit in the European Monetary System, which replaced the European Unit of Account (EUA) and which preceded the introduction of the euro in 1999. It was therefore a time of tightening integration in the sphere of money, supported by the already functioning customs union and the development of rules for the functioning of the common market. It is worth emphasizing that cooperation in the field of common money has already existed in African countries[3].

The following countries belonging to individual monetary unions were included in the research:

- EMU: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain.
- WAEMU: Benin, Burkina Faso, Cote d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal, Togo.
- CAEMC: Cameroon, Central African Republic, Chad, Congo Rep., Equatorial Guinea, Gabon.

The selection of countries (in the case of EMU) was dictated by the length of participation in the grouping.[4] Most countries participated in the integration process for the vast majority of the research period. Moreover, all 12 countries adopted the common currency, the euro, in 1999.

[3] Moreover, previous data for African unions was incomplete.
[4] Croatia, Cyprus, Estonia, Italy, Latvia, Malta, Slovakia and Slovenia are excluded from the study.

5. Results

The study of cycle synchronization was carried out using spectral analysis. The research results for three monetary unions – WAEMU, CAEMC and EMU – are presented in Tables 1, 2 and 3[5].

Table 1. Cyclical factor statistics of real GDP dynamics in relation to the reference series (WAEMU)

Country	Coherence	Number of additional cycles with respect to the reference series	Cross-correlation		
			r_0	r_{max}	t_{max}
Benin	0.18	-3	0.26	0.32	1
Burkina Faso	0.37	0	0.57	0.57	0
Cote d'Ivoire	0.81	0	0.90	0.90	0
Guinea-Bissau	0.05	-2	0.21	0.21	1
Mali	0.17	0	0.37	0.37	0
Niger	0.32	-1	0.47	0.47	0
Senegal	0.25	-1	0.48	0.48	0
Togo	0.17	-2	0.43	0.43	1

Source: results of own research

The coherence coefficient determines the extent to which changes in economic fluctuations of the entire monetary union affect the fluctuations of a given country. Based on the research results, we can conclude that in the case of WAEMU countries this is a small impact. The exception is Cote d'Ivoire, whose dependence of fluctuations can be assessed as high. It can also be concluded from the data in the table that most countries are characterized by fewer business cycles than the entire group. Assessing the synchronization of cycles based on the correlation coefficient, it should be concluded that it is weak or moderate. The high convergence of Cote d'Ivoire cyclical fluctuations is confirmed. There is moderate synchronization for Burkina Faso, Senegal, Niger, and Mali. This is also confirmed by the values of the correlation coefficient with the shift (in these countries, synchronization is the highest without the shift). However, the low values of the coherence coefficient do not allow formulating a conclusion about a moderate correlation of cyclical fluctuations of the WAEMU countries because the cycles of individual countries are weakly dependent on the cycle of the entire union. It seems that the convergence of cyclical fluctuations in African countries is influenced by the specificity of events of different importance for these economies or different impact strengths.

[5] Due to the end-point instability of the HP filter, as a robustness check, the spectral analysis was also performed with the removal of the first and last two datapoints from the time series. The results did not differ significantly from the original data and this did not affect the conclusions.

Similar conclusions can be drawn when analyzing CAEMC (Table 2).

Table 2. Cyclical factor statistics of real GDP dynamics in relation to the reference series (CAEMC)

Country	Coherence	Number of additional cycles with respect to the reference series	Cross-correlation		
			r_0	r_{max}	t_{max}
Cameroon	0.42	-1	0.62	0.62	0
Central African Republic	0.13	-1	0.22	0.26	3
Chad	0.37	-2	0.59	0.59	0
Congo, Rep.	0.04	-1	0.17	-0.25	-3
Equatorial Guinea	0.16	-2	0.42	0.42	0
Gabon	0.25	-3	0.41	0.41	0

Source: results of own research

The coherence coefficient indicates a moderate dependence of Cameroon and Chad fluctuations on the fluctuations of the entire monetary union. In other countries this relationship is weak. No single CAEMC country has the same number of cycles as the entire grouping. The correlation coefficient confirms the relatively stronger cyclical convergence of the Cameroon and Chad economies.
In the case of EMU, the situation is different (Table 3).

Table 3. Cyclical factor statistics of real GDP dynamics in relation to the reference series (EMU)

Country	Coherence	Number of additional cycles with respect to the reference series	Cross-correlation		
			r_0	r_{max}	t_{max}
Austria	0.85	0	0.89	0.89	0
Belgium	0.89	-1	0.91	0.91	0
Finland	0.50	1	0.66	0.66	0
France	0.91	-1	0.92	0.92	0
Germany	0.79	-1	0.86	0.86	0
Greece	0.52	0	0.67	0.67	0
Ireland	0.23	0	0.46	0.46	0
Italy	0.95	0	0.94	0.94	0
Luxembourg	0.39	-1	0.61	0.61	0
Netherlands	0.88	1	0.90	0.90	0
Portugal	0.72	0	0.81	0.81	0
Spain	0.85	-1	0.89	0.89	0

Source: results of own research

First of all, in almost all countries, the coherence coefficient is very high. This proves the strong interdependence and integration of European economies. Therefore,

economic fluctuations in these countries are interdependent, and economic phenomena have an impact on other member countries. It should also be emphasized that there are countries with relatively weaker synchronization, such as Ireland, Luxembourg and Finland. This is, to some extent, determined by the specificity of these economies (Luxembourg), connections with American capital (Ireland) or the trade structure (Finland). The difference in the number of cycles between individual countries and the entire EU does not exceed 1, which also distinguishes EMU from WAEMU and CAEMC. The correlation coefficients for EMU countries are also significantly high in most cases. It is worth emphasizing that they reach the highest value without the leads/lags of the time series.

The analysis shows that the synchronization of business cycles in the European monetary union is much higher than in African unions. In order to illustrate the scale of the difference between unions using one value, average values of correlation coefficients were calculated for each union. The results are presented in Table 4.

Table 4. Average correlation coefficient of countries included in individual monetary unions

Union	Average correlation coefficient of countries[6]
WAEMU	0.30
CAEMC	0.20
EMU	0.87

Source: results of own research

The calculations confirm that the countries of the European Monetary Union are characterized by the highest degree of business cycle synchronization. WAEMU can be ranked second and CAEMC third.

6. Conclusion

The empirical research reported on here achieved the research goal. This allowed us to draw the following conclusions:

- The cycles of the EMU countries are more synchronized than the cycles of the WAEMU and CAEMC countries, which is confirmed by the values of the correlation coefficient. High values of the coherence coefficient prove the strong interdependence and integration of European economies. The values of the cross-correlation coefficient also indicate better synchronization of the cycles of European countries than those of African countries.

[6] Since correlation coefficients are not additive, Fisher's transformation was used to calculate mean values.

- It seems that the convergence of cyclical fluctuations in African countries is influenced by the specificity of events of different importance for these economies or different impact strengths.
- Cooperation on money is not enough to achieve a relatively high level of cycle synchronization. To some extent, this contradicts the endogeneity theory. Projects aimed at coordinating macroeconomic policies and creating formal mechanisms aimed at the convergence of economies also seem necessary.
- African countries included in WAEMU and CEAMC are likely to experience permanent inadequacy (cyclical and structural) of the single monetary policy.
- This may partly stem from their different integration paths.

The conducted research, like any empirical analysis, is based on certain assumptions and is not free from limitations. The research should be extended to include time series with a different frequency, e.g. quarterly. However, due to the rather unambiguous results, the authors do not expect that such a change would result in a correction of the conclusions. Another modification may be to use a different statistical data filtering procedure or to extend the time series. Other areas of convergence identified by OCA theory can be considered future research directions, including: inflation or trade structure.

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A cross-country analysis of the effects of firm characteristics and regional factors on small firm competitiveness

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This study explores the influence of firm characteristics and regional factors on firm competitiveness of Small and Medium-sized Enterprises (SMEs) using a cross-country analysis of Hungary and the Czech Republic, based on the Resource Based View (RBV) and insights from geographical economics and regional development frameworks. Cross-sectional regression models are used to analyze a dataset of 331 SMEs distinguished along urban and rural divide in the two countries. The findings of the study show that firm size has a positive and significant association with firm competitiveness suggesting the importance of a firm's scale in harnessing competitive advantage. Firm age relates negatively with firm competitiveness, indicative of the likely inertia challenges faced by older firms thus affecting their propensity to adapt to market dynamics as well as to innovate. While the study fails to validate significance of urban-rural location dichotomy as a predictor of competitiveness, firm agglomeration, measured by the number of firms in regional clusters positively relates to competitiveness, pointing to potential benefits of agglomeration economies. Based on the findings, targeted policy actions that consider the context of the environment in which firms operate are recommended in order to foster firm competitiveness. By adopting a comparative perspective, this study contributes to the understanding of contextual nature of SMEs. The study extends practical insights to firm owners, policy makers and development practitioners for fostering firm competitiveness.

Keywords: *SME competitiveness, cross-country analysis, RBV, regional development, urban–rural location*

1. Introduction

The competitive dynamics of firms and their strategic positioning in various geographical locations have gained significant attention in strategy and regional economic development studies. According to the resource-based view (RBV), firms attain and maintain a competitive advantage by acquiring and managing resources that are valuable, rare, inimitable, and non-substitutable (Barney 1991).The theory of firm-specific attributes has been widely used to explain how heterogeneity in performance outcomes occurs (Barney et al. 2001, Peteraf 1993).

Studies have expanded the Resource-Based View (RBV) to investigate the spatial aspects of firm competitiveness. These studies emphasize the importance of urban versus rural settings in shaping firm strategies and resource configurations (Porter 1998a). The distinction between urban and rural areas is crucial because it affects access to resources, market opportunities, and competitive pressures (Krugman 1991, Scott–Storper 2015). Urban regions, which are characterized by higher population density and greater economic diversification, offer firms a variety of competitive advantages. These include access to larger markets and pools of skilled labor (Florida 2002). Conversely, firms in rural areas face distinct challenges and

opportunities. These include lower competition intensity but also limited access to critical resources and networks (Storper–Venables 2004). The location influence on firm competitiveness is similarly affected by country-specific factors, such as institutional frameworks, economic policies, and regional development initiatives (North 1990). Cross-country comparisons have shown significant differences in how firms use geographic and institutional contexts to create competitive advantages (Porter 2000, Saxenian et al. 1995).

Despite considerable theoretical and empirical evidence, the RBV, geographical economics, and regional development there still exist gaps in understanding the link between firm characteristics, competitive dynamics, and the urban–rural divide, particularly from a cross-country perspective. This study aims to investigate how firm size, age, and industry sector affect competitiveness in urban and rural regions of Hungary and the Czech Republic.

1.1. Study objectives

The overriding purpose of the study is to explore the effect of firm attributes and geographical location influence on SMEs competitiveness within the framework of the RBV. Specifically, as follows:

- To examine the influence of firm characteristics, such as size, age, industry sector, and firm agglomeration (measured as the number of firms in established regional classifications, counties in the case of Hungary and regions in the case of the Czech Republic), on the level of competitiveness of SMEs;
- To explore the influence of firm location in urban and rural contexts across Hungary and the Czech Republic on firm competitiveness;
- To analyze the interaction effects between firm attributes, specifically size (measured by the number of employees) and geographical location (urban vs. rural), on firm competitiveness. The study establishes the firm-size effect moderated by firm location; and
- To compare the dynamics of firm characteristics and regional aspects on the competitive dynamics of SMEs in the two countries.

To classify locations as urban or rural in Hungary and the Czech Republic, the study uses zip codes associated with each firm in the dataset. Accordingly, administrative and economic centers of the NUTS 3 regions as identified by the zip codes are considered urban while local administrative units in the periphery of the NUTS 3 centers are considered rural. Similarly, the categorization of firms into regional clusters is determined by zip codes. This method allows for precise categorization of geographical areas and comprehensive analysis of firm concentration.

2. Literature review

2.1. Perspectives of competitiveness

The notion of competition is a multidimensional and intricate phenomenon that may be examined at several levels of inquiry (Szerb–Terjesen 2010). The levels encompass macro, meso, and micro perspectives, each offering distinct perspectives on the essence of competitiveness. At the micro level, a company's internal resources and competencies, such as human capital, management style, innovation processes, and market positioning, contribute to its competitive advantage (Porter 1998b). Additionally, Shvindina (2022) proposes that benchmarking can also be used to measure micro competitiveness by comparing a firm either past or future performance indicators to its peers. The meso and macro levels consider competitiveness at Shining industry and national levels respectively.

Different factors have been cited as being affecting competitiveness. The theoretical framework suggested by (Chikán et al. 2022) emphasizes the significance of ordinary capabilities (OC) and dynamic capabilities (DC) in enhancing corporate competitiveness. In this case, operationality, which measures the result of ordinary capabilities, is required for a company to achieve its existing goals, whereas adaptivity indicates the company's capacity to adjust to shifts in resources and non-operational routines. In addition, Chikán et al. (2022) also discuss the concept of the Firm Competitiveness Index (FCI), which integrates financial and market competitive advantage based on the firm's technological and evolutionary fitness. This conceptual index is suggested as a way to measure how functional operations are regarded to contribute to overall firm-level competitiveness.

In similar assertions, employing a system dynamic approach to analyze the connection between resources and capabilities, Szerb et al. (2020) highlight that small firm's competitiveness is greatly influenced by the configuration of its resources and capabilities which when effectively coordinated catapults the firm to stand out from competition owing to better performance. These resources include human capital, product innovation, technology, and decision-making ability. Based on the Resource Based View of the firm (RBV) the authors emphasize on the combination and harmonization of configurations of competitive pillars as an effective way to remain competitive.

Drawing on a Polish perspective, Sipa et al. (2015) identify a range of factors as key influencers of small firms' competitivenessClick or tap here to enter text. The featured aspects include company image, product brand, lower product price, and focus on specific customer groups. Other factors include adaptability to market demand and innovation. To a great extent, this perspective aligns well with assertions by Szerb et al. (2020), who recognize the role of strategic management as one of the key pillars of competitiveness configuration.

Insights regarding the territorial characteristics influencing competitiveness are discussed in Metaxas et al. (2016). In this study, agglomeration factors and market access are observed to have insignificant positive influence on small and medium-sized firms' competitiveness, with improvement in this factor reducing the chance of small firm growing to medium-sized by 20%. Similarly, regional policies also

significantly impacted competitiveness with a negative influence against Southern European firms. Additionally, urban infrastructure such as transport networks, are found to be significant predictors of competitiveness. Labor availability and cost factors are also identified as significant competitive aspects from a regional perspective.

2.2. An overview of SME performance in Hungary and the Czech Republic

SMEs play an important role in both Hungary and the Czech Republic, as is the case in many other countries globally. The European commission report on SME performance indicate that in 2022, SMEs accounted for the majority of business enterprises and employment. In Hungary's case, SMEs accounted for 99.9% of total business enterprises and employed 70.2" of the workforce, contributing 56.2% of the total value added. Similarly in the Czech Republic, SMEs accounted for 99.8% of total enterprises, employing 67.4% of the labor force and contributing 53.5% to value added (European Commission, 2023a, 2023b). while both countries recorded modest growth rates in the sector in nominal terms (3% in Hungary and 8% in Czech Republic), persistent high inflation rates dampened the real growth.

Table 1. A comparison of SMEs and large firms' performance in Hungary and A comparison the Czech Republic

Metric	**Hungary SMEs**	**Hungary Large Enterprises**	**Czechia SMEs**	**Czechia Large Enterprises**
Number of Enterprises	713,411 (99.9%)	957 (0.1%)	1,082,947 (99.8%)	1,639 (0.2%)
Persons Employed	2,051,172 (70.2%)	872,712 (29.8%)	2,551,953 (67.4%)	1,236,587 (32.6%)
Value Added (€ Billion)	46.5 (56.2%)	36.3 (43.8%)	74.4 (53.5%)	64.7 (46.5%)

Source: own construction based on European Commission SME performance report 2022

At the sector level, while SMEs across the various sectors in Hungary demonstrated resilience notwithstanding impacts of broader economic conditions, the performance in the Czech Republic was mixed with a notable dismal performance in the construction sub-sector.

Both countries face challenges that impact the sector with varied levels of influence. In the case of Hungary, critical challenges include shortage high-skilled sectors and an innovation performance below the EU average (European Commission 2023b). In contrast, SMEs in the Czech Republic face challenges with administrative and regulatory procedures as well as an entrepreneurial gap indicated by a limited number of start-ups (European Commission 2023a).

Table 2. Key challenges faced by SMEs in the Czech Republic

Key Challenges	SME Impact
Administrative and Regulatory Procedures	Major obstacle to investment and business operations; considered a significant barrier to doing business due to fast-changing legislation.
Limited Number of Start-Ups	Reflects an entrepreneurial gap, placing Czech at 21st in the EU for start-up density; suggests potential underutilization of innovative business creation.
Skills Shortages and Labour Market Needs	76% of businesses report difficulties finding ICT specialists, the highest in the EU; indicates a critical talent gap affecting digital transformation and competitiveness.
Late Payments	Affects SME resilience and growth, with 61% of companies experiencing late payments, significantly higher than the EU average of 43%.

Source: own construction based on European Commission SME performance report 2022

2.3. Theoretical underpinning

The measure of firm competitiveness in this study is drawn from the framework of the resource-based view of the firm (RBV) and the configurational theory. The key feature of the framework presented by the configurational approach to competitiveness analysis is its acknowledgement and emphasis of the comprehensive and interconnected nature of the factors affecting a firm's competitive position (Ketchen et al. 1993). This method acknowledges the intrinsic complexity of the business environment and goes beyond the conventional reductionist linear methods. This approach is constructed as a congruence following several theoretical propositions and frameworks.

The origin of the configurational approach lies on the configurational theory motivated by Miller and Friesen (1980), who assert that those configurations of aspects provide a more comprehensive understanding of organizational dynamics than the examination of individual factors separately. The theory therefore posits that a firm's competitive advantage usually results from the complex combination and alignment of different organizational aspects as opposed to from the total of the individual components. These components include, among the components, the diverse resources, procedures, structure, and strategy.

The RBV stems from the application of the configurational theory to explore the contribution to sustainable competitive advantage of specific configurations of resources and capabilities by Barney et al. (1991). As a key theory within the configurational approach, the RBV emphasizes that a firm’s competitive advantage stems from its unique and valuable resources, thus introducing the concept of valuable, rare, imitable and non-substitutable (VRIN) resources as key determinants of competitive advantage within the configurational philosophy. In this context configurations analysis involves identifying and aligning these resources in a way that creates a unique competitive position.

Based on the developments made by Barney on the application of the configurational in assessing a firm’s resources and capabilities, a number of studies

have followed in application of the RBV. In a novel study developing a system dynamic approach for assessing competitiveness (Szerb et al. 2020), the RBV is employed in the study to illustrate how resources and capabilities are interdependent and how their configuration affects performance and firms' competitiveness.

In essence, the approach emphasizes that the interactions of resources and capabilities result in the creation of competencies, which in turn contribute to improving a firm's competitive position and overall performance. This aligns well with RBVs proposition that competitiveness is a multidimensional contrast and relates positively with resources and capabilities.

3. Methodology

The present study uses a growing amount of data collected as part of the Global Competitiveness Project (GCP) survey (http://www.sme-gcp.org), which hitherto includes firm-level data from twelve countries across Europe, Asia, and South America. The data is classified into ten pillars, including domestic market, networking, internationalization, human capital, product, technology, marketing, online precedence, decision making, and strategy. Additionally, the dataset includes specific characteristics of firms.

The study covers a sample of 331 SMEs, with 199 firms in Hungary's sample – comprising 104 firms in the urban regions and 95 in the rural regions – and 132 in the Czech Republic's, comprising 38 in the rural setting and 94 in the urban setting. The sample was selected to include only firms classified as Micro, Small and Medium-Sized Enterprises (MSMEs) according to EU standards, and only those with complete data were included. Given that the dataset is expanding, data was collected at different times, with information pertaining to Hungary being collected in 2018 and that relating to the Czech Republic in 2019.

Table 3. Sample distribution

SN	Country	Sample Size	Percentage of Total	Year of Survey
1.	Hungary	199	60	2018
2.	Czech Republic	132	40	2019
3.	Hungary + Czech Republic	331		

Source: own construction based on survey data

The firms in the sample are classified into 21 categories based on NACE 1 classification which covers a broad range of industries, such as agriculture, manufacturing, construction, wholesale and retail trade, transportation, information and communication, financial and insurance activities, real estate, professional, scientific, and technical activities, administrative and support services, education, healthcare, arts, entertainment, and recreation, among others.

3.1. Description of variables

3.1.1. Dependent variable

The dependent variable in this study is the competitiveness score of firms, which is a unified index of their resources and capabilities inspired by the Resource-Based View (RBV). The dataset includes this metric for individual firms, which has been computed as the average score across ten pillars of competitiveness. Each pillar comprises various variables that contribute to the overall score. The methodology for deriving the competitive score for each firm is outlined as follows following (Szerb et al. 2020):

Step 1. Normalization of variables

Each variable within the dataset is normalized to a range of {0,1] using the following formulae:

$$x_{ij}^{*} = \frac{x_{ij}}{max(x_j)} \quad j = 1, \ \ldots . j; i = 1, \ \ldots . . N$$

Where *x** denotes the normalized value of variable *j* for firm *i*, *xij* is the original value of variable *j* for firm *i*, and max*(xj)* is the maximum of variable *j* across all firms. The normalization of the variables allows for consistency in measurement by scaling the values of each variable relative to the highest observed value.

Step 2. Categorization of the variables into competitive pillars

The normalized variables (J) are grouped into 10 vectors (v), each corresponding to the distinct competitive pillars defined based on the RBV. The pillar scores are the average value of the variables included in each pillar calculated as:

$$p_{iv} = \frac{\dot{a} \sum_{K=1}^{K} x_{i,v}^{*}}{K} \quad v = 1, \ \ldots \ldots . 10; k = 1, \ \ldots \ldots \ldots K$$

Where p_{iv} is the pillar score for firm i in pillar v, $x_{i,v}^{*}$ stands for the normalized values within pillar v for firm *i*, and *K* the total number of variables within the pillar. These are then normalized as follows to allow for comparison across pillars:

$$p_{iv}^{*} = \frac{piv}{max(p_v)}$$

Step 3. Computation of the Competitive Index

Finally, the overall competitiveness index for each firm is as a summation of the normalized pillar scores:

$$CI_i = \sum_{1}^{10} p_{i,v}^{*}$$

Thus, the computed index indicates firm competitiveness score by combining various resources and capabilities into a single measure.

3.1.2. Independent variables

The independent variables of the study represent various aspects of firm attributes and geographical or locational settings. These variables are used to determine the effect of firm characteristics and regional aspects on firm competitiveness. Table 2 presents a description of each of the variables.

Table 4. Description of independent variables

Variable	Description
Firm Size	Total number of employees within a firm. The range of possible number is {1, 248} based on the EU classification of MSMEs. This variable also captures the scale of firms.
Firm Age	Age of firm (in years) as at the time of the survey. It also captures the experience of the firms.
Industry share	Percentage share of industry in which firm belongs. It captures the share of the corresponding firm's industrial identity of the total industries in the sample.
Number of Firms in Industry	Industry size or concentration in which firms belong
Number of Firms in Region	Reflects regional density of firms, indicating a measure of clustering or firm agglomeration
Country Dummy:	Binary variable of firm's country of operation 1 = Hungary 0 = The Czech Republic
Location Dummy	Binary variable distinguishing between firms' location 1 = Urban 0 = Rural
Firm size and location interaction term	An interaction term to capture the impact of firm size within locational context.

Source: own construction

4. Results and analysis

This study employs a quantitative methodology to explore the connections suggested by the stated objectives. A cross-sectional regression model is utilized to examine the impact of firm characteristics and regional factors on firm competitiveness.

4.1. Descriptive statistics

Table 5 shows the summary statistics of the variable, suggesting a dataset with significant heterogeneity. The mean competitiveness score is moderate at 4.98, with scores ranging from 1.68 to 8.27 and standard deviation of 1.36, indicating significant heterogeneity in competitiveness scores among the firms in the sample. The mean of Firm Size and the median show significant differences, suggesting a right-skewed distribution of this variable with longer tail of firms having high number of employees. This suggests that within the sample, majority of firms are relatively small. With a standard deviation of 28.2, there is indication of high variability in firm sizes. Firm age appears symmetric with the equivalence in the mean and median (16).

Additionally, the mean age of 16 is suggestive of relatively well established and experienced firms in the sample. The standard deviation of Number of Firms in industry of 8.94 with a maximum of 38 and minimum of 6 and a mean of 16.5, reflects considerable variability in the number of firms across the industries. The regions exhibit a moderate firm density, with a high standard deviation indicating substantial heterogeneity in regional distribution of firms. The binary distributions of country and location dummies show a mean of 0.601, indicating a sample bias towards the referenced group.

Table 5. Summary statistics, using the observations 1 – 331

Variable	Mean	Median	S.D.	Min	Max
Competitiveness_Score	4.98	5.01	1.36	1.68	8.27
Firm_Size	18.6	9.00	28.2	1.00	220.
Firm_Age	16.0	16.0	7.70	2.00	35.0
Number_of_Firms_in_Industry	16.5	13.0	8.94	6.00	38.0
Industry_Share	4.98	3.93	2.70	1.81	11.5
Number_of_Firms_in_Region	21.5	15.0	20.5	1.00	60.0
CD	0.601	1.00	0.490	0.000	1.00
LD	0.417	0.000	0.494	0.000	1.00

Source: own construction in Gretl software reformatted for readability

The correlation analysis presented in Table 6 shows the non-causal relationship between Firms Competitiveness Score and the various independent variables, as well as the relationships among the variables themselves. The correlation coefficient of 0.322 between Competitiveness Score and Firm Size is positive and moderate, suggesting that larger firms in terms of number of employees tend to have higher competitive scores, pointing to a possible importance of size in fostering competitiveness likely due to a range of factors such as a higher pool of talent, economies of scale, among others. A similar result is seen with respect to the correlation between competitiveness core and number of firms in regions. With a weaker coefficient of 0.153, enterprises in regions with a higher density of firms have a higher competitiveness score, pointing to possible benefits of agglomeration economies.

Table 6. Correlation analysis

	Competitiveness Score	**Firm_Size**	**Firm_Age**	**Number_of_Firms_in_Industry**	**No_of_Firms_in_Region**
Competitiveness Score	1.000	0.322	0.003	-0.004	0.153
Firm Size	0.322	1.000	0.179	-0.004	-0.012
Firm Age	0.003	0.179	1.000	-0.022	-0.119
NO. of Firms in Industry	-0.004	-0.004	-0.022	1.000	0.221
No of Firms in Region	0.153	-0.012	-0.119	0.221	1.000

Source: own construction in Gretl software reformatted for readability

4.2. Inferential analysis

A cross-sectional model is used to examine the relationships inferred in the objectives of the study. First, an aggregate model combining the samples in the two countries is estimated to establish aggregate effects. the model is generally presented as follows:

$$log\ (Competitiveness\_Score) = \beta 0 + \beta 1\ log\ (Firm\_Size) + \beta 2\ log\ (Firm\_Age) + \beta 3\ Country\_Dummy + \beta 4\ Location\_Dummy + \beta 5\ log\ (Number\_of\_Firms\_in\_Industry) + \beta 6\ log\ (Number\_of\_Firms\_in\_Region) + \beta 7\ L\_SxLD + e$$

Where Bo represents the intercept, B1. B7 are coefficients of the independent variables and e is the error term.

For estimation, the model is log transformed to linearize the equation and to allow for elasticity interpretation. In this case therefore a percentage change in an independent variable will lead to a percentage change in the dependent variable inferred by the coefficient of the concerned independent variable. The log transformed model is represented as follows:

$$log\ (Competitiveness\_Score) = \beta 0 + \beta 1\ log\ (Firm\_Size) + \beta 2\ log\ (Firm\_Age) + \beta 3\ Country\_Dummy + \beta 4\ Location\_Dummy + \beta 5\ log\ (Number\_of\_Firms\_in\_Industry) + \beta 6\ log\ (Number\_of\_Firms\_in\_Region) + \beta 7\ L\_SxLD + e$$

Where

B0 is the model's intercept while the coefficients of the independent variables are represented by B1 to B7. Log (Competitiveness_Score) represents the natural logarithmic transformation of the dependent variable. Log (Firm_Size) is the log

transformation of Firm Size, log (Firm_Age) – log transformation of Firm Age, log (Number_of_Firms_in_Industry) – log transformation of the Number of Firms in their respective Industries in the sample and log (Number_of_Firms_in_Region) - log transformation of the Number of Firms in the Region. Country_Dummy (CD) indicates the binary variable for country, with 1 representing Hungary (HU) and 0 representing Czech Republic (CZ), while Location_Dummy (LD) represents the binary variable for location, with 1 for urban and 0 for rural locations. L_SxLD represents the interaction term between the log-transformed Firm Size and the Location Dummy while e is the error term.

Table 7 shows the results of model progression from model 1 through to 4 estimated by sequential addition of variables to capture their impacts on the dependent variable. There is slight improvement in the models as seen in their respective R squared statistic, indicating modest improvements in the model's explanatory ability through the progression.

Table 7. Model progression of aggregate estimation

	Model 1	Model 2	Model 3	Model 4
const	1.51*** (0.06738)	1.51*** (0.06839)	1.47*** (0.14250)	1.46*** (0.14274)
l_Firm_Size	0.12*** (0.015761)	0.12*** (0.01582)	0.12*** (0.01603)	0.12*** (0.02099)
l_Firm_Age	−0.07*** (0.02477)	−0.07*** (0.02488)	−0.06*** (0.02465)	−0.06** (0.02482)
Country Dummy: 1=HU, 0=CZ	−0.05* (0.03049)	−0.05 (0.03186)	−0.06 (0.03978)	−0.06 (0.04076)
Location Dummy: 1=Urban; 0=Rural		−0.007 (0.03248)	−0.012 (0.03277)	0.006 (0.09108)
l_Number_of_Firms_in_Industry			−0.02 (0.04186)	−0.02 (0.04217)
l_Number_of_Firms_in_Region			0.03 (0.01314)	0.03** (0.01323)
L_SxLD (interaction of Firms size and LD)				−0.008 (0.03202)
R-Squared	*0.1552*	*0.1553*	*0.1716*	*0.1718*
F-Statistic	*(3, 327) =18.89***	*(4, 326) =14.14***	*(6, 324) =10.46***	*(7, 323) =8.98***
AIC	*88.18*	*90.13*	*87.7*	*89.62*
SIC	*103.39*	*109.14*	*114.13*	*120.1*

Source: own construction in Gretl software reformatted for readability
Note: Dependent variable: l_Competitibeness_Score; Heteroskedasticity-robust standard errors, variant HC1. *N = 331, SE in parenthesis*

Both firm size and age are consistently significant throughout the model progression (models 1 to 4), with firm size positively associated and firm age negatively associated with competitiveness scores. The positive association between firm size and compositeness suggests that as firms grow, their competitive position

increases, possibly due to greater resource accumulation underscoring the importance of scale expansion that leads to economies of scale (Acs–Audretsch 1987). Conversely, the negative association between firm age and competitiveness is suggestive of the challenges older firms are exposed to in maintaining flexibility and adapting to competitive trends, thus emphasizing the importance of innovation (Coad et al. 2016).

Model 1 also shows that firms in Hungary are less competitive than those in the Czech Republic, as indicated by the negative coefficient of the Country Dummy variable. However, the significance of this association diminishes as more variables are included. This is consistent with studies that have indicated the importance of firm-specific factors over broad geographic characteristics (Porter 1998a). The results suggest that the Location Dummy variable does not have a significant effect, indicating that firm competitiveness is not differentiated by Urban–Rural location in this case. This could be due to the well-developed and balanced conditions that support firm activities in both Hungary and the Czech Republic, as they are developed countries.

The number of firms in regions measuring agglomeration has a positive and statistically significant effect, suggesting that firm agglomeration in regions fosters competitive effects. This could be due to a range of reasons, including knowledge spillovers, a more robust supply chain, and other agglomeration economies. Furthermore, the results suggest that the effect of company size on competitiveness is similar in both urban and rural areas, as demonstrated by the coefficient of the interaction term.

4.2.1. Country comparison

Table 6 shows the country comparison between Hungary and Czech Republic based on their specific sample. Similar cross-sectional analysis specified as follows is used:

Generalized Equation for Model 3

– For Hungary:

$$log\ (Competitiveness\_Score)\ HU = B0 + B1log\ (Firm\_Size) + B2log\ (Firm\_Age) + B3Location\ Dummy + B4L\_SxLD + B5log\ (Industry\_Share) + B6log\ (Number\ of\ Firms\ in\ Region) + e$$

– For Czech Republic:

$$log\ (Competitiveness\_Score)\ CZ = \gamma 0 + \gamma 1log\ (Firm\_Size) + \gamma 2log\ (Firm\_Age) + \gamma 3Location\ Dummy + \gamma 4log\ (Industry\_Share) + \gamma 5log\ (Number\ of\ Firms\ in\ Region) + e$$

Where:

β0 and γ0 are the constant terms for Hungary and the Czech Republic, respectively, B1 and γ1 are the coefficients for log-transformed Firm Size in each country, B2 and γ2 represent the coefficients for log Firm Age, B3 and γ3 denote the coefficients for the Location Dummy variable (1 for urban, 0 for rural), B4 and γ4 are

the coefficients for the interaction term between firm size and location dummy (L_SxLD), B5 and γ5 are the coefficients for the log of Industry Share and B6 and γ6 indicate the coefficients for the log Number of Firms in Region. e is the error term

Table 8. Cross-country analysis of Hungary and the Czech Republic

	Hungary (N=199)			Czech Republic (N=132)		
	Model 1	*Model 2*	*Model 3*	*Model 1*		
const	1.4*** (0.09247)	1.4*** (0.10669)	1.29*** (0.1663)	1.66*** (0.10546)	1.66*** (0.111)	1.48*** (0.13759)
firm Size	0.1*** (0.02461)	0.1*** (0.03694)	0.1*** (0.0381)	0.13*** (0.02132)	0.13*** (0.02617)	0.13*** (0.02498)
l_Firm_Age	−0.03 (0.03067)	−0.03 (0.0315)	−0.03 (0.03083)	−0.14*** (0.04279)	−0.14*** (0.04292)	−0.12*** (0.04273)
Location Dummy: 1=Urban; 0=RuralD	−0.01 (0.04006)	−0.02 (0.13404)	−0.02 (0.1352)	−0.01 (0.05644)	−0.02 (0.1227)	0.005 (0.12518)
L_SxLD		0.004 (0.04876)	−0.001 (0.05062)		0.004 (0.04076)	−0.001 (0.0417)
L_ Industry Share			0.0302 (0.0457)			0.02 (0.03277)
l_Number of Firms in Region			0.0233 (0.03187)			0.03** (0.01530)
R-Squared	*0.0794*	*0.0794*	*0.0835*	*0.2864*	*0.2865*	*0.3213*
F-Statistic	*(3, 195) =5.73***	*(4, 194) =4.29***	*(6, 192) =2.85***	*(3, 128) =14.67***	*(4, 127) =11.03***	*(6, 125) =8.56***
AIC	*67.22*	*69.22*	*72.33*	*23.04*	*25.03*	*22.43*
SIC	*80.4*	*85.68*	*95.38*	*34.57*	*39.45*	*42.61*

Source: own construction

Note: Dependent variable: l_Competitibeness_Score. Heteroskedasticity-robust standard errors, variant HC1. *SE in parenthesis*

The findings show similarities in some elements and significant variations in others. The model progression demonstrates a continuous and statistically significant positive correlation between firm size (l_Firm_Size) and competitiveness score in both Hungary and the Czech Republic. This result highlights the importance of scale, as previously mentioned. Although both countries show a negative coefficient of firm age (l_Fim_Age), indicating a decrease in competitiveness among aging enterprises, this association is only statistically significant in the Czech Republic.

There is no significant effect observed for the Location Dummy variable or the interaction between firm size and location (L_SxLD) in the model progression for both countries. The sample suggests that firm competitiveness is not predicted by variations in urban–rural location. The interaction term is similarly insignificant suggesting that the impact of firm size on competitiveness does not vary between urban and rural settings.

In the case of Hungary, industry Share in which the firms belong and Number of Firms in Region show a positive but insignificant association with competitive sores. The absence of significant competitive effect of industry share (size) which essentially measures concentration, potentially points to heterogeneity off firms within industries. In contrast, for the Czech Republic, the number of firms in the region becomes significant in Model 3, indicating a positive relationship between regional firm density and competitiveness, suggestive of the presence of agglomeration economies in the Czech context.

5. Discussion

The aim of this study has been to explore the relationship between firm characteristics, geographical location and firm competitiveness in the context of SMEs in Hungary and the Czech Republic, aligning with the Resource Based view of the firm and the configurational approach. The study explores the impact of firm size as represented with the number of employees, age, geographical location on competitiveness alongside the effects of regional firm density and the urban rural dichotomy. The findings bring to fore an intricate relationship between the variables.

The models estimated show a positive association between firm size and competitiveness, which aligns with the Resource-Based View (RBV) assertion that a firm's resources, including its scale, contribute to its potential to achieve a competitive advantage (Barney 1991). This highlights the role of a firm's scale in boosting its capacity to leverage economies of scale and resource accessibility (Porter 1990). A growing number of employees in a firm can increase the talent and ideas pool, which can result in the promotion of innovation. Conversely, there is a negative association between firm age and competitiveness, which suggests that older firms may face bottlenecks in responding to market dynamics. This is consistent with Hannan and Freeman's (1984) view that, as organizations age, their propensity to adopt change diminishes, leading to higher levels of organizational inertia and slower reaction times compared to younger firms. To navigate this challenge, continuous innovation efforts can be pursued.

The significance of the country dummy diminishes as the model progresses in the aggregate estimation, aligning with Krugman's (1992) geographical economics assertions. This emphasizes the superiority of firm-specific factors over geographical determinants in influencing competitiveness. However, the positive association between the number of firms in a region and firm-level competitiveness validates the evidence of the competitive effect of regional firm agglomeration, which is consistent with Porter (2000) perspective. Agglomeration economies may arise from various factors, such as knowledge spillovers, innovation, and resource pooling.

Contrary to previously held views, this study does not confirm the view that urban–rural location is a significant driver of firm competitiveness. Scott and Storper (2003) suggest that firms located within dense networks in urban areas have advantages such as convenient access to resources, information, and collaborations, which contribute to improved productivity. However, the insignificant effect of location, together with its interaction with firm size, in the context of this study may

indicate the presence of developed regional infrastructure in the two countries that does not significantly distinguish between urban and rural areas.

6. Conclusion

Based on the empirical evidence and subsequent analysis presented in this paper, a number of policy recommendations can be deduced. Given the notable disparities in the impact of business characteristics, specifically age and size, on firm competitiveness in Hungary and the Czech Republic, it is reasonable to propose the implementation of tailored policies with the objective of promoting competitiveness. Both Hungary and the Czech Republic can derive more advantages by implementing policies that offer incentives to increase the size of their firms, considering the strong and positive correlation between firm size and business competitiveness. Although the age of a firm does not have a substantial impact on competitiveness in Hungary, the Czech Republic has the potential to mitigate this negative affect by implementing policies that foster continuous innovation. One such policy may involve the establishment of innovation centers that cater to firms with low inertia. Furthermore, due to the notable positive impact of regional firm concentration in the Czech Republic, the implementation of policies that promote cluster formation, networking, and partnerships could potentially yield advantages in fostering the growth of agglomeration economies. Furthermore, although the urban-rural split did not indicate substantial distinction, it does not undermine the significance of blanked regional development programs. The potential lack of significance in the influence of this variable in the present study may be attributed to unobserved factors, as prior research has demonstrated the impact of location (Scott–Storper 2015, Storper–Venables 2004).

In summary, this study has demonstrated the impact of business attributes and geographical variables, while also shedding light on the potential intricacies of this association through the comparison of Hungary and the Czech Republic. In addition to emphasizing the importance of implementing policies tailored to specific contexts, even in regions with similar socio-economic characteristics, as observed in the two countries examined in this study, the results indicate the necessity for firm strategies to surpass the examination of general factors like company size and age. Instead, firms should take into account the specific economic, industrial, and regional contexts when making decisions.

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Increasing poverty: The impact of Russian-Ukrainian war on Central Asia

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Central Asia, historically closely tied to Russia and Ukraine, has experienced severe repercussions from the 2022 Russian–Ukrainian war. The five Central Asian nations – Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan – have faced worsened poverty and an increased vulnerability of households. The paper employs a postcolonial theoretical perspective to investigate the nuanced effects of the Russian–Ukrainian war on the region. The results show that even after three decades of independence Central Asia remains economically, politically and militarily dependent on Russia. Shocks in the Russian economy have had significant effects on the region which has not recovered after the COVID-19 pandemic. The military conflict has triggered persistent poverty and inequality issues, stalling the progress made by Central Asia in reducing poverty over the past two decades. After two years, the economic damage has been substantial and long-term negative outcomes of the conflict are about to come.

Keywords: Russian–Ukrainian war, Central Asia, poverty

1. Introduction

Over the past two decades, the Central Asian region has made substantial progress in its development with far-reaching growth prospects. The region`s GDP has been increasing at an average rate of 6.2% per year reaching $347 billion in 2021 (Eurasian Development Bank 2022).

The population of Central Asian states keeps growing at the rate of 2% per year reaching 77 million people in 2021 (Eurasian Development Bank 2022). Inward FDI stock is estimated at $211 billion while foreign trade turnover has surged sixfold since 2000.

Apart from these remarkable advancements, the Central Asia region holds considerable economic and political importance due to its strategic location, vast natural resource reserves and historical heritage. The region owns rich reserves of natural resources, in particular oil in Kazakhstan and Turkmenistan, natural gas in Uzbekistan, and minerals in Tajikistan and Kyrgyzstan. Central Asia is a crucial transit route for international trade connecting Europe, Asia, and the Middle East, serving a bridge between East and West. The region`s geographical positioning and proximity to conflict-prone areas is particularly notable in Tajikistan`s extensive border with politically and economically unstable Afghanistan.

Despite the remarkable advancements and its economic and political importance, the international community still fails to recognize the economic significance of Central Asia. Central Asia remains one of the least researched regions in the world.

One of the topics that has been least researched on Central Asia is postcolonial studies. Postcolonial studies are a field of academia examining the lasting influence

of colonialism on contemporary societies, cultures, and politics. Postcolonial studies particularly focus on those regions that once were under European colonial rule. However, in recent years many scholars have considered the Tsarist era and the Soviet period as instances of colonialism. While the degree of Russia's colonial role in Central Asia remains debatable, its cultural, political, and economic legacy is undeniable. Even three decades after independence, the Central Asian states continue to navigate their relationship with Russia within the shadow of this past. The deteriorating situation in Russia poses a great risk of triggering economic and political crises in Central Asia.

The paper seeks to investigate the nuanced effects of the Russian-Ukrainian war on Central Asia through a comprehensive review of the existing literature and available data, answering the research question "How has the Russo-Ukrainian war reinforced the postcolonial power dynamics between Russia and the Central Asian states?"

The first section of the study focuses on postcolonial studies. The second part reports on two channels through which the repercussions of war reverberated in Central Asia exacerbating existing poverty challenges.

2. Theoretical framework

The term "postcolonial" refers to the end of the colonial period and describes the historical interactions between Asian, American, and African communities subject to colonization by imperialist powers and Western societies (Dosbolov–Sönmez 2023). Postcolonial studies examine the lasting impact of a dominant culture on another society and analyze the effects of colonization on identity and culture.

The term "postcolonial" was coined by several scholars including Ashcroft et al. (2002, p. 2) to describe "cultures affected by imperialism, ranging from the time of colonization to the present day". According to Young (2001), postcolonialism emerged to express a range of critical ideas, oppositional political identities, and aspirations rooted in the ongoing political and cultural history of resistance against colonialism and imperialism.

Fanon (1963, 2008) examines the effect of race on colonizer–colonized relations, mentioning how colonizers impose their culture, language, religion, and education, making colonized individuals feel culturally inferior and less important, justifying the dominance of colonizers. Fanon connects decolonization with a violent stressing of its role in achieving freedom by colonized people.

Among other works, the works of three scholars – Said (2003), Spivak´s 1988 theory of the subaltern, and Bhabha 1994´s ideas of hybridity and mimicry are foundational to postcolonial studies. Said´s 2003 concept of Orientalism is pivotal to postcolonial theory analyzing how post-Enlightenment European civilization asserted dominance over the East. Said characterized the Orient as a close neighbor to Europe, from which it derives its civilizations and languages. The concept of Orientalism refers the collective institutions and practices engaging with the Orient and dominating it. The Western perspective employs a dualistic framework to construct an "Orient", assigning characteristics to its people such as exotic, emotional, feminine, backward, and hedonistic, which sharply contrast with Western ideals such as logic,

masculinity, civilization, and modernity (Said 2003). This has resulted in a biased and distorted understanding and a skewed perception of Eastern cultures.

The Indian scholar and theorist Gayatri Spivak reframed Antonio Gramsci´s concept of the subaltern, applying it to marginalized groups in postcolonial countries. Spivak (1988) argues that as these communities are burdened by poverty, oppression, and exploitation, they are left voiceless and unable to stand against colonial rule. One of the main points of Spivak's scholarship is that knowledge production often serves the interest of its creators as European academia including Michel Foucault and Gillies Deleuze developed theories which ultimately supported Western economic and ideological interests, justifying Western colonization and perpetuating Western imperialism and European values on indigenous populations. Colonial oppression severely limits the ability of subalterns to express their identities and voices independently.

Bhabha (1994) introduced novel ideas such as mimicry and hybridity to postcolonial studies. In postcolonial studies the concept of mimicry is utilized to describe people who replicate Western cultural norms, values, and behaviors frequently distancing from their own cultural heritage. In the colonial era, mimicry served as a tool for colonizers seeking power and influence. By mirroring the conduct of the ruling class, imitators could ascend social hierarchies to the detriment of one´s cultural identity. Alongside benefits of mimicry for the colonizer, the author mentions the potential threats. Imitators who internalize Western values such as justice, equality, human rights and democracy, could inevitably sow the seeds of resistance. The potential to mimicry to challenge colonial authority became vivid when the colonial power transgresses the colonizer´s boundaries. To counter this, the colonizer usually imposes a partial imitation model on native population characterized by "almost, but not quite" which still impose vulnerability to the colonial power.

Another concept in postcolonial discourse introduced by Bhabha is "hybridity". This term signifies a fusion of Western and Eastern cultural elements. In the context of colonial and postcolonial studies, it represents the balance held by colonized between their heritage and the imperial legacy. Bhabha characterizes hybridity as a tool used by the colonized to resist colonizers. According to the author, a colonial system is characterized by internal contradictions. Over time, the rulers are changed by the population they ruled, as the colonized might demand equity, and as a result, this hybrid identity undermines the imperial power.

Postcolonial studies have been a relatively new area of research in the post-Soviet states and at the same time the blind spot in the scholarship of Central Asian colonial past. If the Tsarist Russian period is identified as a colonial era, the Soviet Union's legacy is less clear due to several factors: (1) the current Central Asian leaders and senior managers rose to power during the Soviet era and have Soviet mentality and education and are reluctant to criticize the Soviet past; (2) the region is still heavily dependent on Russia for political, economic, and the security support developing a robust postcolonial discourse; and (3) production of new knowledge dedicated to postcolonial studies is greatly limited by state ideology and politics.

To apply a postcolonial perspective to the relationship of Central Asia and the Soviet Union, a fundamental question arises: Was the USSR a colonial empire, and if so, was the Central Asian region colonized?

Academic sources offer divergent perspectives on this matter. One viewpoint, represented by Hirsch (2005), identifies the Soviet Union as a colonial empire with typical characteristics of domination and control. Conversely, other scholars such as Khalid (2007) and Abashin (2014), argue that the Soviet Union was a unique entity concentrated on modernization rather than traditional colonial exploitation.

While acknowledging elements of control and resistance, the relations between the Soviet Union and Central Asia are more complex than a simple oppressor–oppressed dynamic.

The perception of Russia and the Soviet Union as a colonizer has dramatically shifted throughout history. In the 1920s, early Soviet historiography condemned the Tsarist empire as a brutal colonizer viewing it as an "absolute evil" (Gorshenina 2007). However, by the 1930s this narrative shifted as Soviet ideology started to note the advantageous aspects of Russian rule. The Tsarist conquest was recast as a "lesser evil" (Alimukhamedov 2022), in contrast to other potential colonizers and internal conflicts in the region due to Russia's more developed social structure and connections to revolutionary movements. By the 1950s this narrative changed entirely into "absolute good" (Nechkina 1951), and by the 1960s Soviet discourse totally rejected terms like "colonization" and "conquest" replacing them to terms such as "unity" and "solidarity". Official Soviet ideology claimed that it had decolonized Central Asia freeing its people from the legacy of Tsarist imperialism and local feudalism (Gorshenina 2021).

However, the perestroika era (1986–1991) revealed the fragility of these ideological constructs, as local intellectuals and the public openly and increasingly criticized the Soviet system, merging anti-colonial and nationalist sentiments and demanding cultural and linguistic recognition (Igmen 2012).

The appearance of the famous "mankurt", an individual who had forgotten his cultural identity portrayed by the Kyrgyz author Chingiz Aitmatov in *The Day Lasts More Than A Hundred Years* (1980) haunted the political discourse opposing Soviet rule, arguing that Soviet imperialism sought to eradicate Central Asian identities and so-called modernization program was questioned (Karagulova–Megoran 2011).

In the perestroika period the local intelligentsia drawing parallels with the distress of "Third World" countries (such as India, Pakistan, Afghanistan and Iran) questioned the idea of equality within the Soviet Union, characterizing it as dependency relations between the center and the periphery. Interestingly, the Soviet system tolerated such critique, therefore some scholars claim the perestroika as the beginning of the postcolonial period in the Soviet context.

Contemporary Russia being formally a federation with many nations living there, exhibits increasing nationalist tendencies which dwaft its imperial past. A main narrative focuses exclusively on the Russian-Soviet empire as solely of a story of the Russian nation and culture, and this viewpoint, rooted in Soviet period academic doctrines and beliefs, denies accepting the colonial nature of the empire. In Soviet-Russian literature the terms "colony" or "metropole" explain the empire's expansion as a "voluntary accession" which brought mutually beneficial results (Gorshenina 2021).

The lack of official recognition of Russia's colonial legacy in Turkistan is supported also by the absence of commemorations, monuments, and educational

emphasis related to the Russian presence in Central Asia. Even if Russia is reluctant to recall its colonial history and denies its colonies or colony-like politics in the Tsarist and Soviet context, it has developed a new "neo-colonial co-dependence relationship" with the Central Asian states, still holding the significant power and influence (Abashin 2020, p. 7).

Central Asian's postcolonial era began in 1991 with gaining independence. The region now confronts economic, political, cultural, and linguistic remnants of 70 years of Russian colonialism. Economic challenges persist due to historical resource exploitation, interconnection of the Soviet republics' economies to each other, and subsidized economy. Politics in the region is also shaped by postcolonial dynamics.

Even after the demise of the Soviet Union, the idea of "Russian superiority" has not disappeared and Russia has not lost its central role in Central Asia using the region as a resource base (Abashin 2014, Gorshenina 2021).

The Russian–Ukrainian war has exacerbated these dynamics, pressing these nations to choose between aligning with Russia or risk economic consequences. The continued economic interdependence of Central Asia with Russia has exacerbated the region´s persistent poverty and inequality.

The Russian war in Ukraine has created shockwaves in every corner of the world causing a food and energy crisis, surging poverty, and starvation. According to a report by the United Nations Development Program (UNDP, 2022), the war has pushed approximately 71 million people into poverty worldwide, driving the global poverty rate to 9.2% (World Bank, 2024). Perhaps nowhere else have the effects of the Russian invasion of Ukraine been felt stronger than in Central Asia, which has developed close economic, political ties and cultural similarities to Russia as a part of colonial past.

Economically, Russia remains a major trading partner for Central Asia's states, particularly in the energy and natural resources sectors. Russia serves as a pivotal market for Central Asian export, which encompass oil, gas and minerals. Moreover, the Russian Federation leads investment and infrastructure development projects in the region.

Politically, Russia exerts significant sway in Central Asia through various ways, including diplomatic relations, security cooperation, and multilateral organizations such as the Collective Security Treaty Organization (CSTO), the Eurasian Economic Union (EAEU), Commonwealth of Independent States (CIS), and the Shanghai Cooperation Organization (SCO). These regional integration groups enhance Russia's geopolitical influence and enable its involvement in regional affairs.

Additionally, historical bonds between Russia and Central Asia dating back to the Soviet era continue to influence their relations. Significant Russian-speaking populations live in most of Central Asian countries, fostering strong cultural exchanges.

Two years after the start of the full-scale invasion of Ukraine, Central Asia faces direct and indirect effects of the war. While the impact of the war has been felt across the entire region, the non-commodity exporters – Kyrgyzstan and Tajikistan – have taken the most considerable hit in particular.

3. The ripple effect: The impact of Russian–Ukrainian conflict on Central Asian poverty

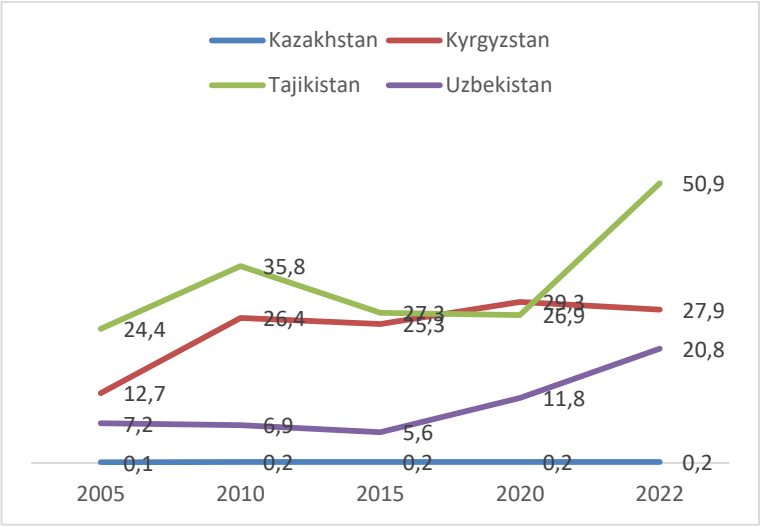
Paradoxically, the war has opened several opportunities for the Central Asian states. The region reaped gains through various channels: (1) the US and Western sanctions have compelled numerous Russian businesses to relocate to Central Asia, and, consequently, thousands new businesses have been registered in Kazakhstan and Kyrgyzstan, and to a lesser extent in Uzbekistan and Tajikistan, with many multinational companies moving their staff to the region; (2) fleeing persecution and conscription into the Russian army, many highly educated and skilled Russian individuals have brought not only valuable human capital to the region but also financial capital by transferring their wealth; and (3) export and import indicators in the region have increased due to the region serving as a new transit hub between Russia and the rest of the world. An influx of capital, a heightened level of domestic consumption, and fresh business and economic activity has led to unexpected tangible economic growth in the region.

Nevertheless, the adverse implications of the conflict weigh significantly heavier on Central Asia. The Russian–Ukrainian war has affected the region through remittances and trade, having brought increased poverty and exacerbating socio-economic problems in Central Asian.

In response to the Russian invasion of Ukraine, the US and European countries have imposed sanctions on Russia which resulted in thousands of international companies leaving the Russian market and weakening the Russian economy. The Russian economic downturn was specifically hurtful for remittance-dependent Central Asian countries. Russia has been the main destination for labor migration from Central Asian states, especially from Kyrgyzstan, Tajikistan, and Uzbekistan. According to the official statistics, over 5 million people from these countries work in Russia, and the number can be even higher because of workers in informal economy (Washington Post 2022a). Coming from poverty-ridden rural areas workers regularly send money to their home countries. Money transfers are the only source of income for households, helping to fulfil families' basic needs such as food and healthcare. For example, according to the report, remittances reduced the national poverty rate by 11 percentage points in Kyrgyzstan (United Nations 2022).

The two Central Asian countries – Kyrgyzstan and Tajikistan are especially dependent on remittances from Russia, which make up about 30% and 50% of their GDP, respectively.

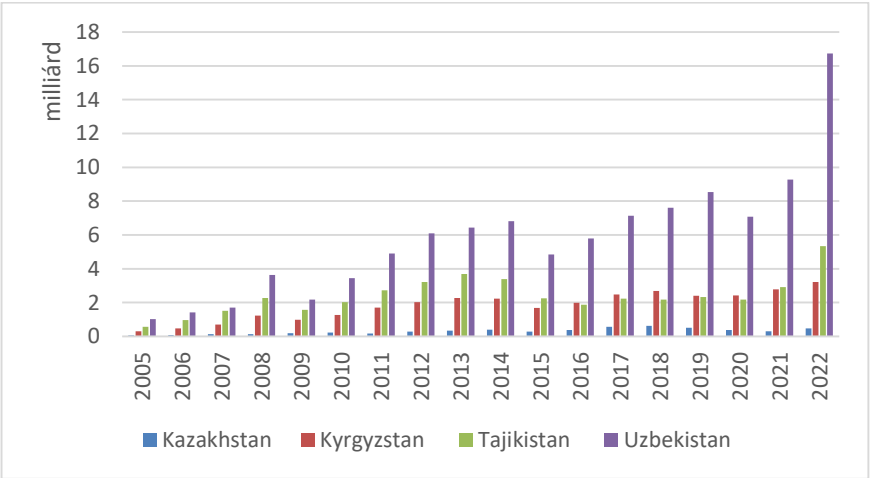
Figure 1. Remittances received by Central Asia countries for 2005–2022, % of GDP



Source: own construction based on World Bank Indicators (2024)

The imposition of sanctions had severe effect on the Russian labor market, resulting in job losses, salary cuts and migrants leaving the country in order to avoid conscription into the Russian army. Consequently, there has been a decrease in remittance inflows. By the close of 2022, IMF (2022) cautioned that a decline in remittances could push one million people into poverty in the region.

Figure 2. Remittances received by Central Asian states for 2005-2022, in billion dollar



Source: own construction based on World Bank Indicators (2024)

Nevertheless, data from 2022 indicates a steady increase in remittances in the region primarily propelled by capital migration due to the inflow of Russian migrants

to the region, fleeing the war and mobilization. Russian migrants were receiving not only money transfers but also many of them were transferring their wealth, either as a precautionary measure or to facilitate payments abroad. Additionally, many Russian companies were forced to leave and relocated to the region, which further boosted money transfer.

The World Bank Group (2022) projected decreased remittances for the years 2023–2024 in the region. According to World Bank predictions, remittances will fall by 21% in Uzbekistan, 22% in Tajikistan and 33% in Kyrgyzstan. Another international organization, IMF (2022b) forecast contraction of remittances by 5–13% by 2026.

Central Asia still has limited and concentrated trade partners. Russia remains the largest source of import for Central Asian states importing mineral products, base metals and chemicals, as well as electric machinery and food (except for Kyrgyzstan, where Russia ranks second behind China). In exports, Russia is the largest destination for Kyrgyzstan and second for Kazakhstan and Uzbekistan in buying mineral products, textiles, base metals, and vegetables (OECD 2022).

Table 1. Share of key trading partners in Trade turnover of Central Asian countries in 2021, in percentages

Country					
Trading	CA	Kazakhstan	Kyrgyzstan	Tajikistan	Uzbekistan
Russia	21.6	23.9	31.6	22.5	18.6
China	20.4	17.9	21.1	14.0	17.5
Turkey	6.0	4.0	5.7	6.5	8.7
CA	9.9	6.2	21.2	28.0	13.9

Source: Eurasian Development Bank (2022)

As the war erupted, Central Asia found itself in a challenging position. As the region with its 1% global trade share is one of the least integrated regions into the global market in Asia and the Pacific, it heavily relies on routes through Russia. Businesses are compelled to transport viral goods – seeds, fertilizers, production resources, and raw materials via alternative routes, leading to surged logistics and insurance costs.

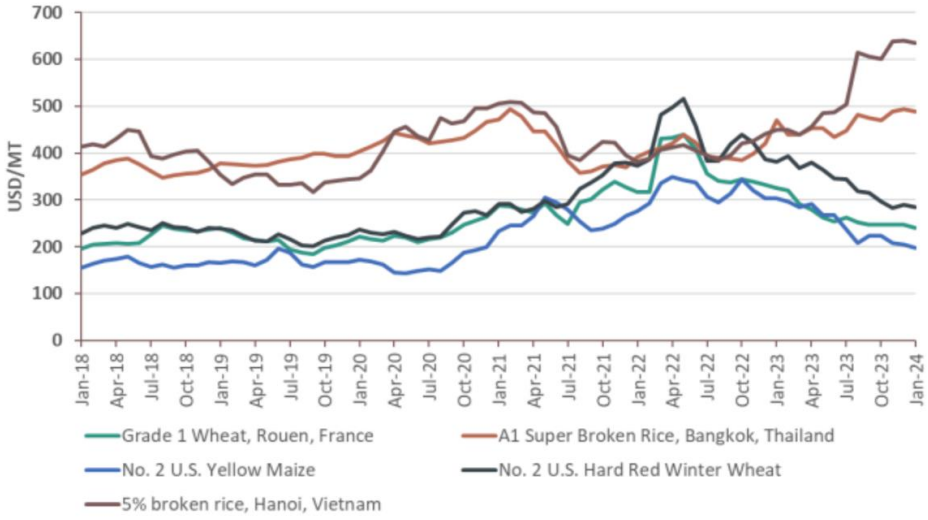
The Russian–Ukrainian war has triggered the global food crisis, due to the significant roles both countries play in the world food market. Russia and Ukraine are the main exporters of wheat, corn and sunflowers. For example, Russia and Ukraine account for about a third of global wheat exports. Ukraine, in particular, holds a prominent position among the world's top three grain exporting countries, earning it the title of the "breadbasket of Europe" (Knox 2022).

Low-income Central Asian countries especially rely on Ukrainian and Russian wheat exports. For example, Tajikistan and Kyrgyzstan imported 100% in 2020 and 55% in 2021 from Russia respectively (OECD 2022).

As Russia has blocked 7 of the 13 ports of Ukraine, limiting its shipping potential, the country simply cannot export its products. Moreover, grain storage facilities were destroyed, and fertilizer plants have been shut down. Many farmers have joined the army and left their lands. Russia, which was one of the main exporters

of fertilizers, and, due to banking limitations, is not able to sell its products, which has affected farmers around the globe, in particular Kyrgyzstan and Tajikistan, which heavily rely on the agricultural sector.

Figure 3. Food commodity prices in selected international markets. January 2018 – January 2024

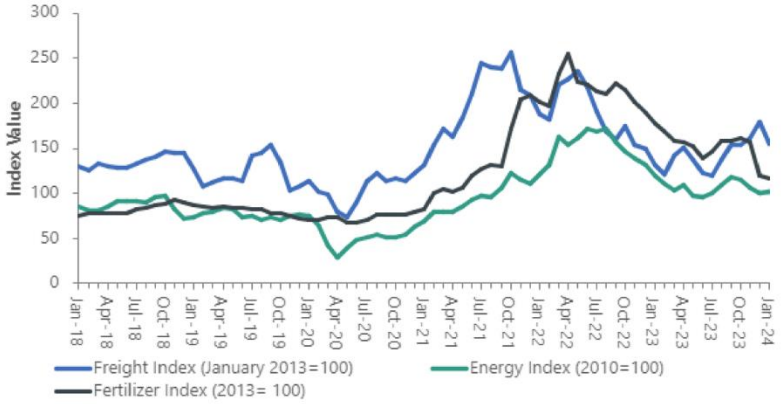


Source: Food and Agricultural Organization of the United Nations (FAO), World Bank

Note: The ICG Freight Index considers costs from significant grain exporting countries. Crude oil composes more than 80% of the World Bank energy index, while nitrogenous fertilizer contributes over 40% of the fertilizer index

Consequently, food prices have surged. Low-income countries such as Tajikistan and Kyrgyzstan, where 70% of income (IMF 2022b) is allocated to food expenses and grain is the staple food, increased food costs for wheat, sugar and cooking oil caused additional financial strain on the households. The surging food prices can be life-threatening for many families and households in the region. According to the Washington Post (2022a), because of the debt burden, Kyrgyzstan is not able simply to deal with the hunger crisis.

Figure 4. International Energy, Fertilizer, and Freight Cost Indices. January 2018 – January 2024



Source: International Grains Council and World Bank

For example, food prices have increased by almost 50% since 2019 in Kyrgyzstan. In Tajikistan, bread prices have increased by 25-30%, sugar, meat and eggs by 40-50%, and energy resources by 200%, while overall inflation reached 12% in Uzbekistan (Bekbassova 2023) and 20.3% in Kazakhstan (Benin et al. 2023).

High inflation was also exacerbated by the increasing energy-intensive goods and services, causing a worldwide energy crisis. According to the World Economic Forum between February and September 2022, the cost of coal rose by 176%, crude oil and petroleum by 51%, and natural gas by 94%, increasing household expenditure by between 2.7 and 4.7%.

The higher energy prices push vulnerable families in Central Asia into energy poverty, as energy dependence is an urgent issue in Kyrgyzstan and Tajikistan, where energy imports from Russia account for 60% and 30% of domestic utilization, respectively.

4. Conclusion

Central Asia is a strategically important region which must balance between its colonial past and geopolitical challenges in the present. Even more than three decades after the dissolution of the Soviet Union, Central Asia continues to maintain a high level of economic dependence on Russia.

Today, the Central Asian states must navigate a postcolonial landscape concentrated on sovereignty, resource control, and economic development. Decolonization efforts require a comprehensive analysis considering political, cultural, economic, and social factors. Diversification and regional cooperation can be among potential steps to assist the decolonization process in the region.

First, the recent disruption of supply chains, resulting from the ongoing war, highlights the region's high reliance on transit routes through Russia. Furthermore, Russia continues to be one the largest trade partners in the area. An overwhelming

90% of Central Asian individuals choose Russia as a destination for labor migration. Historically, Russia has served as a regional hub for knowledge transfer, technology access, and know-how. Russia's isolation will end this trend. Diversification of both trade routes and migration destinations are imperative. To ensure continuing access to the cutting-edge technologies and knowledge, Central Asian countries should forge stronger links with other regional hubs.

And second, regional cooperation serves as a key factor in bolstering the resilience of relatively small and undiversified economies of the region to crises and external shocks. So far, the Central Asian region remains one of the least integrated regions in the world with the region's connectivity indicator averaging below 60% in terms of access to the global GDP placing the region at the lowest end of the spectrum. As the Central Asian states possess complementary energy resources with the Kyrgyz Republic and Tajikistan owning hydropower potential, while Kazakhstan, Turkmenistan, and Uzbekistan have substantial renewable energy potential alongside flexible fossil fuels, regional benefits arise from interstate trade. Moreover, the region can strengthen relations with other regional players such as China and Turkey to avoid excessive economic and political dependence.

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Chapter III
Sustainability, Policy, and Social Responsibility

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International efforts to introduce a unified public sector accounting framework

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Public sector financial accounting is important in the areas of measuring, evaluating and providing data on the economics of public organizations operating with public money. Decades ago, there was a need to develop global public sector accounting standards, the primary goal of which is to improve the quality of annual reports prepared by public sector agents, making budgeting financial data of individual nations more comparable. At the same time, other motives also appear in the background of unification efforts, such as the need for transparent management, improved accountability, and the construction of an accounting information system which supports more well-founded management and control decisions. The International Public Sector Accounting Standards (IPSAS) contain the international framework of public sector financial accounting standards used by several governmental and public organizations worldwide. The "European equivalent" of the IPSAS framework is EPSAS (European Public Sector Accounting Standards), which is a system of accounting rules tailored to the budget sector of the member states. The purpose of our research is to outline a comprehensive status report on the current state of international public sector accounting standards. In this paper, the strengths and weaknesses of international budget accounting standards, both the opportunities and dangers inherent within them, are examined. The findings are based on the results of secondary research. It is concluded that a harmonized budget accounting framework is needed, the primary stage of which can be provided by the member states. During harmonization, national sovereignty may be violated, but simultaneously, a comparative, well-consolidated budget database can be obtained, which can even create a more accurate and fair community financing system.

Keywords: IPSAS, EPSAS, Public sector accounting

1. Introduction

The public sector financial accounting system is of particular importance for public sector organizations (central and local government budgetary institutions) which use public money, for accurate measurement and transparent recording of public spending, for public scrutiny of their management, for informing the various market agents, and for financiers and investors. The International Public Sector Accounting Standards (IPSAS) standards were initially developed and applied with the aim of creating uniform and transparent accounting practices at the micro level of the public sector. IPSAS were developed specifically to meet the financial reporting requirements of public sector organizations globally and the European Public Sector Accounting Standards (EPSAS) is currently being developed. For the macro-system, the reporting guidelines for GFS (Government Finance Statistics) are set out in the United Nations System of National Accounts (SNA) (United Nations at al. 2009) and the new ESA 2010 (European System of Accounts 2013) (Barton 2011).

On November 8, 2011, the Council of the European Union adopted Directive 85/2011/EU, which sets out the requirements for the budgetary framework of the

Member States. "The Directive states that budgetary data to ensure comparability between Member States plays an important role in the EU budget. The Directive considers it necessary to establish uniform accrual accounting standards and points out that the budgetary accounts primarily show only cash flows, which does not provide adequate information for the accrual-based ESA 2010 methodology" (Lukács et al. 2023, p. 118).

2. The link between accounting and statistical reporting systems in the public sector

On May 21, 2013, the European Union adopted Regulation (EU) No 549/2013 of the European Parliament and of the Council. ESA 2010 replaced ESA 95, which was in force before 2014. National Accounts are at the heart of economic statistics, providing an appropriate framework for summarizing and analyzing economic processes. ESA 2010 is in line with the guidelines of the SNA2008, the United Nations system of national accounts, which is accepted and used worldwide, thus ensuring the comparability of macro statistical indicators at a global level (Cîrstea 2014).

The introduction of ESA 2010 was necessitated by the changes in the economy over the last few decades and, importantly, by the fact that it is now consistent with the IMF Balance of Payments Statistics (BPM6). The link between the two reporting systems (GFS at macro level and IPSAS at micro level) is important for transparency and efficiency, as the public accounting systems are usually the main source of data for the compilation of GFS aggregates. Moreover, the compilation of aggregates in national accounts and accrual-based public finance statistics is based on cash-based fiscal reporting in most Member States.

The harmonization of government accounting systems would allow policy makers and other stakeholders to analyze the financial position and performance of governments and the long-term sustainability of public finances, as highlighted by the European Commission (EC) in March 2013 (EC 2013). The availability of a robust accrual accounting system is a key issue for the development of a high quality GFS.

Public sector accounting has two main objectives:

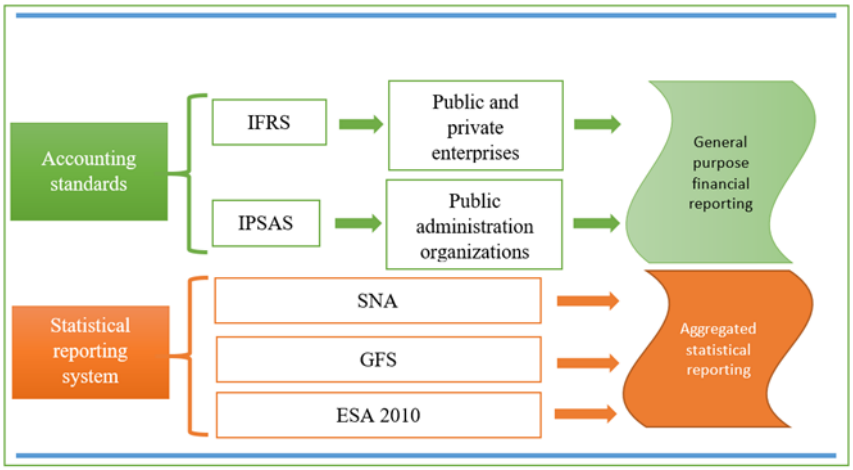
1. to fulfil the "traditional" accounting tasks of providing the data required for periodic reporting and the obligation to prepare annual accounts.
2. to measure budget implementation, to support the final accounts and to measure the budget deficit (or surplus).

Aligning the two sets of objectives is a daunting task. The second objective is not met in an accruals-only accounting approach, as the budget is prepared on a cash basis. The cash-based accounting approach does not provide a reliable, true and fair view of the assets, liabilities, financial position and revenue situation. The accounting objectives mentioned above can be met through an accounting information system supported by a modified accrual accounting approach.

This explains the importance of the interaction between micro-accounting rules, such as IPSAS or future EPSAS, and GFS-based macro-accounting information, as the two systems need to co-exist. This is why ESA 2010, which was adopted by

Regulation (EU) No 549/2013 of the European Parliament and of the Council of May 21, 2013 (EU, 2013), is important for the EU and was used for the first time to provide data to Eurostat from September 1, 2014. Figure 1 below illustrates the link between the accounting and statistical reporting systems in the general government sector.

Figure 1. The relationship between accounting and statistical reporting systems



Source: Dasí González et al. (2018)

Statistical reporting systems have been introduced by international bodies to collect information on countries in order to compare their performance on a standardized basis. The GFS, developed by the International Monetary Fund (IMF), deals exclusively with financial information on the general government sector, while the United Nations (UN) SNA and ESA 2010 coverage extends financial information on governments to include national accounts data.

The EU Government Finance Statistics (GFS) are based on the ESA 2010 methodological rules, which are based on the world-wide SNA 2008, supplemented by additional Eurostat decisions and guidance, with particular emphasis on the ESA 2010 Manual on Government Deficits and Debt. It is also important to note that EU Member States also prepare GFS for reporting to the IMF and the IMF GFS Manual is based on the SNA.

The International Public Sector Accounting Standards Board (IPSASB) developed a work program on the convergence of IPSASs with national accounting systems and a research report in 2005 systematically identified similarities and differences between the two reporting frameworks (IPSASB 2005). In 2011, the IPSASB approved a new project (IPSASB 2011) aimed at further reducing the differences between IPSASs and GFS reporting guidelines for the public sector (Ilie–Miose 2012)*(The Conceptual Framework for General Purpose Financial Reporting by Public Sector Entities* 2014).

More recently, the IPSASB's Conceptual Framework for General Purpose Financial Reporting (GPFRs) by Public Sector Entities (IPSASB, 2014) pointed out that the information provided by GPFRs can be useful for the compilation of national

accounts as input to the preparation of statistical financial reporting models, although the IPSASB acknowledges that GPFS were not developed specifically to meet the needs of national accounting systems. Nevertheless, as IPSASB (2012) emphasizes, there are significant benefits to be gained from using a single integrated financial information system for the preparation of IPSAS financial statements and GFS reports. This will reduce the time, cost and effort of preparing GFS reports, while at the same time improving the source data for the reports, with additional benefits in terms of report quality, including timeliness. It is also reasonable to expect an improvement in the comprehensibility and credibility of both types of reports.

It is important to note that IPSAS financial statements and GFS reports have many common features, in particular that both allow for reporting on financial, accrual-based information; government assets, liabilities, revenues and expenditures; and comprehensive information on cash flows.

But the fact is that there is still a considerable gap between the two reporting frameworks. The IPSASs and the GFS reporting guidelines still show substantial discrepancies, which are the result of uncoordinated development activities by the three organizations (EC 2013, IMF 2014, IPSASB 2012) (Jesus–Jorge 2016).

Figure 2. The main conceptual differences between the three public finance accounting systems

	GFS	**IPSAS**	**Budgeting (pure cash flow approach)**
Aims	Economic impact assessment Determination of net lending/borrowing	Evaluation of financial position and performance	Financial balance (cash)
Scope of those required to report	Institutional units and sectors	Business entities and consolidation	Public sector (the boundaries of the public sector differ in EU countries)
Presentation criteria	With accrual-based exceptions	In general, accrual-based	Cash based approach in most countries
Evaluation	Current market prices (in general)	Fair value, historical cost and more	The short-term financial flow of rights and obligations
Re-evaluation	It appears on a separate account	Yes	Not possible

Source: Dasí González et al. (2018)

European Government Finance Statistics (GFS) are produced according to ESA 2010 rules. They differ from the fiscal standards, which are specific to each member state in terms of the scope of entities and the principles used to record transactions. At the national level, the statistical authorities are responsible for ensuring that the reported data complies with the legal provisions. At the European level, Eurostat is responsible for providing the statistical methodology for compiling EDP statistics and for assessing the quality of the data reported by Member States for EDP purposes. In addition, in line with its proposal for a Council Directive on

requirements for budgetary frameworks of the Member States, the Commission will support the implementation of the general government accounting standards, which provide the information necessary to compile ESA-based data for all subsectors of general government. Eurostat intends to play an active role in the framework of IPSAS, which support accrual-based public accounting in line with ESA principles.

The ESA is the conceptual framework for national accounts for assessing and monitoring the implementation of fiscal discipline within the EU member states. The source of this data is micro-level budgetary accounting, and it is therefore necessary to clarify the relationship between the two systems and to achieve a certain consistency, at least in terms of principles. Furthermore, differences between the two accounting information systems may also call into question the reliability and comparability of aggregate financial decisions that sustain the EU (International Monetary Fund 2014).

The relevance of IPSAS standards manifests itself in a number of areas:

- Improving transparency and comparability: the introduction of IPSAS standards creates transparency in the financial practices of public sector entities. The standardization of standards allows for comparisons between different organizations, which improves transparency and comparability. This is important for monitoring the use of budgetary resources and for informing financial decisions.
- International acceptance: IPSAS standards contribute to the international market credibility of public sector institutions through their international acceptance. Uniform accounting practices and consistency with international standards increase the attractiveness of public institutions to foreign investors and creditors.
- Improving the quality of financial reporting: financial statements based on IPSAS standards are of higher quality than those based on outdated local standards which do not comply with international standards. This increases the reliability and relevance of the reports.
- Simplifying relations with funders: the use of IPSAS standards allows financial information to be more easily available and understandable to financiers, such as international organizations and creditors. This contributes to easier and more efficient access to finance.
- Communication with the public: IPSAS standards make financial information easier for the public to understand. This helps public sector organizations to explain and present their budgeting and financial results to citizens, therefore increasing trust and accountability.

3. The introduction of IPSAS in the European Union: The emergence of EPSASs

The implementation of IPSAS requires the existence of an accrual accounting system, i.e. cash accounting is not suitable for the application of international accounting standards. Member states have different views on the application of accounting

approaches, and even the accounting treatment of economic events sometimes differs between central and local government entities.

3.1. The relationship between IPSASs and the European Union

The introduction of IPSAS standards in the Member States of the European Union has been a slow process, as Member States have had and continue to have their own accounting systems (International Federation of Accountants 2005).

For the EU, the application of IPSAS can be assessed in the following aspects:

- Convergence between IPSAS and IFRS
  The European Union has a long history of using International Financial Reporting Standards (IFRS) for the private sector. The European Commission has supported the introduction of IPSAS for public entities, but convergence between the two systems has not been easy. Nevertheless, several EU Member States have introduced IPSAS elements in public accounting.
- Harmonization with EU Structural Funds
  Harmonization of the EU financial system with IPSAS standards was particularly important where EU Structural Funds were used. The EU wanted uniform accounting practices for all Member States to ensure that the funds were properly used and controlled.
- Differences between countries
  Differences between EU Member States have led to a number of difficulties in applying IPSAS. Each country has its own budgetary and accounting traditions and reconciling these with IPSAS standards was a complex process. Some EU Member States have still not implemented IPSAS standards as this would have meant major changes and costs in accounting systems.
- The EU's own standards
  The European Union also has its own budgetary and accounting rules, which are followed by the EU institutions. The links and alignment between the EU's own standards and IPSAS have also been a challenge during the implementation of IPSAS.

Next, the accounting systems applied in the EU countries for central and local government are examined. Table 1 shows a summary of the applied reporting methodology according to central and local government subsectors gathered from the reports of EU member states containing data related to the excessive deficit procedure.

Table 1. A summary of the applied reporting methodology of EU member states

Country	Central government			Local government		
	Accrual based	Cash based	Mixed	Accrual based	Cash based	Mixed
Austria		X				X
Belgium			X	X		
Bulgaria		X			X	
Cyprus		X				X
Czech Republic		X			X	
Croatia		X				X
Denmark			X			X
Estonia			X			X
Finland			X			X
France		X		X		
Germany			X			X
Greece		X			X	
Hungary		X			X	
Ireland		X		X		
Italy		X			X	
Latvia		X			X	
Lithuania		X			X	
Luxemburg			X			X
Malta		X		X		
Netherlands		X		X		
Poland		X			X	
Portugal		X				X
Romania		X			X	
Spain	X			X		
Sweden		X		X		
Slovakia		X			X	
Slovenia		X			X	
Total	**1**	**20**	**6**	**7**	**11**	**9**

Source: own construction based on EUROSTAT EDP Tables, October 2023.

As can be seen in Table 1, only Spain uses the accrual approach as the basis of accounting for the calculation of the balance of payments at central government level, while Belgium, Denmark, Estonia, Finland, Luxembourg and Germany use mixed bases, with the other countries reporting on a cash basis. For local government, seven countries use accrual basis, nine countries use mixed basis, and eleven countries use cash basis. It is also important to note that 11 countries use different accounting bases for their central and local governments.

Although accrual accounting is used in some countries, there is a tendency in some areas to use off-balance sheet transactions, which should also be taken into account when assessing the use of accrual accounting (Farshadfar et al. 2022).

3.2. The emergence of EPSASs

The basis for Community accounting rules is laid by Directive 85/2011/EU on "Requirements for budgetary frameworks of the Member States". There was no uniform accounting practice in the European Union, which is why it is necessary to collate the member states' public accounting systems in order to achieve harmonization. The Directive also aims to promote the comparability of member states' budgetary data, which is essential for the EU budget. The Directive also takes into account the fact that budgetary accounting traditionally records cash flows (cash flow approach), but this does not provide sufficient information on the budgetary management of a Member State. The ESA 95 system relies on accrual-based information and Eurostart; therefore it recommends that member states use accrual-based accounting standards in order to be consistent with ESA. This is also important because the data derived from the ESA system is essential for the functioning of the European Union's budgetary surveillance framework. ESA (European System of National and Regional Accounts) is the European system of national and regional accounts. It is a system of 17 macro-economic statistical indicators designed to provide data for economic analysis and decision-making. Currently, ESA 2010 is in force within the EU, which was adopted in 2013 and has been in use since 2014 (when the Directive was drafted, it was ESA 95). In Hungary, the new Public Accounts Regulation (Government Decree 4/2013 on Public Accounts) was also adopted in line with the requirements of the Directive (Directive 85/2011/EU on the requirements for the budgetary framework of the Member States; Hungarian Central Statistical Office, 2014).

In the presentation of Directive 85/2011/EU and the IPSAS standards, it has already been stated that there is a need for a uniform public sector accounting regulation within the EU in order to ensure financial stability and more transparent public management. It was decided to create the European Public Sector Accounting Standards (EPSAS), which provide a good basis for the development of a single public sector accounting standard, but without amendment cannot be applied adequately to the regulation of budgetary accounting, given that these standards are designed for enterprises. The report states that the IPSAS standards are not the most suitable for implementation in their current state and that it is therefore necessary to base EPSAS standards on these standards, which are therefore based on IPSAS and take into account the specificities of the budgetary sector.

Two working groups have been organized by Eurostart to prepare the development of EPSAS. By developing a completely new set of standards, the EU can adapt them to the specific needs of the Member States, so that standards that are applicable in practice can be developed. The EPSASs will be prepared in the light of the accrual approach and will therefore bring a major change to the public accounting systems of the member states, but the Commission would provide all the help it could to integrate this approach into the accounting system (Lorson et al. 2023, Harsányi et al. 2016, Sforza–Cimini 2017). Four major factors which influence the design of EPSAS are accrual accounting, harmonized financial statements, compliance with ESA 95 methodology and governance. Accrual accounting has been largely absent from the public sector accounting system and is not obligatory, so these standards

would provide a binding basis for the introduction of accrual accounting in the budgetary accounting systems of the Member States. Uniform rules are needed to ensure that the financial reporting of individual national governments is consistent and comparable at international level, this will ensure harmonized financial statements.

The working group responsible for the creation of EPSAS held its first meeting in September 2015 and has since hosted 13 meetings up to October 2022. In October 2022, the debate on the implementation of EPSAS was still ongoing: whether the use of the standards should be voluntary, partially or fully obligatory for member states. The EPSAS project is still facing difficulties, the most significant of which are the following: the issue of the costs of implementing EPSAS; the problem of similarity between EPSAS and IPSAS; and the question of how far and at what level EU member states would tolerate obligatory accounting standards and the applicable legal approach to EPSAS (Lorson et al. 2023). The implementation of EPSAS was initially set for 2020, with 2025 being the target now. The process of introducing EPSASs and how to implement them is still under discussion.

3.3. Expected trends in IPSAS standards

Currently, 25% of 150 countries use accrual accounting, and about half of these use IPSAS directly or by reference. Within five years, about 65% of these countries will apply accrual accounting, and of these about 75% will apply IPSAS in the manner described above. IPSAS implementation projects are currently underway worldwide, involving countries across all continents. The main focal points are Latin America and the Caribbean, the Middle East and Africa, but also South East Asia and China. In Europe, the European Commission is working with the Member States on the European Public Sector Accounting Standards (EPSAS), which also use IPSAS as a reference point (Dieterle 2022).

The IPSAS standards are expected to become global. More and more countries and public sector organizations are realizing the importance of transparency and international acceptance. More public sector organizations will adopt IPSAS standards over the coming years. The IPSAS standards will continue to evolve to meet changing circumstances and requirements. Governmental and public sector entities need to be prepared for the application of the new standards and for possible changes in the preparation of financial statements. Technology and automation are playing an increasing role in financial accounting. In applying IPSAS standards, public sector organizations need to adapt to new technological trends such as artificial intelligence and blockchain technology. Further progress in harmonization between IFRS and IPSAS is expected. In parallel with IPSAS, there is a growing demand for sustainability reporting. In the future, public sector organizations will be required to include sustainability and ESG (Environmental Social Governance) aspects in their reporting.

The motivations for adopting a single accounting system are either external (donors' or investors' motivation to increase transparency) or internal (adoption of IPSAS as part of a holistic governance reform or as a means of increasing credibility and confidence in the financial capacity of a government or organization). Among

international organizations, the United Nations (UN), the North Atlantic Treaty Organization (NATO), the Organization for Economic Co-operation and Development (OECD) and the International Federation of Accountants (IFAC) are important preparers of general purpose financial statements, as well as are major European agencies such as the European Organization for Nuclear Research (CERN), the European Space Agency (ESA) and the European Aviation Safety Agency (EASA), which have already successfully implemented IPSAS or IPSAS-like standards. These IPSAS-based financial statements have already undergone independent external audits in recent years (Dieterle 2022, Tóth 2020).

3.4. The relationship between international and Community budgetary accounting and Hungary

The application of IPSAS standards in the public sector in Hungary started in the 2000s. The transition to the new accounting system in the public sector has been a long and slow-moving process (Vértesy 2020).

Next, some important points on the application of IPSAS are presented, with the focus on Hungary:

Transition process: the Hungarian public sector has gone through a long transition process to adopt an IPSAS-compliant accounting system. This involved adopting new legislation and training accounting professionals. Public budgetary institutions such as Ministries and other central institutions, as well as local governments, have been involved in the implementation. In Hungary, a modified accrual accounting system has been in place since January 1, 2014, both at the central and local budget level. Annual (and periodic) budgets, however, continue to be prepared on a cash basis, as (cash) revenue and expenditure appropriations are included. The accounting information system in Hungary is extremely complex, as economic events are recorded in two subsystems: the cash-based budgetary accounting subsystem and/or the accrual-based financial accounting subsystem. The budgetary accounting subsystem provides the information needed for the budget. In Hungary, a move to accrual accounting would be possible if the annual accounts included only statements presenting information (assets, results, and performance) generated on this accrual basis. As long as the annual budget – as the financial basis for public finance management – plans and accounts for cash receipts and cash payments, cash accounting (budgetary accounting subsystem) is indispensable.

Training and education: the application of IPSAS requires the re-education and training of the professionals concerned. One of the major obstacles to the introduction of IPSAS in Hungary may be the lack of relevant professionals and the low willingness and lack of motivation of current professionals and employees to undergo further training. Various educational programs and training courses help accountants and financial professionals to understand and apply IPSAS. Its development in Hungary is still incomplete. Hungary has accounting professionals with IFRS knowledge, however, they are mainly skilled in applying IFRS tailored to private entities. The development and implementation of a national education network (trainers, curricula, methodology, and educational infrastructure) is recommended in order to adapt international budget accounting standards to the domestic context.

Upgrading accounting systems: to implement IPSAS, accounting systems must also be upgraded. Public institutions have also had to introduce new accounting software to comply with IPSAS standards. In Hungary, there is currently no uniform (applicable) accounting system in use. It would be therefore advisable to standardize it in terms of comparability, reliability and transparency of the data which can be extracted from the accounting information system.

Reporting and auditing: the content and format of financial statements will also have to change with the adoption of IPSAS. Financial statements must be prepared in accordance with the new standards. At present, the auditing of annual accounts is not obligatory in Hungary, however, the extension of the application of international accounting standards would, in our view, once again justify the reintroduction of the obligation to audit accounts, irrespective of the size of the organization (Tóth 2024).

4. Conclusions

The European Commission is giving priority to the implementation of EPSAS in EU member states. The processes for applying EPSAS are as follows:

Following EU guidelines: as a member of the European Union, Hungary is obliged to follow EU guidelines.

Increasing the efficiency of EU funding: the use of EPSAS can help to manage EU funding more efficiently by requiring uniform accounting procedures and reporting. This will increase transparency and facilitate the monitoring of EU funds.

International market credibility: the application of EPSAS can contribute to the international market credibility of the Hungarian public sector. A uniform accounting practice increases the attractiveness of the country for foreign investors and creditors.

Sustainability and transparency: the application of EPSAS allows for the integration of sustainability aspects into financial reporting, which is becoming increasingly important for public sector organizations. Increasing transparency through the use of EPSAS can help to strengthen public confidence.

The introduction and application of IPSAS standards is key to the transparency of financial practices of public and public sector entities, international acceptance and the improved quality of financial information. Its implementation in the EU Member States has been a slow process, but the benefits are clear. Further expansion and development of IPSAS standards is expected in the future, as public and public sector organizations increasingly adapt to changing circumstances and technological trends. Further harmonization of IPSAS with IFRS and the growing demand for sustainability reporting will also play a key role in the future.

The application of IPSAS and EPSAS in Hungary is a complex process that requires the cooperation of public sector institutions, government and financial professionals. The application of IPSAS has already begun in Hungary, but the introduction of EPSAS offers the opportunity for further development and to increase international market credibility. Harmonization with EU guidelines and uniform accounting practices can allow for further progress in the public sector. The

introduction of EPSAS also offers important opportunities for sustainability and transparency in Hungary.

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CSR as a Marketing Tool and Influence on Consumer Behaviour in the Food Market

Kristína Igarová – Zdenka Kádeková – Ingrida Košičiarová

The submitted paper focuses on the application of CSR as a marketing tool in the practice of food companies in Slovakia. Currently, the concept of corporate social responsibility is very widespread. Making profit is no longer the only goal, companies are gradually starting to feel a certain obligation to be involved in the society in which they operate. Even the company on the Slovak food market is increasingly interested in building a good name and brand awareness through CSR activities. To achieve the given goal and obtain the required data, it was based on a questionnaire survey with a total of 946 respondents. To achieve this goal, two research questions and hypotheses were set, which we evaluated using various statistical methods. After evaluating the data obtained from the conducted questionnaire survey, it was found that the respondents do not prefer buying food from a socially responsible food companies based on advertising and that only the youngest generation Z is willing to invest more in socially responsible food products based on advertising. The survey focuses on CSR as an element of marketing communication and its influence on the formation of consumer preferences. At the threshold of the 3rd millennium, CSR is also associated with rationality and irrationality in the creation of preferences in the purchasing behavior of consumers.

Keywords: Corporate Social Responsibility, Consumer behavior, Food Companies, Marketing Communication

1. Introduction

Currently, the topic in the field of corporate social responsibility (CSR) is very popular and topical. In recent years, it has become necessary for companies to behave in a socially responsible manner.

Food companies on the Slovak food market are increasingly interested in building a good name and brand awareness through socially responsible activities. The public very sensitively follows the CSR activities and their promotion of each company on the market.

CSR that affects not only companies but also consumers and customers for whom these activities are communicated and used as a marketing tool. Responsible business is synonymous with trustworthiness, which leads to customer loyalty and ultimately influences consumer behaviour.

In this study, we focus on CSR as a marketing tool in the food market and the impact of these activities on consumer behaviour.

The study is divided into theoretical and research part. At the theoretical level, the study deals with the definition of social responsibility, its pillars, and the aspect of CSR. We also pay attention to CSR in the food market. The research part consists of established hypotheses and the evaluation of a questionnaire survey, focused on the impact of CSR on consumer behaviour on the food market in Slovakia.

2. Concept of Corporate Social Responsibility

Corporate social responsibility (CSR) is a rapidly developing topic in recent years. Nowadays, corporate social responsibility has been followed by an even more demanding concept of sustainable development. Based on this concept, the fulfilment of social, economic and environmental goals was required over time as a holistic result of the functioning and development of food enterprises (Vevere–Svirina 2020).

Corporate social responsibility is a key issue for any organization aiming for long-term sustainability. Sometimes it is mostly a voluntary concept, which once again increases the pressure on organizations to make a positive contribution to society and reduce their negative impact on various aspects. On an international scale, governments are moving towards enforcing certain elements of corporate social responsibility, especially when it comes to environmental protection (Fáilte Ireland 2023).

The concept of CSR has evolved as a result of a change in the business perspective, which results from a limited model, mainly oriented towards profit maximization, which is largely concerned with the quality of life, the preservation of resources and the fulfilment of the general interests of society. In other words, a view included in the principles of sustainable development (Popa–Salanta 2014).

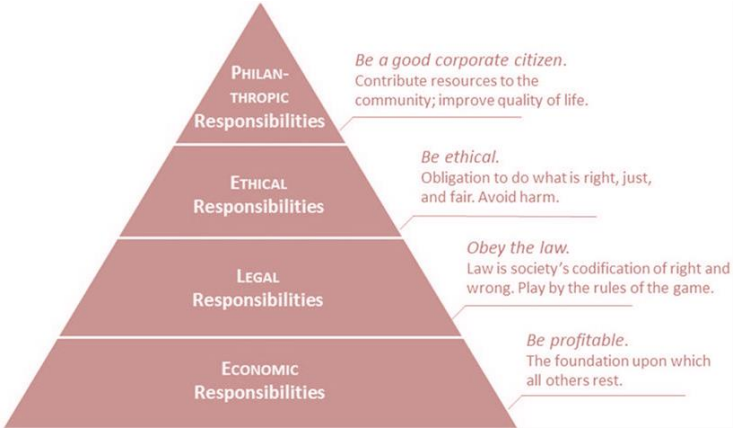
Corporate social responsibility describes how a company manages its industry and takes responsibility for its social impact. CSR includes various characteristics such as economic dependence, legal conformity, ethical requirements and social impacts (Wong 2021).

The origins of social responsibility can be traced back to ancient Roman laws. This idea and companies were preserved in English laws and later spread into the seventeenth and eighteenth centuries. During this period, author Adam Smith's (1981) states that society's needs and wants can best be satisfied through the free interaction of individuals and organizations in the marketplace. At the same time, the role of honesty on the part of all parties involved is recognized.

2.1. 3P of CSR

Despite the increasingly frequent use of the phrase "corporate social responsibility" not all users perceive this term in the same way. Carroll's pyramid (Fig. 1) is one of the most frequently cited and preferred CSR models; it includes four roles: economic (offering products and services), legal (compliance), ethical (adherence to codes of conduct and ethical standards), and philanthropic (donation and volunteering) (Carroll 2016). In addition, Dahlsrud modeled a four-dimensional CSR framework. For the temporal and spatial flexibility of CSR, additional dimensions can be added. The global environment currently provides retail with many opportunities to actively participate in various corporate social responsibility efforts (Dahlsrud 2008).

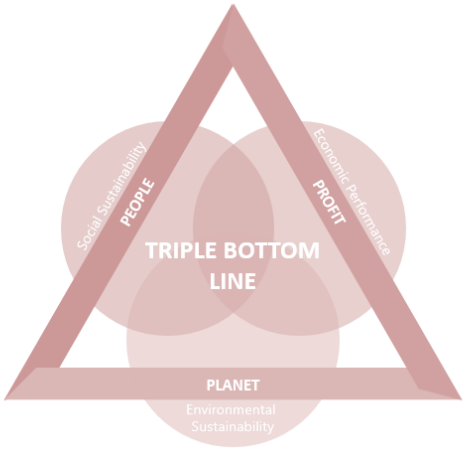
Figure 1. Carroll's pyramid



Source: own construction

Most CSR theories admit that the basis of the idea is the concept of Triple Bottom Line (TBL) (Žak 2015). This theory is also known as the 3Ps or three pillars of CSR. It states that the company should be responsible for three functions: Profit, People and Planet, i.e. economic, social and environmental responsibility. Only if a company takes care of all three aspects of the Triple Bottom Line (Fig. 2) can it be called sustainable, because they are all extremely closely related (Księżak–Fischback 2017).

Figure 2. Triple bottom line



Source: own construction

Caring for a business for profit and for people makes a business fair, but failing to protect the environment will destroy the planet. On the other hand, if a company only cares about the planet and people, and forgets about profit, the CSR policy is tolerable, but the company does not achieve the necessary profits for prosperity. Again, if a company pays attention to profit and the planet, it shows less concern for people, the company is

viable and profitable, but in the long run it can lead to a decline in the morale of its employees and a violation of the social contract (Khan 2012).

In the context of CSR, investors and other interested parties have also been interested in ESG in recent years, and it is even referred to as the trend of the decade (Woldfavor 2022). ESG (abbreviation from the combination of the words "Environmental, Social, Governance) can be defined as the evaluation of sustainability using various environmental, social and management metrics used to evaluate the extent to which a company is sustainable and resilient in order to be responsible for its sustainability claims (Księżak–Fischback 2017).

Many understand ESG as CSR elevated to a measurable strategy – it brings transparency and responsibility for the environmental and social impacts of a company. In its concept, CSR takes into account all stakeholders in society, while ESG focuses directly on ESG investors. ESG disclosures are linked to the competitive advantage of food companies, as the company provides sustainable solutions to environmental and social problems. In addition, by engaging in ESG activities, food companies can redefine their product offering in line with society's needs for better environmental protection and quality of life. The concept of ESG means that companies must not only report financial indicators and data, but also non-financial ones. By means of non-financial indicators, the company shows the resilience of business in terms of 3 pillars – impacts on the environment, social sphere and corporate governance (Jungbauerová 2022).

2.2. CSR on Food Market

Corporate social responsibility has become a central theme in the food industry. The food industry faces a growing demand for sustainability (Westerholz–Hohler 2021). Consumer interest in corporate social responsibility (CSR) activities has increased significantly in recent years. Consumers are increasingly aware of companies ecologically, economically and socially responsible practices (Vitell 2015) and are interested in their short- to medium-term and even long-term effects.

Companies have implemented CSR measures to help the environment and be competitive in the market (Suganthi 2019); the importance gained by these practices means that most companies develop CSR strategies that are more complete and comprehensive (Kádeková et al. 2022).

In recent years, CSR has become strategically important for targeting consumers as food businesses launch their own private labels. The food business is not only the most vibrant sector, but it is also complicated and rapidly evolving, with enormous opportunities created by consumer intent. When implementing CSR strategies, businesses need to understand how consumers perceive and respond to CSR measures and activities (Kádeková et al. 2020).

There are other reasons for implementing CSR practices in the food industry (Porter–Kramer 2006). Overall, a CSR strategy has significant potential to create a sustainable competitive advantage and help expand into other countries with different cultures. From the consumer's point of view, the implementation of CSR in company strategies also has many advantages. CSR activities improve the image of both the company and the brand, which can satisfy the external audience and subsequently increase the value of stocks (Igarová et al. 2023).

Food businesses invest heavily in their marketing in the area of social responsibility (CSR) (Swaen et al. 2021). The adoption of CSR as a topic in marketing communication is of course not a completely new phenomenon. Firms have adopted various communication platforms, such as communication of CSR activities, to emphasize related topics in their communication strategy (Sahadev et al. 2022).

In the agri-food sector, food companies strive to be responsible for:

- negative impacts on the environment and depletion of natural resources and biodiversity,
- implementation of safety standards affecting people's health and life,
- application of unfair business practices due to significant bargaining power in the supply chain (Michaud 2013).

The solution to the negative image of food brands can be the correct use of responsible marketing practices based on the appropriate presentation of CSR through marketing tools. This has led many companies to develop comprehensive CSR marketing strategies and invest heavily in responsible marketing (Suganthi 2019).

The communication of CSR activities that food companies carry out is crucial for the perception of CSR by consumers. The communication of CSR activities increases the transparency of the company and promotes dialogue between companies and stakeholders, which helps to legitimize the behavior of companies, strengthening their corporate image, reputation and improving the results of relations with consumers, such as attitudes and pro-company behavioral intentions linked to consumer behaviour (Kim 2017).

3. Results

The aim of the contribution was to focus on the issue of CSR as a marketing tool on the food market by consumers in Slovakia. The aim of the research was to find out to what extent consumers and their consumer behaviour are influenced by the social responsibility of companies in the food market and whether they perceive these activities as a marketing tool.

In order to find out and collect the necessary information and data, we conducted a questionnaire survey using Google Forms. The questionnaire was distributed online (via social networks and email communication) and was delivered to different age categories. To ensure the representativeness of the sample, we shared the questionnaire with associations of different age categories. The age categories were divided into generations X, Y and Z. A total of 946 respondents from Slovakia took part in the research, of which 501 were men and 445 were women.

The survey consisted of 57 questions divided into 4 sections. In the sections, we investigated the general profile of the respondent, such as the respondents' general awareness of corporate social responsibility. The respondents answered the question whether the respondents know specific food companies based in Slovakia that are dedicated to and apply CSR and whether these activities influence consumer behavior and, if so, which specific age groups. Furthermore, we asked the respondents how

they perceive the CSR activities of the individual pillars and whether they perceive them as a marketing tool, and at the end of the survey we focused on questions regarding the impact of marketing communication on the consumer behavior of the respondents.

In the first hypothesis, we assume that there are differences between generations and whether they prefer to buy food from socially responsible companies that they know from advertising. Respondents were asked the question "Do you prefer to buy foods that you know from advertising?". Respondents had a choice of three options:

- *Yes, I prefer*
- *I don't know*
- *No, I don't prefer*

Out of the total number of 946 respondents, 319, which represents 33.7%, prefer to buy well-known foods from advertisements. 309 respondents (32.6%) do not prefer to buy food that they know from advertising. If there was no statistically significant difference between generations, there should be a similar distribution of responses for each age group. A detailed analysis of responses within each age category is shown in Figure 3.

Generation Z represents the largest group of respondents aged 18-27, consisting of a total of 336 respondents. Of these, 106 (31.5%) prefer buying food from advertisements and 122 (36.3%) do not. The percentage of people who prefer not to buy food based on advertising is highest in Gen Z.

In the least numerous generation Y, which consists of 292 respondents, the option I don't know prevails, which was chosen by 111 respondents (38%). 91 respondents (31.2%) prefer well-known products based on advertising, and on the contrary, advertising has no effect on product preference among 90 people (30.8%).

Generation X 43-57 consists of a total of 318 respondents. A total of 122 of them (38.4%) prefer to buy foods that they know from advertisements, 99 (31.1%) don't know and 97 (30.5%) do not prefer such foods. The proportion of people who prefer to buy food based on advertising is the highest in this generation.

Figure 3. Preferences of respondents when purchasing food from advertising

Source: own construction

For statistical evaluation of the hypothesis, we used Pearson's Chi-square test of independence. The P value of the Pearson Chi-square test of independence is 0.104. We do not reject the null hypothesis of independence. There are no differences between generations and whether they prefer to buy food from socially responsible businesses that they know from advertising.

In the second hypothesis, we assume that generation X is willing to invest more in foods they know from advertising than generation Z. Based on the obtained results, we can say that a total of 175 respondents in both generations would invest in buying food of a socially responsible product based on the advertisement they saw (Fig.4).

A total of 49% of respondents from Generation Z would invest in such foods. As for Generation X, the percentage of respondents who would pay extra or invest in such foods is 44%. When comparing generations X and Z, there is a percentage difference of about 4%.

Figure 4. Willingness to pay for food from advertising

Source: own construction

The P value of the Chi-square test using the Yates correction is 0.477. We reject the null hypothesis. Generation Z is willing to invest more in socially responsible food products that they have seen in advertising than Generation X.

4. Conclusion

The topic of social responsibility of food companies in all three pillars has recently been a very extensive topic, both in the food market and for consumers. Nowadays, consumers are highly informed and have many competitive options in terms of product choices. At the threshold of the 3rd millennium, the field of CSR is also connected with rationality and irrationality by creating purchasing preferences among consumers.

In CSR activities, food businesses support human, financial and material resources for the benefit of the public. These activities are designed by companies in order to improve their reputation, gain awareness and increase the value of their brand.

The aim of the submitted paper was to focus on social responsibility activities in the practice of food businesses in Slovakia and their impact on consumer behavior. In the research, we focused on three age generations and specifically on generation X, Y and Z. However, we were most interested in the differences between generations X and Z. We assumed that their consumer behavior would also be influenced by factors such as their age. After evaluating the data obtained from the conducted questionnaire survey, in which a total of 946 respondents took part, the results showed that the preferences of the respondents when buying food that they know from advertising are very small. In the second hypothesis, we assumed that there would also be differences between age generations and whether respondents are willing to invest in food from a socially responsible company that they know only from advertising. The results showed that generation Z is willing to invest more in socially responsible food products that they have seen in advertising than Generation X.

The presented contribution supports the intentions of many researchers on the use and influence of social responsibility as a marketing tool of companies. Based on the analysis, we can say that CSR represents an important role in building the good name of companies and consumer loyalty. It is important for food companies to harness the power of the CSR concept and use credible advertising of their activities.

Acknowledgments

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Overview of the institutional background of Carbon Capture, Utilization and Storage (CCU/S) Technologies in the European Union

Krisztina Kádár – Zsófia Kószó

Nowadays, global climate change is an outstandingly important issue. In order to minimize its negative consequences, carbon dioxide (CO_2) emissions and their atmospheric concentration must be reduced. Despite the ambient CO_2 concentration being unprecedently high, it is a challenge to reduce it because the emissions are very diverse and there is no one-size-fits-all solution for them. The multifaceted problem thus requires multifaceted solutions, such as Carbon Capture, Utilization and Storage (CCU/S) technologies besides the other decarbonization tools. However, due to being an emerging technology, the appropriate regulatory and political background is still in its infancy, but these technologies are gaining more and more attention. The purpose of this review is to discuss the current institutional background of CCU/S technologies in the European Union (EU). By examining the critical points for CCU/S technologies to be deployed widespread, it can be seen that the EU considers these solutions to be of strategic value due to their future importance and relevance in climate change mitigation.

Keywords: carbon dioxide, carbon capture, carbon utilization, carbon storage, CCUS technologies in the EU

1. Introduction

For the sake of our future, global climate change has been getting increasing attention in the past decades and in our present as well. Although, without greenhouse gases and their effect, life could not exist on Earth, anthropogenic greenhouse gas emissions, including carbon dioxide, have upset the balance of nature (Alsarhan et al. 2021).

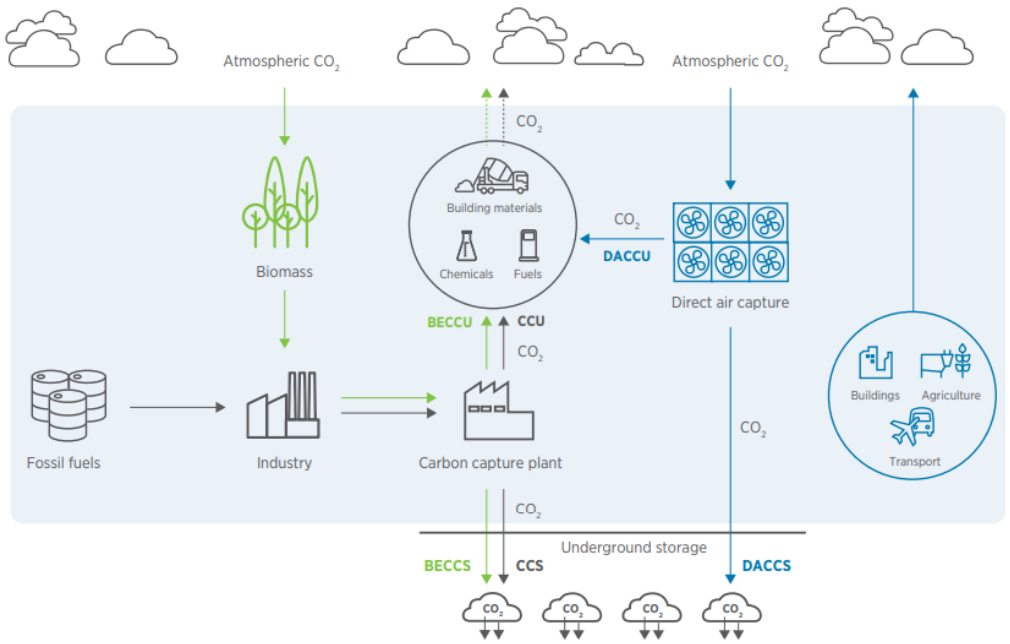
The reduction and management of the unprecedently high level of CO_2 concentration (~420 parts per million) (NOAA 2023) and emissions are essential, and it is more expedient to consider CO_2 as a resource and not as waste (Anwar et al. 2020, Dibenedetto et al. 2014). To mitigate climate change and to achieve the set climate goals, it is necessary to switch from the conventional fossil-based economy to more predictable, cheap and low-carbon, even zero carbon energy systems. The EU manages this issue with high importance and addresses it in its policy. As there is no one-size-fits-all solution to do so, a wide range of different technologies are needed (Cuéllar-Franca–Azapagic 2015, Rezaei et al. 2023).

CCU/S technologies can mean such solution in mitigating climate change. CCU/S refers to technologies in the field of Carbon Capture and Utilization (CCU), and Carbon Capture and Storage (CCS). There is a wide variety of carbon capture and separation solutions (MAN Energy Solutions 2022, Maniarasu et al. 2023, Kenarsari et al. 2013) that aim to capture CO_2 directly from the ambient air (direct air capture, DAC) (Bouaboula et al. 2024, Sun et al. 2023) or the flue gas of emission points

(Astuti et al. 2024, Cuéllar-Franca–Azapagic 2015). Cabon capture and storage technologies include the separation of CO_2 produced by large-scale industrial and energy sector plants, and also the transport and the long-term storage of CO_2 (CCUS Set-Plan 2022). Carbon capture and utilization, or CCU, is the process by which captured CO_2 is used in industrial processes or to produce products and raw materials as they consider carbon dioxide as a resource and not as waste (Baena-Moreno et al. 2019). CCU technologies are used in the production of everyday CO_2-based products such as building materials, synthetic fuels, chemicals, plastics (Butnar et al. 2020). CCU thus replaces carbon-intensive products already on the market, reducing dependence on fossil resources and promoting the transition to the Circular Carbon Economy (CCE).

CCE, which is based on the circular economy model, would achieve sustainable economic growth with the help of carbon dioxide (Figure 1), and can also play a fundamental role in achieving climate stabilization (Alsarhan et al. 2021). With its 4R (Reduce, Reuse, Recycle, Remove) model, in addition to reduction, reuse and recycling, it pays attention to a fourth component, the removal of CO_2 as well (Kokal 2020).

Figure 1. The Circular Carbon Economy



Source: Lyons et al. (2021)
Note: /BECCS=Bioenergy with Carbon Capture and Storage; BECCU= Bioenergy with Carbon Capture and Utilization; DACCS=Direct Air Capture with Carbon Storage; DACCU= Direct Air Capture with Carbon Utilization/

CCU/S technologies may serve as the only solution to reduce emissions in key sectors where other alternatives, such as electrification, are extremely expensive

or impractical (IEA 2020b). According to the International Energy Agency (IEA), CCU/S technologies can contribute to the aggregated CO_2 emission reductions in the energy sector by 15% by 2070, and they play a key role in the following four ways: (1) they can manage emissions from existing power generation/industrial plants by retrofitting them with the technology applications; (2) they are able to support the low-carbon blue hydrogen production; (3) they can serve as a solution for hard-to-decarbonize industries (i.e. steel, cement, fertilizer production) and also for aviation and maritime transport (i.e. with the productions of synthetic fuels); and (4) by the removal of CO_2 from the atmosphere they can help to achieve the circular (carbon) economy.

The purpose of the present paper is to overview the institutional background of carbon capture and storage, and carbon capture and utilization technologies in the European Union. During this overview, starting from the basics, the most important areas will be discussed, which helps to better understand the topic. In our work, we aim to discuss the most defining points in the field of CCU/S in order for their deployment to map the present situation of CCU/S technologies and their relevance in the future. In this study, some frameworks and reports are overviewed that can influence the spread of the use of carbon capture, utilization and storage (CCU/S) technologies, and the role attributed to CCU/S in the decarbonization scenarios is also examined. In addition, we take a look at completed and operational pilot projects in the field of CCS and CCU separately, but also those that cover the entire value chain, including transportation, as well as provide insight into future infrastructure development plans that enable the transport and storage of CO_2. We also list the main organizations and networks that, among other things, help spread the application of CCU/S technologies. Last but not least, we present some support options that provide financial assistance for the implementation of CCU/S projects.

2. CCU/S-relevant background in the EU

In connection with the mitigation of climate change, many frameworks and reports have been prepared at the international level. The contents of these define basic directions and goals for both the near and the distant future. The documents below are all directly or indirectly related to the solutions provided by CCU/S technologies, with the help of which the set targets can be reached.

2.1. European Green Deal

The European Green Deal is a set of policy measures made public in December 2019 and designed to make the EU's economy sustainable: to reduce the net GHG emissions by 55% by 2030 based on the year 1990, and to achieve climate neutrality by 2050 being the first climate neutral continent in the world (European Commission, 2019). Its aim is to turn environmental challenges into opportunities in all policy areas, to ensure that the green transition is fair and that all economic actors are involved and not left behind.

The political activity generated by the European Green Deal and the legally binding targets related to achieving carbon neutrality by 2050 have raised the interest

of both political decision-makers and industrial stakeholders in carbon capture and storage, and carbon capture and utilization (Popielak et al., 2024). CCS and CCU can significantly support the achievement of EU objectives, providing a path for sectors that heavily rely on energy-intensive industries, and help preserve jobs in core sectors of the EU economy (IEA, 2020a). In the meantime, the creation of additional sectors along the CCU/S value chain can be realized, which can contribute to the preservation of industrial competitiveness. The EU is also working with global partners to facilitate the development of an international carbon market, a key tool for creating economic incentives for climate action.

2.2. Intergovernmental Panel on Climate Change: Sixth Assessment Report

The Intergovernmental Panel on Climate Change (IPCC) evaluates the latest climate change related scientific findings and recommends solutions to address the arising issues (IPCC 2024). They provide regular assessments, and their objective is to promote governments by providing them information on a scientific basis, so they can receive help in developing climate policies. With these reports, the organization wants to draw the attention of the world's decision-makers to the extent of global changes caused by society.

Three Working Groups are operating under the IPCC. In 2022, Working Group III., which deals with the mitigation of climate change, reported in the Sixth Assessment Report (IPCC AR6 WG3) (IPCC, 2022). According to their report, the Nationally Determined Contributions (NDCs) of the countries signing the Paris Agreement do not contribute sufficiently to the achievement of the goals set in the Agreement, as being inadequate, too broad and insufficient. In order to achieve the goal of limiting global warming to 1.5°C, it is necessary to reduce emissions in all sectors, including and highlighting the energy sector and the industry, where significant transformation is needed. Some of the existing measures taken in many countries are proving to be very effective. However, IPCC proposes to expand and apply them fairly on a wider scale. These measures and steps taken by the countries are the building blocks of achieving significant emission reduction.Renewable Energy Directive: Revisions.

2.3. Renewable Energy Directive: Revisions

Since the introduction of the Renewable Energy Directive (RED) (2009/28/EC) in 2009, renewable energy sources have become more and more widespread: in 2023, the share of renewable energies in the energy consumption of the EU has increased to 24.5% (European Commission n.d.b). It set the EU target: 20% renewables by 2020 and national binding targets.

The directive's ambitions and measures have been revised a few times. A revision was made and entered into force in 2018 (2018/2001/EU) (European Commission n.d.b). The RED II set a comprehensive European target for the share of renewable energy: 32% by 2030, and rules had also been formed to remove potential barriers, encourage investment and reduce the costs of technologies. In addition, the realization of the broad involvement of the actors gained attention,

citizens and businesses were provided with the opportunity to participate in the transition to clean energy.

In 2021, the European Commission proposed another revision (COM/2021/557 final) to accelerate the deployment of using renewable energy sources in the EU (European Commission, n.d.b). The RED III (EU/2023/2413) entered into force in November 2023 and has set a new overall renewable energy target: at least 42.5% by 2030 with an additional 2.5% top up aiming for 45%. The new directive speeds up the licensing procedures for new renewable energy power plants (i.e. solar panels, wind turbines) (Európai Parlament 2024).".

In regards of the CCU/S relevance, there are some significant numbers that could affect the possibilities for CCU/S technologies. In the transportation sector, member states can chose either to reduce the greenhouse gas emission intensity in the transportation by 14.5% until 2030 from the use of renewables, or to realize a share of renewable energies to be at least 29% by 2030 in the final energy consumption (Council of the European Union 2023). In addition, advanced biofuels and renewable fuels of non-biological origin (RFNBOs) sub-target is set of 5.5% in the share of renewable energies in the transport sector; within which target, the RFNBOs in this share are required to reach 1%. Moreover, in the industrial sector, there are set targets: by 2030 42% of the hydrogen used should come from RFNBOs, and by 2035 60% should. Besides these, in order to boost the fuel transition in maritime transport, the share of RFNBOs in the total amount of energy supplied to the maritime transport sector is required to be at least 1.2 % from 2030 (European Parliament–Council of the European Union 2023).

These specific expectations also promote the creation of a market for CCU products within the industry (mainly in the petrochemical and refining sector), as it is required for the transport industrial actors to fulfil the targets, i.e. to purchase CCU products (Farkas-Csamangó et al. 2023, Thielges et al. 2022).

2.4. EU Emissions Trading System: Revision

The EU Emissions Trading System (ETS), set up in 2005, is the world's first and largest carbon dioxide market, i.e. international emissions trading system, covering approximately 45% of the EU's greenhouse gas emissions (European Commission 2016). The Emissions Trading System is a key tool of the EU's climate change policy to cost-effectively reduce greenhouse gas emissions. The latest revision of the EU ETS Directive (2003/87/EU), adopted in 2018, sets the total amount of emission allowances for the period 2021–2030, in line with the EU's previous emissions reduction target (Erbach 2022). The committee's proposal for the amendment consists of five main elements (Erbach 2022): a reduction of emissions cap and setting more ambitious linear emission reduction targets for greenhouse gas emissions; a revision of the rules for free allocation of allowances and the stability reserve of the market; extending the ETS to maritime transport; establishing a separate new ETS for buildings and road transport; and increasing the Innovation and Modernisation Funds and new rules on the usage of ETS revenues.

According to the Commission's proposal, in order to align with the increased GHG emission reduction targets in the European climate law, it is necessary to reduce

emissions from the sectors covered by EU ETS by 62% by 2030 (including the extension to maritime transport) compared to the 2005 level (European Council 2023). In order to achieve the set goal, the proposal increases the annual linear reduction factor by 4.3% per year in 2024–2027, and 4.4% in 2028–2030. The proposal would also extend the EU ETS to CO_2 emissions from maritime transport, with particular regard to large vessels over 5,000 gross tonnages, which would be gradually introduced between 2025 and 2027.

The Council and the European Parliament agreed that, from 2027, a new, separate emissions trading system (ETS II) will be created, which will include the distribution of fossil energy used for heating buildings and fuel for road transport and additional sectors. Regulated organizations, i.e. fuel distributors will supply fuels to the sectors. Under ETS II, all allowances would be auctioned, and none would be provided for free. For this reason, it is likely that the price of road transport and heating fuels will rise, therefore the resulting indirect social effects will be dealt with by the legislative proposal on the Social Climate Fund.

Fluctuations in the CO_2 price within the EU ETS impact the cost-effectiveness of CCS and CCU technologies, contributing to market uncertainty (Lamberts-Van Assche et al. 2022). The level of CO_2 prices in the EU ETS is influenced by various factors, including commodity prices, policy shifts, and geopolitical events. To enhance the EU ETS's effectiveness, policymakers should consider promoting environmental research networks, international cooperation, and organizational innovation (Mandaroux et al. 2023). Moreover, the examination of technology, current regulations, and case studies underscores the importance of implementing CCU/S systems in Waste-to-Energy (WtE) contexts to reduce CO_2 emissions (Bertone et al. 2024). This initiative aligns with the ambitious goal of achieving carbon neutrality in waste management in the EU. The EU ETS Directive 2023/959 outlines a plan to incorporate WtE incinerators into the EU ETS by 2028. This move could significantly drive the adoption of CCU/S in WtE incineration plants, as it mandates WtE facilities to financially account for their fossil CO_2 emissions.

2.5. REPowerEU Plan

In May 2022, the European Commission presented the REPowerEU plan, the overall goal of which is reducing Europe’s dependence on the Russian fossil fuels, preferably before 2030 (Dinu 2023, European Commission 2022g). The plan also outlined the measures that can be used to respond to the sharply rising European energy prices, as well as preparing gas reserves for winter. It accelerates the transition to clean energy and focuses on providing help for the EU in saving energy, producing clean energy and diversifying the energy supplies.

In 2022 the Council and the European Parliament reached a political agreement on financing the REPowerEU Plan (European Commission 2022h). Even though the details of REPowerEU are not entirely clear, there is a strong motivation to change the energy system faster than previously planned. In the current situation, it can be expected that the public will accept the accelerated change to a greater extent, considering the technologies that were previously considered negative and the costs associated with them.

It is a subject of question what effect the REPowerEU Plan will have on the field of CCU/S (Farkas-Csamangó et al. 2023). Reducing the use of fossil resources may also affect the extent to which CCU/S technologies will be needed and applied. Although, in spite of the climate policy goals, among traditional energy sources an increase in the performance of coal power plants can be expected in the short term. In addition, although to a much lesser extent, natural gas and crude oil will still be part of the energy system in 2030 and 2050 – in this case, CCU/S can also play a role. In addition, Carbon Dioxide Reduction (CDR), which is part of most emission scenarios, will also rely heavily on CCS technologies. Besides, CCU will be important to achieve the target levels of e-gases and e-fuels. Moreover, REPowerEU also pays particular attention to the flourishing of the hydrogen industry (Uhde 2022). While doing so, in addition to hydrogen, products produced from it, i.e. ammonia, methanol, e-kerosene, or e-gasoline, play an important role. It also has an indirect effect on carbon dioxide: in addition to hydrogen, the production of e-fuels requires access to critical raw materials such as CO_2 from sustainable sources.

2.6. Industrial Carbon Management Communication

The European Union is committed to reach climate neutrality by 2050, in order to reach that the European Commission set out how to take advantage of CCU/S technologies (European Commission 2024b). It is stated that while currently making an effort to reduce emissions, we need technologies that can capture the CO_2 and utilize or store it as well. The Industrial Carbon Management Communication was adopted in 2024. It goes into details about how CCU/S technologies can serve as solutions contributing to 90% emission reduction by 2040 and to reaching climate neutrality by 2050.

The identified set of actions describe how to enable CCU/S technology deployment and the single market establishment for CO_2 in Europe with the necessary infrastructural developments. Preparatory work has already started on a regulatory package in regard to CO_2 transport and storage. Moreover, the volume of industrial carbon removals will be assessed by the Commission to meet the previously set goals, including the assessment of removal and storage processes to be accounted for under the EU ETS. In connection with the industrial uptake of sustainable carbon, establishing a clear accounting framework for CCU became a goal of the Commission.

In addition, for the establishment of the EU's CO_2 value chain, the Commission set out horizontal actions to create an enabling business environment. It is planned to happen in three fields of action: investment and funding; research, innovation and public awareness; and international cooperation.

2.7. Net-Zero Industry Act

On April 25, 2024, the European Parliament formally adopted the provisional agreement reached on the Net-Zero Industry Act (NZIA) (Global CCS Institute 2024). Being a key legislation in the field, it is anticipated to strengthen the EU's net-zero industry, making it more competitive and resilient, and also to contribute significantly to achieve climate neutrality by mid-century. The NZIA is designed to support the scaling up of a wide range of net-zero technologies, which are considered essential

for Europe's decarbonization efforts, including Carbon Capture and Storage (CCS). Specifically, the act designates CO_2 capture, transport, and storage projects as net-zero strategic projects, which are eligible for several benefits, such as streamlined and efficient permitting procedures and priority status at the national level.

The Act facilitates the creation of net-zero strategic projects, which are crucial for strengthening the resilience, strategic autonomy, and competitiveness of the EU's net-zero industry (European Commission n.d.c). These projects receive additional advantages, including 'priority status' at the national level, expedited permitting processes, dedicated support through the Net-Zero Europe Platform (including financial guidance), and urgent treatment in judicial and dispute resolution procedures, in accordance with both national and EU regulations

3. CCS and CCU in Decarbonization Scenarios in the EU

The EU examines the feasibility of the objectives through different decarbonization scenarios, depending on the solutions used. As a possible method, CCU/S technologies were also considered in some scenarios, their role and the importance of their application are evaluated as follows.

Currently, many models are used to analyze future scenarios of decarbonization at national, regional and global levels (Butnar et al. 2020). The most prominent of these are the Integrated Assessment Models (IAMs), which corroborate the IPCC assessment reports.

An important finding made during the investigation of the role of CCU technologies in the decarbonization of Europe is that, in addition to the rich portfolio of CCS technologies (Dalla Longa et al. 2020), there is no mention of CCU in global IAMs (Butnar et al. 2020). The broader literature also highlights the issue that CCU technologies are missing from global IAMs. Nevertheless, in 2018 CCU was listed as a key technology in the EU's "Clean Planet for All" report (European Commission 2018). PRIMES (EU-scale Energy System Model) scenarios compatible with 1.5°C and 2°C temperature targets suggest that by 2050, 47-80 Mt of CO_2 will be sequestered as products, and an additional 154-372 Mt of CO_2 will be used during the production of synthetic fuels. In order to ensure carbon neutrality in these scenarios, only CO_2 can be used for synthetic fuels and products that does not come from the flue gas produced by the combustion of fossil fuels. The level of CO_2 utilization in this study is approximately 50% of the total CO_2 captured.

The central role that could be played by the CCU/S in the realization of climate ambitions was confirmed by the "Review of Carbon Capture Utilisation and Carbon Capture and Storage in future EU decarbonisation scenarios" in 2020, which presents the role of CCU/S on the road to carbon neutrality (Butnar et al. 2020). The document emphasizes that the application of these technologies is essential to achieve net zero carbon dioxide emissions by 2050.

According to the 1.5°C scenarios, the median carbon dioxide sequestered by CCS will be between 230-430 Mt CO_2/year in 2030, which may increase to 930-1,200 Mt CO_2/year by 2050 (CCUS Set-Plan 2022). CCS for carbon dioxide removal is a topic that has undergone a more detailed review compared to previous assessments. According to the models that use Bioenergy with CCS (Bio-Energy Carbon Capture

and Storage, BECCS) and CCS with direct CO_2 capture from the air (Direct Air Carbon Capture and Storage DACCS), the role of these technological solutions has significantly increased in the mitigation of climate change and to meet the previously determined target levels. In the modelled 1.5°C scenarios, which also consider carbon sequestration, the global cumulative CO_2 removal between 2020 and 2100 is 30-780 Gt CO_2 for BECCS and 0-310 Gt CO_2 for DACCS. The values for the 2°C scenario are 170-650 Gt CO_2 (BECCS) and 0-250 Gt CO_2 (DACCS). It can be seen that the modelled CO_2 removal values range within wide limits, which is due to the consideration of different costs, the availability of technologies and the assumptions regarding the limiting factors.

Assuming that all planned activities are implemented in the upcoming period, the target figures required for the 2°C scenario by 2030 can still be reached, however, it would be still far from the values of the 1.5°C scenario (CCUS Set-Plan 2022). It is more than unlikely that all the planned projects will be realized. Following the path of the current scenario, we will not be able to achieve the 2050 objectives. For this reason, it is essential that (as many as possible) commercial-scale projects start up by 2030, and following this, facilities with commercial-scale capacity spread more and more until 2050.

The contribution of CCU to the climate goals is still unclear, as the carbon footprint is not always quantified during modelling and scenario creation (CCUS Set-Plan 2022, Farkas-Csamangó et al. 2023). However, it is indisputable that CCU technologies could contribute to emission reductions by avoiding new emissions by using existing ones, and in certain use cases CO_2 can be permanently stored (incorporated into the final product). According to estimates, by 2050, the amount of CO_2 used by CCU technology may reach up to 7 gigatons, which can be used to produce materials such as various fuels and chemicals.

In the document entitled "Stepping up Europe's 2030 climate ambition, Investing in a climate-neutral future for the benefit of our people", the European Commission also noted the critical importance of the industrial-scale installation of CCU/S systems, which should achieve significant results in this decade (European Commission 2020). It also shows the importance of the upscaling of CCU/S technologies, identifying the key factors hindering their development, and creating economic conditions and a favorable political framework related to them.

4. CCU/S pilot projects in Europe

Although CCU/S technologies are relatively new, there are already laboratory developments, demonstration projects, or even industrial-scale facilities in Europe. In this section, we have collected the projects that are of the greatest importance – without any claim to completeness. To emphasize, in this section we are presenting ideas from Europe and not only the European Union, as the United Kingdom (UK) left the EU in 2020, but several projects were launched there while they were a Member State of the EU, so in our point of view, it is justified to take a look at the UK as well.

There are several databases available to track the CCU/S pilot projects. One of them is the database of the Global CCS Institute, which focuses on CCS projects

mainly in the United States of America (USA) (Global CCS Institute n.d.). Another one is the database of CO_2 Value Europe which focuses on CCU project in the EU, without aiming the claim to completeness (CO_2 Value Europe 2024). The IEA CCU/S Database is the most comprehensive one covering projects since the 1970s (with capacity of more than 100,000 t/year, or for DAC facilities 1,000 t/year) on the whole CCU/S value chain: carbon capture, transport, storage and utilization (IEA 2024).

4.1. Carbon Capture and Storage Projects

The Global CCS Institute's 2023 report lists 41 projects currently in operation (most of them are operating in the United States, Canada and China), of which only four are located on the European continent: two in Norway, one in Hungary, and one in Iceland (Global CCS Institute 2023a). The Norwegian Equinor Sleipner project and the Hungarian MOL Szank Field project began operating in the 1990s, the other Norwegian project, Equinor Snohvit, launched in the second half of the 2000s, while the Icelandic project started in the early 2020s. Their activities are different, since while the Icelandic and Norwegian projects store carbon dioxide geologically, in Hungary it is used for Enhanced Oil Recovery (EOR).

According to the report published in 2023, a total of 155 CCS projects in various stages of readiness (early development, advanced development, in construction, operational) are under development in Europe (Global CCS Institute 2023a). There was a rise of 63% in projects of different development stages and operation since the previous report in 2022 (Global CCS Institute 2023b).

For many projects, improvements and progress are made in the advanced development stage, such as the following two (Global CCS Institute 2023a):

- (i) The Exergi KVV8 facility in Stockholm may be the largest biomass-based combined heat and electricity power plant in Europe. The BECCS project to be used in the facility can remove up to 0.8 Mt of CO_2 per year.
- And (ii), the proposed BECCS project for the UK's largest power station, Drax Power Station in Yorkshire, is making steady progress and could reach 8 Mt/year CO_2 capacity. Drax has announced a partnership with Mitsubishi Heavy Industries to capture the plant's carbon emissions (IEA 2021).

Also, in the early development stage, such as the ENI Ravenna Hub project will be one of the first CCS projects in the Mediterranean region. The project will initially carry out its decarbonization activities in Ravenna, Northern Italy, and later offer other players in the region the opportunity to manage their emissions.

4.2. Carbon Capture and Utilization Projects

Based on the CO_2 Value Europe database, there are a total of 103 completed and 145 ongoing CCU projects in Europe (CO_2 Value Europe 2024). These projects are extremely diverse in terms of the technology used, its maturity or technology readiness level (TRL 3-9) and the type of product produced.

Among the technologies at TRL 9 maturity level, there are two completed and three ongoing projects in Europe (Table 1) (CO_2 Value Europe 2024).

Table 1. Completed and ongoing TRL 9 CCU projects in Europe, 2024

Project name	**Country**	**Timeframe**	**Status**	**CCU information**	**Products**
Biocat 3	Denmark	2017-2020	completed	catalytic and biological conversion	fuels: methane
VABHYOGAZ 3	France	2016-2020	completed	chemical conversion	chemicals: bicarbonate
Carbon2Product Austria (C2PAT)	Austria	2020-2030	ongoing	chemical conversion	fuels and chemicals: hydrocarbons, olefins, captured CO_2
COLUMBUS	Belgium	2020-2025	ongoing	biological conversion	fuels: methane
Project AIR	Sweden	from 2019	ongoing	thermal conversion	chemicals, fuels: methanol

Source: own construction based on CO_2 Value Europe (2024)

A large number of TRL 8 CCU projects can also be found in Europe (5 completed and 34 ongoing projects), some examples are the following:

- BioPower2Gas: The completed project in Germany operated at three different locations between 2013 and 2016. All three units used the same technology, biological conversion in order to produce methane.
- CO_2ncrEAT: The mineralization project in Belgium, which uses CO_2 to produce building materials, aims to reduce emissions from the construction industry. The project started in the spring of 2022.
- George Olah Plant: One of the longest-operating projects is the George Olah Plant in Iceland, which has started in 2009. In the plant, methanol is produced by chemical conversion.
- LIPOR: One of Portugal's special CCU projects started in February 2021. In contrast to the projects listed so far, LIPOR deals with the production of aviation fuel and special chemicals, as opposed to common CCU products (methane, methanol).

Commercialization of CCU technologies is at an early stage, but within the next five years several ongoing and announced projects could reach industrial scale (CCUS Set-Plan 2022).

4.3. Entire CCU/S Value Chain Projects

According to the IEA CCU/S Projects Database, there are 5 projects in Europe that cover the whole CCU/S value chain. There are 4 operational projects and 1 project is under construction (IEA 2023):

- Iceland: two projects will use DAC in order to store CO_2, the Climeworks Mammoth Project will start in 2024 and the Climeworks Orca project has already been operating since 2021.
- Norway: two projects are storing CO_2 in the natural gas processing/LNG sector, the project called Sleipner launched in 1996, and the Snohvit CO_2 capture and storage project started in 2008.
- Hungary: MOL Szank field CO_2 EOR project started using CO_2 in EOR in 1992 and it is operating in the natural gas processing/LNG sector.

5. International CO_2 Infrastructure: Transport and Storage

Due to the growing demand for CO_2 sequestration, the need for transport and storage infrastructure is increasing; in light of this, CO_2 storage has developed rapidly (Global CSS Institute 2021). Harbor Energy, Neptune Energy, MOL and Independent Oil and Gas are just some of the companies that have publicly expressed interest in using European assets for CO_2 storage.

CO_2 is mainly transported by pipeline, but other modes of transport, such as water, rail or road transport, are also becoming increasingly important (IOGP 2019). Many CCS projects planned in Europe aim to transport CO_2 from one country to another with the aim of storing CO_2. Cross-border CO_2 transport can promote regional cooperation and the development of infrastructural connections through regional projects. The same approach is used by the Norwegian Northern Lights project.

The Northern Lights project aims to create a European CO_2 transport and storage network based on water transport (Northern Lights n.d.). By importing Europe's carbon dioxide emissions, the project aims to achieve economies of scale and lower costs, while at the same time making a larger-scale contribution to the reduction of CO_2 emissions of the EU. In 2017, the CO_2 transportation part of the project received the status of a Project of Common Interest (PCI), which was renewed in 2022 in order to expand the geographical scope of the project in Belgium, France, Germany, Ireland, the Netherlands, Sweden and also for locations in the United Kingdom (Northern Lights 2022). Companies Equinor, Total and Shell are responsible for the transport and storage part of the project. The project is scheduled to start operations in 2024 and its extension to cross-border transport of CO_2 is expected to take place from 2026 by shipping the first biogenic CO_2 from Denmark to Norway (Northern Lights 2023).

The development of CO_2 transport infrastructure, the connection of industrial clusters and storage sites is essential in order to exploit economies of scale at regional, national and European levels. The transition from individual solutions to the creation of clusters is crucial for the development of efficient CO_2 networks.

6. CCU/S Clusters and Organizations in the EU

In the case of CCU/S technologies, bottom-up organizations and clusters are already emerging, but the spread of the technologies' application is also promoted by specialized organizations in the European Union.

6.1. Clusters

The concept of industrial clusters is well known in the field of economic development. An industrial cluster means the geographical concentration and cooperation of businesses, suppliers and associated institutions related to each other in a given area, and there can be many reasons for its formation (Global CCS Institute 2016).

The efficiency and cost-effectiveness of the future carbon dioxide transport infrastructure will be determined by whether it can capture emissions from clusters of industrial facilities (IOGP 2019). According to a report in 2018 by Endrava and Carbon Limits, emissions from European power plants, industrial facilities and waste treatment facilities were 2.4 Gt/CO_2, which is two-thirds of all European CO_2 emissions (around 3.8 Gt CO_2). Within these two-thirds, 89% of emissions come from facilities emitting more than 100 kt CO_2/year, which accounts for 32% of these facilities. This indicates that the decarbonization of larger installations will enable effective and timely progress in reducing the EU's overall CO_2 emissions.

In the case of CCS, it is an advantage that the geographical location of many emission-intensive facilities (either in industry or energy) is concentrated within a narrow area (Global CCS Institute 2016). Such clusters can be found, for example, around energy facilities and ports. This gives the opportunity to create a CO_2 capture and/or storage cluster by uniting CO_2 emitters located relatively close to each other and connecting to a large CO_2 storage through an extensive infrastructure. In this case, the size of the infrastructure is not measured for the individual user, but for the combined needs of the users.

Several existing CCS clusters can be identified within the European Union (Global CCS Institute 2016, Aker Carbon Capture 2022), for example:

- France - Le Havre cluster (COCATE);
- Scandinavian region - Skagerrak/Kattegat cluster; and
- Bulgaria - ANRAV CCUS cluster.

Joining clusters can also be beneficial for smaller companies, as they can take advantage of economies of scale typically found only in large companies, get quick access to information networks (formal and informal) and skilled labour force, enjoy proximity to suppliers and/or customers (Global CCS Institute 2016).

6.2. Organizations

In the European Union, a number of organizations have been established with the aim of helping the deployment and application of CCU/S technologies and their spread across the EU.

6.2.1. CCUS Zero Emission Network (ZEN)

The goal of the Zero Emissions Network is to accelerate the spread of CCU/S throughout Europe by building networks, and to contribute to the reduction of CO_2 emissions in industrial clusters and hubs by sharing knowledge and experience related to CCU/S (European Commission 2022h). Its duties include providing stakeholders with important information to make informed decisions about CCU/S, and development of concrete and feasible plans for the development of CCU/S value chains.

ZEN partners have extensive expertise and knowledge in the field of the CCU/S value chain, including land and water transportation, pipeline and energy industries, and CO_2 storage (SINTEF 2022). The two-and-a-half-year project started in September 2022, the opening event of which was held in Paris, where, in addition to the 14 partners, 60 members of the network were represented. CCUS ZEN is funded by EU Horizon Europe.

6.2.2. Zero Emissions Platform (ZEP)

ZEP is the EU's advisor on the deployment of the CCU and CCS (Zero Emissions Platform n.d.). In addition to consulting, its activities include writing studies and reports, as well as providing consultation opportunities. The organization's members include multinational companies such as BP, Shell, ExxonMobil or GE.

According to the organization, in order to promote a cluster-based approach to CCU/S, the emission sources of the region must be mapped, and a unified position must be developed between the member states and the industry in order to build a common user infrastructure. This could be done by Member States in a coordinated way with industry in order to better identify where there might be cluster opportunities for efficient carbon capture and transport and how to encourage early public financial support for CO_2 infrastructure.

6.2.3. CCUS Forum

The CCUS Forum is an annual event organized by the European Commission, which serves as a common platform for stakeholders (European Commission 2022a). The purpose of the Forum is to bring together representatives of EU institutions, EU and third countries, non-governmental organizations, business sector and academia to facilitate the spread of the deployment of CCU/S technologies (European Commission 2024a).

The first high-level CCUS Forum took place in 2021 (European Commission 2024a). The event attracted nearly 400 participants, demonstrating the growing interest in CCU/S and the need for ongoing dialogue between stakeholders. The first forum resulted in creating three working groups. The first working group deals with CO_2 infrastructure and addresses gaps in infrastructure development. The second group is designed to develop a CCU/S vision document that examines the role of CCU/S in the EU's energy decarbonization, while the third group works for the establishment of industrial partnerships and the greater involvement of industries in technological deployment.

The groups helped prepare the second plenary session of the Forum (European Commission 2024a). At the second meeting of the CCUS Forum held in 2022, Oslo,

almost 300 in-person and up to 1400 online participants gathered. Four working groups were established on CCU/S strategy, public perception, CO_2 infrastructure and CCU/S industrial partnerships.

The third CCUS Forum (in Denmark, 2023) gathered more than 450 in-person and up to 1,400 online participants, and resulted in the establishment of four working groups on CO_2 infrastructure, CO_2 standards, public perception and CCU. According to the CCUS Forum, these numbers illustrate the interest in accelerating the deployment of CCU/S technologies in Europe. The fourth edition of the CCUS Forum is being organized, it will take place in France in 2024.

6.2.4. CCUS Hub

The purpose of the CCUS Hub is to accelerate industrial decarbonization by creating an infrastructure that is suitable for transporting and storing CO_2 from multiple sources in a safe and environmentally responsible way in the long-term (CCUS Hub 2024). The CCUS Hub aims to support policy makers, potential hub developers and emitters who are interested in establishing a CCUS hub by sharing knowledge and experience from the most advanced hubs. This platform was created by the organization called the Oil and Gas Climate Initiative (OGCI), which relies on the knowledge and support of numerous partner organizations.

The platform has three key tools (CCUS Hub 2024). CCUS Hub Search is an interactive map that identifies 279 potential CCUS hubs in 56 countries and matches clusters of CO_2 sources from emitting industries with potential storage sites. The tool serves as a starting point for policy makers, industrial emitters and potential hub developers. The Playbook was commissioned by OGCI, based on in-depth interviews conducted with transport and storage operators, hub developers, regulators and emitters in advanced hubs as part of the KickStarter initiative. Hubs in Action is a collection of profiles of CCUS hubs currently under development, including key information and descriptions of participants, storage capacity and type, and planned starting dates. Currently, OGCI member companies are actively involved in the development of almost 40 emerging hubs, and about 80 are under planning or construction.

7. Supporting System

The work of the organizations presented in the previous chapter is momentous for the spread of CCU/S technologies, however, the provision of financial support is still essential. With the help of grants, research projects can reach industrial scale, and their operation can become more efficient through further developments.

The EU offers several funding programs to finance European energy projects, including CCU/S (IOGP 2019, Farkas-Csamangó et al. 2023). These grants cover the entire range of technological development levels: from research carried out under Horizon 2020 and Horizon Europe to commercial-scale projects of the Innovation Fund. EU funding systems and innovation networks are vital to support the early adoption of CCU/S solutions.

7.1. Connecting Europe Facility and Trans-European Networks for Energy

The Connecting Europe Facility (CEF) is a funding initiative of the European Commission, which includes numerous calls for the development of cross-border CO2 infrastructure (Balakin, 2021, IOGP 2019).

The Trans-European Networks for Energy (TEN-E) policy is also indirectly related to the European support system (European Commission 2023c, Jenkins 2015). TEN-E is a policy that focuses on connecting the energy infrastructure of EU countries. As part of the regulation, eleven priority trans-European corridors and three priority areas have been identified, one of which is the "Cross-Border Carbon Dioxide Network". The EU helps countries in these key thematic areas to cooperate in order to develop better connected energy networks, and also provides financing for new energy infrastructure developments. In the program, CO_2 infrastructure projects can apply for the status of a project of common interest and then receive support within the framework of the CEF.

Among the three sectors of the CEF (energy, transport and digital sectors), EUR 5.84 billion from the budget of the energy sector will be allocated to the implementation of the TEN-E policy in the period 2021–2027 (European Commission n.d.a). Furthermore, the energy sector also focuses on the co-financing of cross-border renewable energy projects, the interoperability of networks and the better integration of the internal energy market (European Commission 2021a). In the listed areas, CEF has so far co-financed studies and works related to PCI in connections with CO2 emissions (European Commission 2022a).

7.2. European Innovation Fund

In November 2023, the European Commission announced the Innovation Fund's 2023 call for propos als (European Commission 2023a). The announced incentives are worth a total of 4 billion euros. The 2022 call is expected to boost the use of industrial solutions to decarbonize Europe. Focusing on the priorities of the REPowerEU Plan, the call provides further support for reducing the EU's dependence on Russian fossil fuels.

Grants are divided to five topics:

- General decarbonization (large-scale): €1.7 billion available
- General decarbonization (medium-scale): €500 million available
- General decarbonization (small-scale): €200 million available
- Cleantech manufacturing: €1.4 billion available
- Pilot: €200 million available

The European Commission invests over €65 million to support the selected 17 small-scale innovation (European Commission 2023b). The selected projects are located in Italy, Spain, Croatia, France, Hungary, Latvia, Greece, the Netherlands, Sweden, Finland and Norway. By supporting the projects, it would help commercialize technologies in the market in energy-intensive industries, as well as contribute to the construction of infrastructure for hydrogen, renewable energy,

carbon capture and storage, and the manufacturing of key components of energy storage and renewable energy sources.

7.3. Horizon Europe

Covering the seven-year period of 2021 through 2027, the European Union's research and innovation framework program, Horizon Europe, was launched in June 2021 with a budget of 95.5 billion euros (European Commission 2021b, Farkas-Csamangó et al. 2023). The funding program is more ambitious than the Horizon 2020 framework program. It provides 30% more resources to support European research excellence and breakthrough innovations, as well as to address the most important societal challenges and creating jobs. In addition, tackling climate change, it accelerates the competitiveness and growths of the EU, and aims to contribute to the Sustainable Development Goals of the United Nations.

In line with the REPowerEU Plan and the European Green Deal, the measures promote the transition to clean energy (European Commission 2022f). In order to support the green transition, Horizon Europe allocates at least 35% of its total budget to climate policy objectives.

In the frames of the second pillar of the funding program, called "Global Challenges and European Industrial Competitiveness", there is a budget of 53.5 billion euros, of which the "Climate, Energy and Mobility" cluster receives a total of 15.35 billion euros (NKFIH 2021). Horizon Europe Work Program 2023-2024 was adopted by the European Commission in 2022. It invests around 13.5 billion euros in research and innovation activities shaping the future of Europe (European Commission 2022b). A significant part of the financing budget is used for targeted measures that support making the society and the economy greener.

The four (A-D) Key Strategic Orientations for the period 2021-2024 of the Horizon Europe Strategic Plan define higher-level objectives in which research and innovation investments are expected to bring about change (European Commission 2022f). For our paper, the relevant key strategic directions could be as follows:

- B – Restoring Europe’s ecosystems and biodiversity, and managing sustainably natural resources: Horizon Europe promotes knowledge creation, expands capacities and innovative technologies, and offers solutions to support ecosystems, ensure a clean and healthy environment and sustainable management of natural resources, contributing to climate change adaptation and achieving carbon neutrality. From the perspective of our work, "Clean and healthy air, water and soil" can be the most relevant of the three impact areas.
- C – Making Europe the first digitally enabled circular, climate-neutral and sustainable economy: Its goal is for the EU to become a provider of green solutions for the benefit of all, and to place Europe in a technological and industrial leading position during the green transition in order for the EU to become climate neutral by implementing the transition in all economic sectors. Among the four impact areas, the followings are relevant for our work:

- Promoting climate change mitigation and adaptation
- Reducing energy dependencies and promoting affordable and clean energy
- Contributing to the regenerative, circular and clean economy

Below, we collected a list from the calls of the "Climate, energy and mobility" cluster which aim to deploy the entire CCU/S value chain (including transport as well) or its separate elements (CC, CCU or CCS) (European Commission 2022c):

- HORIZON-CL5-2023-D3-01-17: Development of CO_2 transport and storage demo projects
- HORIZON-CL5-2024-D3-02-11: CCU for the production of fuels
- HORIZON-CL5-2024-D3-02-12: DACCS and BECCS for CO_2 removal/negative emissions

Moreover, further clusters, such as the "Digital, Industry and Space" cluster (European Commission 2022d) and the "Food, Bioeconomy, Natural Resources, Agriculture and Environment" cluster (European Commission 2022e) also mentions the parts of the CCU/S technologies in their calls.

In funding programs other than Horizon Europe (i.e. Interreg Danube Region Program 2021-2027 (Interreg Danube Region, n.d.), Interreg Central Europe Program 2021-2027 (Interreg Central Europe n.d.), Interreg Europe Program 2021-2027 (Interreg Europe, n.d.)) similar topics are also mentioned to support the low-carbon economy and green innovations, however, due to its volume, we highlighted the Horizon Europe Program.

It can be seen that the European financial support systems also have a place to promote efforts to develop and deploy different CCU/S methods. The financing of these kinds of projects clearly indicates the importance of these technological solutions and anticipates the trends of future technological developments.

8. Critical review of CCU/S technologies

There are numerous reviews that underscore several critical challenges associated with carbon capture, utilization, and storage technologies, i.e. high energy demands of current capture processes, infrastructure requirements for transport and storage, and associated costs (Chen et al. 2022, Gedam 2024, Nath et al. 2024, Prajapati et al. 2024, Tapia et al. 2018). The reviews recommend enhancing capture efficiency, advancing reliable storage site evaluations, improving monitoring technologies, exploring sustainable uses for captured CO_2, and promoting adoption through policy incentives. If coordinated global efforts are made, CCU/S could significantly contribute to achieving carbon-neutral energy systems on a worldwide scale.

Gedam (2024) reviews the role of CCU/S technologies in a low-carbon future, stating these points. First, economic and policy measures will be critical in facilitating the widespread commercial implementation of CCU/S technologies. Reducing energy penalties associated with capture and compression processes is essential for lowering costs. Incentives such as tax credits, carbon pricing mechanisms, and mandates are

vital for encouraging CCU/S adoption, with a need for policies that support both the electricity sector and industrial applications.

Second, the costs of CCU/S vary widely depending on the source of CO_2 and its concentration in the flue gas. Direct air capture is currently the most expensive option but may still play a unique role in carbon removal strategies. The variability in costs is further influenced by the commercial availability of capture technologies and the logistics of CO_2 transport and storage, which depend on factors such as volume, distance, and storage conditions.

Third, international cooperation is vital for the broader adoption of CCU/S technologies. Clear regulatory frameworks regarding project permits, CO_2 storage management, monitoring requirements, and liability issues are essential to attract investment.

Fourth, although progress in CCU/S technology is promising, cost reduction remains a significant hurdle. While the costs associated with CCU/S are declining, they still exceed those of conventional energy production methods. Addressing this economic challenge is crucial to making CCU/S a more competitive and appealing option for industries aiming to lower their carbon emissions. Broad deployment of these technologies, supported by ongoing technological advancements and favourable policies, will be key to reducing greenhouse gas emissions and moving towards a low-carbon future.

And, finally, fifth, CCU/S technologies hold substantial potential for mitigating greenhouse gas emissions. However, further development, testing, and validation are necessary to lower costs, enhance performance, and confirm their effectiveness and reliability in practical applications. The review also emphasizes the importance of supportive policies, such as carbon pricing, investment subsidies, and tax incentives, to drive the adoption of CCU/S technologies.

9. Discussion, conclusions

The present study has aimed to discuss the institutional background that has effect on the spread and deployment of carbon capture, utilization and storage technologies. In order to do so, we have taken a look at the most relevant frameworks and reports in the European Union to map the EU's approach to these technologies. There are several ambitious goals for mitigating climate change set in the EU, however, the efficiency and effectiveness of the undertaken efforts may be the subject of debate.

As the given issue is multifaceted, there is no one-size-fits-all solution for it (Chen et al. 2022, Gedam 2024, Nath et al. 2024, Prajapati et al. 2024, Tapia et al. 2018). Besides the other decarbonization solutions, it can be stated after the revision of the EU's approach, that CCU/S technologies can play a key role, especially in the hard-to-abate sectors such as aviation, maritime shipping, and cement industry as they can help them maintain their competitiveness. It shows the importance of the upscaling of CCU/S technologies, and also the identification of the key factors hindering their development. Creating a supportive legal, policy and business environment is critical to the success of the spread of emerging technologies, including CCU/S as well (Farkas-Csamangó et al. 2023). As their application takes place in a rather complex, currently forming technological, economic and legal

environment, research, development and innovation activities are of prime importance in the development and scalable implementation – it also appears in the examined frameworks and financial supporting systems. Forming CO_2 infrastructure, clusters, pilot projects are also significant in order to showcase the upscaling of these technologies, to accelerate technological development and to promote professional cooperation between stakeholders – professional events, for example workshops are needed to provide them a platform where they can share and change ideas.

Overall, our present study contributed to confirming the promising future role of carbon capture, utilization and storage technologies in the EU climate policy and in reducing carbon dioxide emissions, as several policy and regulatory changes, and endeavours occur in the European Union that include the CCU/S technologies. The topic of CCU/S technologies seems forward-looking; however, further steps are needed to be taken in practice, even the creation of a CCU/S Strategy on EU and national levels.

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The performance of Hungarian sustainability and ESG mutual funds

Dániel Szládek

Sustainable and ESG (environmental, social, and governance) investments are gaining prominence worldwide. The question from a financial viewpoint is whether investors need to sacrifice financial return when making their investment decisions to purchase sustainable or ESG mutual funds. In other words, does investing in socially better or greener mutual funds offer a relatively lower return than traditional investment strategies?
This paper identifies the Hungarian sustainability and ESG mutual funds and analyses the risk-adjusted performance of these mutual funds to answer the question. The results indicate that ESG funds perform better on average only in the bond type category, while funds investing traditionally have better risk-adjusted performance in the mixed and absolute return fund type categories. For equity type funds, the results are ambiguous.

Keywords: mutual funds, risk-adjusted performance, sustainability, ESG

1. Introduction

The aspect of sustainability and the ESG (environmental, social, and governance) framework have substantially altered the investing landscape. Institutional investors have embraced the idea of sustainable and ESG investing, and offer mutual funds that follow such principles. The question from a financial viewpoint is whether investors need to sacrifice financial return when making their investment decisions to purchase sustainable or ESG mutual funds. In other words, does investing in socially better or greener mutual funds offer a relatively lower return than traditional investment strategies?

This paper identifies the Hungarian sustainability and ESG mutual funds and analyses the performance of these funds to answer this question. Four types of funds will be assessed: bond, mixed, equity, and absolute return funds. Not only the returns but also the riskiness and the risk-adjusted performance of the funds will be compared for funds investing traditionally and funds considering ESG aspects to reveal which group performs better from a financial point of view.

The paper is structured as follows: the second section summarises the theoretical background from the literature review about sustainable and ESG funds, as well as the assessment of mutual fund performance. The third section introduces the data collection process and the methodology of the analysis. The fourth section presents the results and discusses the implications. Finally, the fifth section concludes and identifies further research avenues.

2. Literature review

First of all, it is important to understand what is sustainable and ESG investing. According to the European Securities and Markets Authority, ESMA, sustainable investing involves

"an investment in one or several economic activities that qualify as environmentally sustainable" (ESMA 2023, pp. 1–2). These environmentally sustainable activities are defined in the Taxonomy Regulation (EU 2020/852): climate change mitigation, climate change adaptation, the sustainable use and protection of water and marine resources, the transition to a circular economy, pollution prevention and control, and the protection and restoration of biodiversity and ecosystems. It is apparent that sustainable investing focuses on environmental issues.

The framework of ESG, that is environmental (E), social (S), and governance (G) aspects of corporate finance and investing, however, deals with a broader set of issues. Naturally, the environmental pillar is also important in this framework, as resource use, emissions, and environmental innovations are considered when calculating the E pillar score. But there are social impact metrics as well, such as workforce, human rights, community, and product responsibility factors. Finally, the governance of the firms is evaluated with the assessment of the management, shareholders, and CSR strategy to come up with the G score. The three pillars combined give the comprehensive ESG score.

There are three strategies for mutual funds to implement ESG aspects in their investing processes (Hauff–Nilsson 2022). The first one is exclusion, alternatively called "negative screening". In this strategy, firms or entire industries are excluded from the pool of potential investments which are involved in activities deemed harmful to the environment or society, e.g. CO2 emissions, tobacco, and weapons. Negative screening may not necessarily mean total exclusion from investment, e.g. a firm with emissions under a pre-determined limit may get investments. The second strategy is inclusion, or "positive screening", which is a bottom-up portfolio-building procedure which looks for firms achieving or exceeding a certain ESG score. During positive screening, a firm operating in a harmful activity may be included for investment, if the firm stands out from the sector based on its ESG score. The last strategy is called engagement, which means that the mutual fund managers keep a close relationship with the firms in their portfolio to reach the ESG score targets. It is also called shareholder activism, as the funds do not passively invest in the firms, but rather try to actively influence the management of the firms (Hauff–Nilsson 2022).

Capelle-Blancard and Monjon (2014) examine whether there is a relationship between the screening methodology and the performance of SRI funds. Their results show that increasing the intensity of screening (i.e., the degree to which firms are excluded from the investment universe based on strict criteria) reduces risk-adjusted returns, but only for sector-specific screening criteria; tightening more general screening criteria does not worsen financial performance. They also find that positive screening to select the best companies seems to be the most financially efficient method, but this may have the drawback that it does not differentiate SRI funds much from traditional funds (Capelle-Blancard–Monjon 2014).

One of the biggest questions about sustainable and ESG investing is whether there is an opportunity cost, i.e. the investor has to sacrifice financial return for supporting environmental and social goals. The alternative cost of negative screening is examined by Trinks and Scholtens (2017). The impacts of fourteen problem areas are considered: abortion, adult entertainment, alcohol, animal experimentation, contraception, guns, animal fur, gambling, genetic modification, the meat industry, nuclear energy, the pig industry, stem cells, and tobacco. More than 1,600 individual stocks are analysed.

Negative screening reduces the size of the investment universe significantly and the risk-adjusted return is lower compared to not screening out companies in these problem areas, i.e. there is indeed an opportunity cost (return sacrifice) of negative screening (Trinks–Scholtens 2017).

In the next few paragraphs, I will overview the results of some papers about green or ESG mutual fund performance. Climent and Soriano (2011) analyzes the performance of green mutual funds in the United States from 1987 to 2009. Their results indicate that green mutual funds performed worse than traditional funds with similar risk characteristics. However, they also note that in the most recent period from 2001 to 2009, green funds did not have lower returns than traditional ones, thus it seems that the opportunity cost of investing in green funds is waning (Climent–Soriano 2011).

Hartzmark and Sussmann (2019) ask whether investors have a positive view of sustainability in the field of investments. Looking at the capital flows of funds, it appears that they do, as funds with the highest sustainability ratings receive significantly positive capital inflows, while funds with the lowest ratings experience outward capital flows. Based on the survey of investors, the researchers found that investors expect higher financial returns for funds with high sustainability ratings, but the data suggest that this is not the case, i.e. Hartzmark and Sussmann (2019) also find that an investment strategy that prioritises sustainability has a return sacrifice.

In Europe, Abate et al. (2021) assess the performance of sustainable mutual funds in a period between 2014 and 2019. More precisely, they ask whether mutual funds with higher ESG scores perform better financially than funds with worse ESG scores. They find that mutual funds with higher ESG scores generate significantly higher returns than funds with low ESG scores. Their research implies that it is possible to invest in Europe considering ESG aspects without sacrificing financial return (Abate et al. 2021).

In a sample of emerging market countries, Naqvi et al. (2021) compare the performance of green mutual funds and traditional funds investing primarily in the energy sector. They show that renewable energy funds significantly underperform traditional energy funds on a risk-adjusted return basis. Their analysis also reveals that renewable funds performed especially badly during the Covid-19 pandemic. All in all, Naqvi et al. (2021) find that in emerging market countries green energy investments require financial sacrifice.

In Hungary, Németh-Durkó and Hegedűs (2021) evaluate the performance of green bond funds from 2017 to 2020. They contrast the risk-adjusted returns of Hungarian green bond funds with the performance of their traditional benchmark indices. Their results show that there is a green premium (return sacrifice), thus the Hungarian green bond funds underperform their benchmark indices. However, they find that the performance of the green bond funds is gradually improving through the assessed years (Németh-Durkó–Hegedűs 2021).

All in all, it seems that generally there exists an opportunity cost for investing in sustainable or ESG funds. However, some encouraging results are showing that green or ESG fund performance is improving and in Europe could even exceed the risk-adjusted return of funds with a traditional investment policy.

3. Data and methodology

This section introduces the data-gathering process and presents the methodology used to analyze the performance of Hungarian sustainable and ESG mutual funds.

The main source of data was the website of BAMOSZ,[1] the Association of Hungarian Investment Fund and Asset Management Companies. The BAMOSZ website reports extensive data about Hungarian mutual funds. The dataset is accessible through the main page by selecting Investment Funds and clicking on Download. Here, the filters can be applied and the required variables can be selected for download.

The sample was constructed applying the following principles. The period under assessment goes from December 1, 2018, to November 30, 2023. This period spans five years and includes challenging times for the capital markets, e.g. the Covid-19 pandemic, international conflicts like the Russia–Ukraine war, and elevated inflation in the developed world, especially in Hungary. Only mutual funds with at least one full year of history were included in the sample.

Four types of mutual funds were collected: bond, mixed, equity, and absolute return funds. Bond and equity funds, as their names suggest, mainly invest in bonds and stocks, respectively. Mixed funds offer a mixture of bonds and stocks. Absolute return funds do not invest based on asset classes but strive to earn positive returns every year. Another filter applied is that only mutual funds denominated in Hungarian forint (HUF) were selected.

The BAMOSZ dataset indicates whether a mutual fund is classified as an ESG fund or not. Additionally, fund names were checked to include funds whose names contain the words "sustainable" or "responsible". In such cases, the investment policy of the funds was also checked to make sure that they follow sustainable or ESG investment policies. Table 1 presents the number of mutual funds included in the sample categorized by their type and traditional or ESG investment policies.

Table 1. Number of mutual funds in the sample categorized by type and investment policy

Type	Traditional	ESG or sustainable	ESG or sustainable %
Bond	63	4	5.97%
Mixed	82	10	10.87%
Equity	98	18	15.52%
Absolute return	134	6	4.29%
Total	377	38	10.08%

Source: own construction based on BAMOSZ data

Altogether 415 mutual funds are included in the sample, of which 377 follow traditional investment policies, and 38 consider ESG aspects, thus approximately 10 percent of the analyzed funds are ESG or sustainable funds. The biggest ratio of ESG

[1] https://www.bamosz.hu/en

funds is found in the equity category, where a little more than 15% of funds invest with ESG or sustainability in mind.

To compare the performance of ESG and traditional mutual funds, several metrics were collected. First, the returns of the mutual funds were downloaded from the BAMOSZ website. The 1-year, the 3-year annualized, and the 5-year annualized returns were gathered from the BAMOSZ database. Second, it is important to factor in the riskiness of the investments of the mutual funds. A classic risk measure, the standard deviation of the returns is available in the database for the 1-year and the 5-year time horizon. The returns divided by their standard deviation is a method to take the riskiness of the portfolio into account, e.g. dividing the 5-year annualized returns with the 5-year standard deviation of the returns.

Finally, another risk-adjusted return metric is calculated. The Sharpe ratio is one of the most commonly used metrics when comparing investment performance. It is calculated by the following formula (Sharpe 1966):

$$Sharpe\ ratio = \frac{r_i - r_f}{\sigma_i}$$

In the formula, r_i denotes the annualized return of the fund i, r_f means the risk-free rate, σ_i is the standard deviation of the returns of the fund i. Since only the mutual funds denominated in HUF were analyzed, the risk-free rate is proxied by yields of the Hungarian government bonds, also denominated in HUF. The annual yields of the 1-year, 5-year, and 10-year HUF government bonds were collected from the ÁKK website,[2] which is the Government Debt Management Agency of Hungary. For all three maturities, 1-year and 5-year averages were calculated resulting in an average of 9.22% yield in the last year, and 5.07% average annual yield for the last 5 years. These will be subtracted from the 1-year and 5-year annualized returns, respectively, and then divided by the 1-year and 5-year standard deviation of returns, respectively, to get the Sharpe ratio.

4. Results and discussion

This section presents a comparison of the performance of ESG and traditional Hungarian mutual funds. For a start, Table 2 shows the 1-year, 3-year annualized, and 5-year annualized returns of the funds categorized by type and investment policy.

The first column of Table 2 shows the fund type, and the second column indicates the investment policy within the type category. Columns 3 to 5 list the 1-year, the 3-year annualized, and the 5-year annualized returns. Every cell contains three numbers: the minimum, the maximum, and the average value for the respective return metric for the fund type and investment policy category. Funds with traditional and ESG investment policies are compared directly within fund types, and the higher return values are shown in bold. The small number of funds, especially with ESG investment policies, does not make it possible to conduct statistical tests, thus at the

[2] https://akk.hu/

moment, we are left with the direct comparison of the minimum, maximum, and average values.

Table 2. Fund returns categorized by type and investment policy

Type	Investment policy	1Y (%)	3Y (%)	5Y (%)
Bond	Traditional	-9.34; **20.53** 13.42	-8.92; **7.83** 1.81	-2.12; **6.19** 2.38
	ESG	**14.74**; 19.23 **16.97**	**3.88;** 7.63 **5.82**	**4.17**; 5.10 **4.64**
Mixed	Traditional	-8.88; **26.07** **9.77**	-3.01; **16.96** **5.59**	1.50; **10.74** **5.07**
	ESG	**-6.59**; 12.57 5.81	**-0.93**; 5.50 3.26	**2.59**; 4.33 3.46
Equity	Traditional	-82.20; **36.89** **6.91**	-74.32; **27.97** **6.66**	-53.73; **16.28** 5.14
	ESG	**-11.83**; 22.20 -2.95	**-2.60**; 15.73 4.10	**-1.15**; 14.34 **7.17**
Absolute return	Traditional	-13.21; **58.87** 14.79	-6.90; **33.06** **8.54**	-13.73; **16.56** **6.00**
	ESG	**6.32**; 19.76 **14.96**	**4.62**; 5.72 5.21	**3.17**; 4.46 3.94

Source: own construction based on BAMOSZ data

Focusing on the comparison of the averages, Table 2 shows that in the bond type category, funds with ESG investment policies outperform on average traditional funds for all three time horizons. For mixed funds, the opposite is true: ESG funds underperform on average funds with traditional investment policies for all three time horizons. In the equity and the absolute return fund categories, again, traditional funds perform better for two time horizons. In the equity category, ESG funds have higher returns on average when comparing the 5-year annualized returns; in the absolute return category, ESG funds overperform the traditional ones slightly for the latest year. Based on the 1-year, 3-year annualized, and 5-year annualized returns it is apparent that ESG funds tend to underperform on average the traditional funds, except for the bond type category.

Comparing only the returns may not provide the full picture of performance, as a fund may earn a higher return by taking on higher risk. Thus, it is important to factor in the riskiness of the portfolio and calculate risk-adjusted return metrics. Table

3 below presents the 1-year and 5-year standard deviation of fund returns and the 1-year and 5-year return/risk metrics, categorized by fund type and investment policy.

Table 3. Fund return standard deviation and return/risk metric categorized by type and investment policy

Type	Investment policy	1Y σ (%)	5Y σ (%)	1Y r/σ	5Y r/σ
Bond	Traditional	**0.54**; 11.74 6.24	**0.78**; 14.72 6.07	-0.89; **28.07** 5.06	-0.14; **5.39** 1.07
	ESG	1.63; **4.42 3.03**	1.39; **1.41 1.40**	**4.04**; 9.81 **6.81**	**3.00**; 3.62 **3.31**
Mixed	Traditional	**0.53**; 12.70 **6.87**	**0.82**; 13.54 **7.70**	-0.70; **28.00 2.18**	0.18; **6.40 0.84**
	ESG	5.95; **11.26** 7.46	8.48; **10.72** 9.60	**-0.59**; 1.89 0.94	**0.24**; 0.51 0.38
Equity	Traditional	**0.81**; 78.53 15.35	**14.39**; 65.39 19.23	-1.28; **2.72 0.64**	-1.67; **1.03** 0.36
	ESG	11.63; **17.60 14.71**	14.48; **20.81 16.30**	**-0.74**; 1.91 -0.14	**-0.08**; 0.91 **0.43**
Absolute return	Traditional	**0.96**; 13.98 5.32	**1.06**; 28.12 **8.02**	-1.42; **16.06 3.83**	-0.49; **5.92 0.96**
	ESG	3.17; **5.94 4.93**	6.00; **11.65** 10.23	**1.99**; 3.44 2.98	**0.27**; 0.74 0.43

Source: own construction based on BAMOSZ data

In Table 3, the first two columns list the fund type categories and the investment policy within the category. Columns three and four show the 1-year and the 5-year standard deviation of fund returns. Columns five and six list the 1-year and 5-year return/risk ratio, i.e. the return metric divided by the standard deviation of the returns for the same time horizon. As seen previously, every cell contains three values, they are the minimum, the maximum, and the average values for the given metric.

Looking at the riskiness of fund portfolios, a lower value of the standard deviation of the returns means lower risk, which is preferable, and is highlighted in bold. Comparing the standard deviation values of ESG and traditional funds, we can see that ESG funds perform better, i.e. they have a lower standard deviation of returns on average in the bond and equity type categories, both for the 1-year and the 5-year standard deviation. Traditionally investing funds have lower risk in the mixed category. For absolute return funds, the results are mixed: ESG funds have lower risk

on average, considering the 1-year standard deviation, while traditional absolute return funds have a lower 5-year standard deviation of returns.

The return/risk ratio is a basic risk-adjusted return metric, which shows the unit of generated return per one unit of risk taken. A higher value of return/risk ratio means a higher reward for risk-taking, thus it is preferable and is shown in bold in Table 3. Combining the return values from Table 2 and the standard deviation values from Table 3, the return/risk ratio values tell a familiar story. ESG funds perform better on average only in the bond type category for both time horizons (1-year and 5-year). In the mixed and absolute return categories, traditional funds perform better on average on a return/risk basis. For equity type funds, the results are mixed: traditionally investing funds have on average higher 1-year return/risk values, but ESG funds have a higher average for the 5-year metric. Considering the riskiness of the fund portfolios and the return/risk metrics, it seems that ESG funds outperform traditional ones only in the bond type category.

Looking at the Sharpe (1966) ratios, similar results emerge. Table 4 presents the 1-year and 5-year Sharpe ratios categorized by fund type and investment policy:

Table 4. Sharpe ratios categorized by type and investment policy

Type	Investment policy	1Y Sharpe	5Y Sharpe
Bond	Traditional	-1.78; **11.31** 1.86	-1.23; **0.20** -0.50
	ESG	**1.95**; 4.19 **2.95**	**-0.64**; 0.02 **-0.31**
Mixed	Traditional	-1.43; **10.61** **0.44**	-0.82; **0.51** **-0.04**
	ESG	**-1.40**; 0.50 -0.34	**-0.23**; -0.09 -0.16
Equity	Traditional	-11.38; **1.87** **-0.20**	-1.88; **0.71** 0.08
	ESG	**-1.31**; 1.12 -0.77	**-0.43**; 0.59 **0.11**
Absolute return	Traditional	-2.78; **7.53** **1.39**	-1.38; **1.18** **0.09**
	ESG	**-0.91**; 1.77 0.96	**-0.16**; -0.07 -0.11

Source: own construction based on BAMOSZ and ÁKK data

The Sharpe ratio is an advanced risk-adjusted return metric, where surplus return over the risk-free rate is divided by the standard deviation of returns. A higher value is preferable, as it means a higher surplus return for one unit of risk taken, they are shown in bold in Table 4. The results indicate again that funds with an ESG

investment policy only perform better on average in the bond type category. For the mixed and absolute return categories, traditional funds perform better on average. In the equity type category, the outperformance of traditional funds is apparent only for the 1-year Sharpe ratio, i.e. for the last year.

Summarizing the above results, Table 5 demonstrates whether ESG or traditional funds performed better by type categories for all the metrics evaluated.

Table 5. Summary of results

Metric	Bond	Mixed	Equity	Absolute return
1Y r	ESG	Traditional	Traditional	ESG
3Y r	ESG	Traditional	Traditional	Traditional
5Y r	ESG	Traditional	ESG	Traditional
1Y σ	ESG	Traditional	ESG	ESG
5Y σ	ESG	Traditional	ESG	Traditional
1Y r/σ	ESG	Traditional	Traditional	Traditional
5Y r/σ	ESG	Traditional	ESG	Traditional
1Y Sharpe	ESG	Traditional	Traditional	Traditional
5Y Sharpe	ESG	Traditional	ESG	Traditional

Source: own construction based on BAMOSZ and ÁKK data

Table 5 indicates that ESG funds dominate their traditional competitors in the bond type category, overperforming in all the metrics evaluated. For the mixed type of funds, traditional funds perform better in all metrics. In the absolute return category, ESG funds perform better only in the 1-year return and the 1-year standard deviation metrics. In the equity category, the results are mixed, as ESG funds seem to be performing better on the longer-term metrics.

5. Conclusion

As sustainable and ESG investing is getting more popular, researchers and professionals are interested in determining whether this novel approach to investments has an opportunity cost, i.e. whether the investor has to accept a financial sacrifice by investing in such assets, e.g. ESG mutual funds. This paper has analyzed the performance of Hungarian mutual funds to shed light on the topic in this particular market.

Four types of funds were analyzed: bond, mixed, equity, and absolute return. The return, riskiness, and risk-adjusted return of the funds were collected and calculated with data from BAMOSZ and ÁKK. The results indicate that ESG mutual funds perform better on average only in the bond type category, while funds investing traditionally have better risk-adjusted performance in the mixed and absolute return fund type categories. For equity type funds, the results are ambiguous.

Naturally, the analysis has some limitations. First, a relatively small number of ESG or sustainable funds in the Hungarian market does not allow more advanced statistical techniques of comparison with traditional funds. Second, only Hungarian

funds, denominated in HUF were used in the sample, but the sample size could be increased by expanding geographically, e.g. to the CEE region, and by including funds denominated in other currencies as well. Finally, other risk-adjusted performance measures, e.g. Jensen's alpha (Jensen 1968) or max drawdown could be calculated and compared for ESG and traditional mutual funds.

Another avenue of further research could be the detailed evaluation of the investment policies of the ESG and sustainable mutual funds via monthly and annual reports, to uncover why they may overperform in the bond type category, and why they may underperform the traditional funds in the other categories. One thing is certain: sustainability and the ESG framework in finance and the world of investments is a topic that is worth further analysis.

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Analyzing the waste management attitude and behavior of university students

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Effective waste management is a crucial aspect of any sustainable economy. Therefore, analyzing the attitude, behavior and intentions of consumers can lead to significantly reducing waste disposal and positively affecting the environment, economy, and society. This study is part of a comprehensive research project meant to identify and analyze the main factors influencing consumers' behavior towards waste disposal. In this methodological paper the focus group discussion guide used is verified, and the question of whether audio stickers can improve the effectiveness of such focus group discussions is tested. After a thorough overview of the literature both quantitatively and qualitatively, two pilot focus group discussions among Hungarian university students were carried out. The focus guide was built upon previously performed World Café results. Brainstorming emerged as highly effective method for evoking a wider array of ideas. The World Cafe categories, while providing structure, did not foster deeper exploration and in some cases even restricted the responses. The use of audio stickers facilitated the sharing of personal examples and emotions. It also contributed to a more relaxed interview atmosphere. Overall, the methodology used here can help increase the effectiveness of the interviews, which in turn can deepen the understanding of the factors influencing consumers' responsible waste management behavior and attitude.

Keywords: waste management; interview; university students; attitude; behavior

1. Introduction

In the context of increasing environmental threats and their consequences, waste management has become a key issue worldwide (Singh et. al. 2014). Attitudes and practices of good waste management are not a general characteristic of the population but an activity influenced by norms, education, information, and knowledge (Baba-Nalikant et al. 2023). To change our own lifestyles, particular emphasis must be placed on changing attitudes, raising awareness of environmental problems, and encouraging action. In order to shape the attitudes of society and the population, it is necessary to examine the incentive tools and methods to influence people and to map the attitudes of different groups of the population, so that they can be reached with effective methods and appropriate communication tools and channels. One of the growing problems of our time is the increasing amount of waste generated by the population and industry together, much of which remains untreated.

To mitigate the environmental damage, we need to rethink waste management at several levels. The responsibility does not only lie with the organizations involved in waste collection and processing. To contribute effectively to a sustainable future, and to reduce the amount of waste generated and increase the amount of waste collected, we need the cooperation of all stakeholders involved in the process. Governments in power need to put in place the right legislative framework and ensure

that legislation is respected and enforced. Businesses should strive to use more environmentally friendly technologies and to promote sustainability in their operations (Nidumolu et al. 2019). Consumers can help to turn waste into recyclable waste by making informed choices and by collecting the waste they buy separately. Waste management in Hungary is undergoing a transformation. After July 1, 2023, the current system of shared municipal and state waste management was replaced by a centralized waste management system. The new system is in line with EU (European Union) recycling quotas: by 2040, 65% of total domestic waste should be recycled (EP 2018).

We aim to contribute to these targets through the work of our research team. We are working to identify the factors that influence (promote and inhibit) individual selective waste collection. Prior to the present research, we have used literature analysis and World Cafe methodology to identify the main factors that inhibit selective waste collection (e.g. lack of motivation, lack of interest, lack of knowledge, indifference, and laziness). The results shall contribute to the development of educational content that will help raise public awareness and thus contribute to a more efficient collection of household waste. Based on our aims and goals, and the suggestions of the literature, we have formulated two research questions for the pilot focus groups. First, we investigated to what extent the stimuli (interview tools and methods) employed in focus group sessions effectively guide participants' responses towards the intended objectives. We have also examined in the context of focus groups, whether predefined frameworks inhibit or enhance outcomes. Specifically, whether participants confine their responses within given categories, or whether these categories stimulate further discourse. These research questions were answered based on two focus groups, as well as content analysis.

At the beginning of the paper, we briefly outline some insights from previous qualitative studies that have influenced our research design. Subsequently, we explore the background of our study and provide an overview of the preliminary results upon which we have built our methodology. Following this section, we present the findings of our bibliometric analysis, demonstrating the increasing application of focus groups in investigating waste management practices among consumers. We then proceed to examine the potential advantages and disadvantages of utilizing focus groups. Next, we discuss our research aims, detail our data collection methods and results, and conclude with a discussion. It is important to note that this paper primarily emphasizes methodological considerations rather than addressing the waste management practices of citizens in detail.

2. Qualitative approaches in the literature

Our aim has been to use focus interviews in our study. Similar methodological approaches have been utilized in many social science fields. Repisky and Tóth (2019) highlight the importance of rigorous coding processes for interview data, prioritizing independence from pre-existing theories. While our methodology may not directly mirror their recommendations, we have been inspired by their principles to ensure that our analysis reflected the inherent patterns within the data (Gelencsér 2003). Similarly, Obermayer et al. (2021) advocate for structured managerial interviews and

the utilization of software tools like Atlas.ti for qualitative data analysis. In this study this software was also utilized for basic word co-occurrence and content analysis.

In addition to these methodologies, Sántha (2021) outlines typological qualitative content analysis techniques for categorizing data based on similarities. We have recognized its value in qualitative analysis and drawn inspiration from its principles. Géring et al. (2014) provide insights into mixed methods approaches, which integrate qualitative and quantitative data for a comprehensive understanding of research topics. This was also taken in consideration by our research design. Kocsis and Hrabéczy (2023) emphasize the importance of methodological rigor through manual coding and intercoder reliability checks. While our methodology may differ in certain aspects, we recognize the significance of their recommendations in maintaining the credibility and validity of qualitative analysis.

3. Background to the research

Prior to the present study, our colleagues conducted a fact-finding study with approximately 100 participants in 3 different groups in October through December 2023, using the World Café methodology. Data collection was carried out in three steps. A different working technique was used in each step. The steps of the data collection process and the working methods used are summarized in Table 1.

Table 1. Data collection process

Data collection steps		Type of work
1	collecting obstacles to separate waste collection	individual work
2	grouping and categorizing the barriers to separate waste collection and naming the resulting groups	large group work (involving all participants together)
3	processing the content of the jointly developed categories and collecting proposals for eliminating or reducing the obstacles to separate waste collection	work in small groups of 4-6 people

Source: own construction

The factors that prevent separate waste collection were explored by collecting personal experiences of the individuals surveyed through the following question: "What are the factors that prevent you, your friends, people you know or people you do not know from collecting separate waste separately from household waste or from placing it in a designated waste bin?" In the second step of the World Café, the responses collected individually from the participants were grouped and then collectively labeled. In the third step of the survey, these newly formed categories were further developed. Participants were asked to design solutions to eliminate barriers to separate waste collection or to reduce their impact. Participants could make their suggestions at three levels. The three suggestion levels were the micro level (individual, family), the meso level (narrow community, e.g. institutions, employers, training institutions, local government), and the macro level (public or legislative level). The World Café study identified 7 main categories of barriers to separate waste collection (see Table 2).

Table 2. The seven main categories of barriers to separate waste collection

Name of categories	Number of mentions	Percentage of mentions
Lack of willingness to separate waste	45	39.82
Lack of physical conditions for separate waste collection	29	25.66
Lack of credible information on separate waste collection	23	20.35
Lack of financial benefits	5	4.42
Lack of individual skills	5	4.42
Lack of time	5	4.42
Lack of sanctions	1	0.88
Total	113	100%

Source: own construction

The results of previous studies also show that the groups surveyed have a relatively high level of environmental awareness in theory, yet many do little in practice to protect their environment (Szűcs–Hámori 2016). This is in line with our World Café study.

Regardless of the age group, a common characteristic is that the willingness to collect separately and the lack of infrastructure negatively affect the willingness to take active action. This is in line with the findings of Domina and Koch (2002) and of Halvorsen (2012). They show that convenience is an important aspect of selective waste collection (Domina–Koch 2002). The availability of infrastructure and measures to increase accessibility can have a positive effect, while that the lack of infrastructure can have a negative effect on waste collection (Halvorsen 2012).

Based on the results of a study in our country (Szűcs and Hámori 2016), it can be said that the problem in row 3 of Table 3, i.e. the lack of credible information, is also prominent. Szűcs–Hámori (2016) also found that misconceptions about waste collection (e.g. separate waste is poured together during transportation) influence waste collection behavior. The resulting findings were further investigated through a focus group discussions. The main purpose of the focus group discussions is to get to know the problem as thoroughly as possible and to explore it in detail (Malhotra, 2009). One of the main advantages of this methodological triangulation (i.e. using several methodologies to investigate the same research question) is to check whether the results obtained with different methods are correlated with each other (Géring et al. 2014).

4. Bibliometric analysis

As the first step of our analysis, we wanted to find out how common focus group discussions in waste management related research are. Using the Web of Science (WoS) database, we looked at publications where focus group discussions were used out as a means of analysis. WoS was chosen as our main literature database, as it has one of the highest international publication coverages (see, for example, Birkle et al. 2020). When searching for ‘focus interview’, one can find more than 100

thousand documents (160,193 publications as of March 18, 2024). This number shows that ‘focus interview’ is a quite common qualitative analysis method.

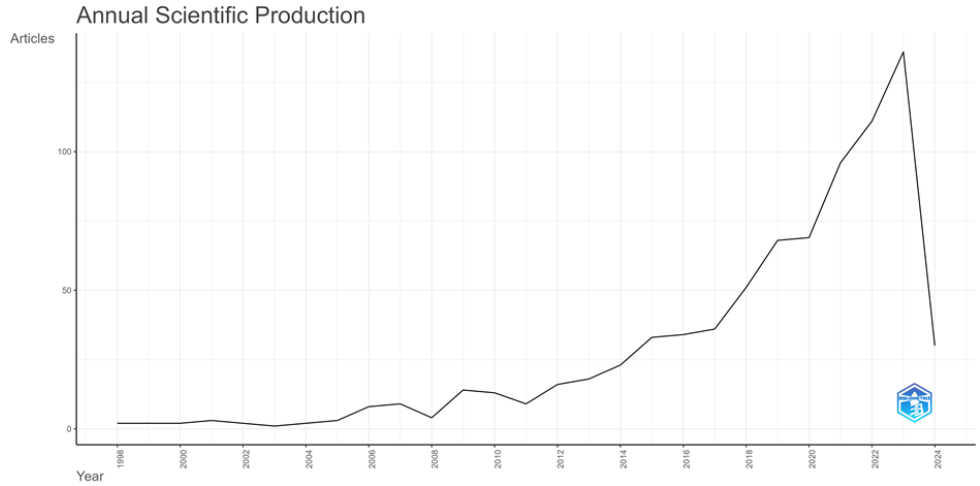
As our research concentrates on waste management, we narrowed down our publication search with the following algorithm ((ALL=('focus interview') AND ALL=(waste) AND ALL=(management)). In this way we were able to retrieve publications related to waste management topics where ‘focus interviews’ were used as means of analysis. One can see that there is a large number of studies using this methodological tool (795 in number as of March 18, 2024, the date when the publication database was downloaded). Using focus group discussions is quite common in waste management related research, thus applying it in our research seems well-motivated. The main bibliometric properties of the database can be seen in Figure 1.

Figure 1. The main bibliometric properties of the publication database

Source: own construction via R (Biblioshiny), based on the Web of Science database

The earliest publication is from 1998, while articles from the first quarter of 2024 are also covered. Most of the documents analyzed are articles and written in English. Other languages used included Spanish, Portuguese, French and, in one document, Lithuanian. The average number of authors is 3.5. Single-authored publications are quite rare (less than 10%). Interestingly, more than a quarter of the documents analyzed are international co-authored papers (28.8%). The time distribution of the number of publications retrieved can be seen in Figure 1. Although the average annual publication growth rate is 10.98% (see also Figure 2), the number of the articles published shows a skewed distribution. Only 2 documents are from 1998, while the number of publications from 2023 is 120.

Figure 2. The time distribution of the number of publications retrieved



Source: own construction via R (Biblioshiny), based on the Web of Science database

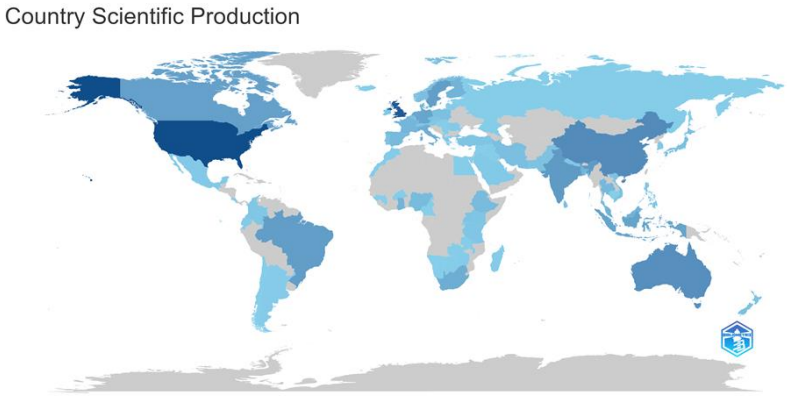
An exponential publication growth starting roughly from 2014 can be observed. Beginning with 2021 more than 100 articles were published each year (except in 2024, an unfinished year). Approximately 45% of the publications analyzed are from 2021, 2022, and 2023.

The average citation per document is 15.93, however, the actual citations of publications show an uneven distribution. There were 631 documents that received at least one citation (79.37%), but only 18 received more than 100 (2.3%). The paper with the most citations (478 citations) presents the results of expert interviews and a literature review on factors causing consumer-related food waste in households and supply chains. It is shown that consumers' motivation to avoid food waste, their management skills of food provisioning, food handling, and their trade-offs between priorities have an extensive influence on their food waste behaviors (Aschemann-Witzel et al. 2015). The publication with the second highest number of citations (285) analyses the causes of food waste in the supplier–retailer interface in Spain and UK (Mena et al. 2011). It can be seen that the citation difference between the top two articles is more than 100, thus, a quite skewed citation distribution can be observed.

The journal containing most of the articles is *Sustainability* (68 articles), while the second highest number of documents is from the *Journal of Cleaner Production* (46 articles). Only 4 contained more than 20 articles, and from the 428 journals present in our publication database, just 108 (less 14%) have more than 2 documents. We also examined the country affiliation of the retrieved publications (see Figure 3).

As a next step, we looked at the geographical distribution of the publications (see Figure 3).

Figure 3. Country distribution of publications related to the topic analyzed



Source: own construction via R (Biblioshiny), based on the Web of Science database

Researchers from both developing and developed countries used focus group discussions to analyze the aspects of 'waste' (waste management). In total, there were 88 countries mentioned. It comes as no surprise that USA (292 affiliations), UK (262 affiliations), China (145 affiliations), and Australia (135 affiliations) are the countries with the highest number of publications. The latter two showed an increasing performance starting from 2008. Interestingly, however, researchers from developing countries such as Ghana (54 affiliations) or Ethiopia (39 affiliations) were also quite active in publishing waste management related articles. When it came to citations, however, English speaking and developed countries seemed to dominate. The most cited countries were the UK, the USA, and Australia, while Denmark, the fourth most cited, was the top non-English-speaking country.

Overall, the quite extensive number of publications related to ‘waste management’ and ‘focus interviews’ supports our assumption that focus group discussions can be an appropriate tool to examine the waste management behavior of consumers. As the retrieved publication database was only used to support the validity of our methodology, only a simple bibliometric analysis was carried out. Thus, a thorough data cleaning and a more complex analysis of the retrieved documents is outside the scope of our present study, and it is left for further research.

5. Advantages and disadvantages of focus groups

Although the data from our bibliometric analysis confirms that the use of the focus group discussion methodology is relevant for the present study, we should be aware that the use of this method, beside advantages, may also have disadvantages. The "course of the interviews is influenced by various social-psychological and psychological mechanisms" (Vicsek 2006, p. 478, our translation). Indeed, it is a well-known fact in the social sciences that increased attention to research subjects alone can influence the behavior of the individuals observed (Perrow 1997).

The homogeneity or heterogeneity of the group also influences the group's results. According to Vicsek (2006), a homogeneous composition tends to create a more pleasant atmosphere and stronger group cohesion, thus homogeneity was one of our aims when selecting the sample of students. The content of the focus group is also an influencing factor. "The topic, the main aspects of the interview outline/guide, the characteristics of the questions (e.g. how broad they are), the order, the style and language of the questions and the specific techniques used in the groups are all factors that influence the way the group proceeds" (Vicsek 2006, p. 489, our translation). We tried to minimize the impact of these influencing factors in our interviews.

In addition to the content and format of the focus group discussion and the impact of the tools and methods used, the personal characteristics of the moderator can also influence the conversation (Farquhar 1999), as can the physical characteristics of the focus group discussion (Stewart–Shamdashani 1990). To ensure that these effects were consistent across both groups studied, discussions were conducted in the same focus group room and the same person conducted the discussions in both cases.

Malhotra (2009) listed other advantages and disadvantages of the focus group discussion, as shown in Table 3.

Table 3. Advantages and disadvantages of focus groups

Advantage	Disadvantage
Special information	Bias towards group selection
Synergy	Bias towards moderator selection
Snowball effect	Bias towards environment
Encouragement	Non-representativeness
Safeness	Inappropriate application
Spontaneity	Bias in the discussion conduct
Valuable thoughts that arise unexpectedly	Disorganization
Specialization	Misinterpretation
Academic rigor	
Structure	
Speed	

Source: own construction based on Malhotra (2009, pp. 188-189)

In our analysis, we have tried to validate the advantages listed above and avoid the disadvantages.

6. Research aims and questions

6.1. Aim of the focus group discussion

In general, the goal of the focus group discussions is to understand household selective waste collection behaviors. We aim to explore factors that promote and inhibit responsible waste management, identify misconceptions and knowledge gaps, and understand motivations behind inaction despite awareness. This includes examining

attitudes and psychological characteristics related to selective waste collection. To achieve these objectives, we investigate the most effective tools and methodologies. This methodological paper details our pilot focus groups, which had two primary aims. First, to test our focus group guide for its effectiveness and suggest improvements. Second, to evaluate the methodology, examining the efficiency of tools like gamification, brainstorming, audio stickers, and presenting pre-existing knowledge.

6.2. Research questions

Although the guiding questions of the two focus group discussions were the same, the methods used to ask the questions differed. Based on our aims and goals, and the suggestions of the literature, we have formulated the following research questions for the pilot focus groups:

- **Research question 1:** To what extent do the stimuli (tools and methods) employed in focus group sessions effectively guide participants' responses towards the intended objectives?
- **Research question 2:** In the context of focus groups, do predefined frameworks inhibit or enhance outcomes? Specifically, do participants confine their responses within given categories, or do these categories stimulate further discourse?

These research questions were answered based on two focus groups, and with co-occurrence, observations, and content analysis, further detailed in the following sections.

7. Data collection and methodology

7.1. The setting and participants

The setting and participants of the study were crucial components that contributed to the depth of the research findings. These, considering the qualitative nature of the method, can be of great importance. They are also stated amongst the weaknesses of the focus group discussions. The recruitment criterion for the participants was to ensure homogeneity and methodological comparability between the two groups. A further criterion was that the respondents should know each other. This was important to be able to create a more relaxed atmosphere in which expressing opinions freely was possible. The basis for our group formation in this part of the research were the students at the University of Pannonia's Faculty of Economics. This section provides detailed insights into the venue, group composition, date, duration, and methodology employed during the research sessions.

Venue and date: The discussions were conducted at the Marketing Laboratory of University of Pannonia. The sessions took place on February 12, 2024.

Group Composition: The participants were divided into two focus groups, each comprising individuals of quite similar backgrounds. The composition of these groups was deliberately mixed based on gender to ensure varied viewpoints and

experiences. However, homogeneity was maintained based on age group and residence to minimize potential biases and enhance the relevance of discussions. Each focus group consisted of five individuals, allowing for intimate and in-depth conversations.

Duration: Each focus group session lasted for 90 minutes, providing efficient time for thorough discussions and engagement with the research tasks.

Methodology: The research methodology employed a combination of open-ended questions and interactive tasks to stimulate participant engagement and support diverse perspectives. Several projective techniques were used during the focus group discussions. Projective, as a technique of association, construction, and expression, encourages respondents to express their motivations, views, feelings, and attitudes (Malhotra–Simon 2017). Various techniques, including audio stickers, brainstorming sessions, World Café categories, and a free association game were utilized to encourage creativity, spontaneity, and depth in responses. These methodologies were carefully selected to foster a dynamic and collaborative environment conducive to meaningful dialogue and exploration of the research topic. Some of these techniques were only used in one group, and the other group served as a control group.

7.2. Methodology

In this chapter, we describe the methodology employed in our research, highlighting the utilization of two types of data collection and analysis techniques to ensure a comprehensive understanding of the research subject. We employed a dual-pronged approach to data collection, incorporating both focus group discussions and observational data.

Focus group discussions: The focus group discussions were conducted and recorded to capture the discussions and perspectives. Subsequently, transcripts of these discussions were generated for in-depth analysis. Textual data from these transcripts were then subjected to co-occurrence and content analysis techniques to identify patterns, themes, and insights relevant to our research objectives.

Observational data: In addition to focus group **discussions**, we integrated observational data gathered by an external observer. Positioned discreetly behind a blank window during the **discussions**, the observer keenly noted down her observations, capturing non-verbal cues, group dynamics, and other contextual nuances that might not be explicitly expressed by participants. These observational data provided supplementary insights and enriched the overall understanding of the research context.

Following data collection, we employed analytical tools to extract meaningful insights from the collected data. Textual data extracted from focus group transcripts underwent thorough examination and analysis using Atlas TI software. This qualitative data analysis tool facilitates the systematic coding, categorization, and interpretation of textual data, making possible to identify recurrent themes, patterns, and connections within the dataset.

8. Tools and methods applied

In addition to open-ended questions, the focus group discussions used a number of interactive exercises and projective techniques.

8.1. Audio stickers

Audio stickers were used as a tuning tool for the experimental group. Sander and Höttecke (2014), in a qualitative study of students' judgement, found that audio matrices are suitable as stimuli.

Figure 5. The audio stickers and their content

Source: own construction

By briefly describing a situation, audio matrices can provoke statements from group discussion participants, trigger ideas and decision-making situations. They have the advantage of being less restrictive than video stickers, as they are not influenced by visual stimuli such as gestures and facial expressions. They can be encouraging or elicit statements, and they tend to resemble to the participants' experiences. The voice matrices are situation and context oriented (Sander–Höttecke 2014). For our experimental focus group discussion, we formulated short messages suggesting 10 inhibiting and supporting factors. We made audio recordings with child, female, and male participants, i.e. voice stickers evoking short descriptions of positive and negative situations. Our aim was to create the most open conversation impulses possible. In the group, after listening to the sound stickers, we asked the participants about their feelings and thoughts. It was interesting to see what feelings they associated with the messages they heard about waste management.

8.2. Brainstorming

The advantage of this method is that a relatively large amount of information can be obtained in a very short time on a given topic, and the evaluation of ideas and solutions is very simple (Nahlik 1987, Osborne 1953). In order to identify good solutions in the interviewees' environment, this method was used to gather information during both focus group discussions. The aim was to identify factors that promote and hinder responsible waste management. The work involved informal responses to questions

written on a whiteboard by the participants, followed by a group discussion to organize and evaluate the written and spoken reflections.

8.3. Free association game

When examining the information channels and content of attitude formation, we asked the students to individually write down on a sheet of paper the topics they suggested. Then we closed the discussions with a **projective technique,** playing association games and recalling stories (Malhotra–Simon 2017). According to Joffe and Elsey (2014), if a question about attitudes and behaviors is asked directly, answers are unlikely to reflect how people see the issue in its full reality and complexity, but the free association technique can offer a window into implicit content (László 2022). The free association games technique provides an opportunity to uncover implicit content and better understand consumers, namely, what selective waste management means to citizens and what concepts they associate with it. Social representations are systems of social influence and communication that constitute the social reality of distinct groups within society (László 2022).

9. Results

9.1. Introducing audio stickers

The results demonstrate that audio stickers are highly effective as an interviewing tool in focus group discussions. They encouraged participants to share more emotional content and personal examples, rather than making generalized statements about others. Furthermore, audio stickers successfully eased the atmosphere, proving to be an excellent icebreaker and facilitating more open and engaging discussions.

Table 4. Comparison of the focus groups based on the results of the brainstorming

	Group 1	Group 2 – with audio sticker
Content diversity	Participants had one opinion each with or without the audio stickers.	
		Content-wise no more information was immediately available thanks to the sticker.
Type of content shared (What feelings do you connect to selective waste management?)	Two participants shared internally induced content, the other three spoke about infrastructure, external factors at the beginning.	Four participants shared feelings and internal factors, and one concentrated on external barriers
Group dynamics	With no sticker, participants were very half-hearted, reserved, and the atmosphere started to get dull after about 30 minutes in the 3rd block of topics.	With the audio stickers, smooth and enthusiastic conversation flowed from the beginning.

Source: own construction

The first thing we found in both groups was that only one response was given to the question asked by the moderator, either with or without a sound sticker. Although no more information was provided using the sound stickers, the conversation started off in a half-hearted and subdued manner without the use of these stickers, and only after about 30 minutes, when the third topic was discussed, did the atmosphere begin to lighten. In contrast, when employing sound stickers, the conversation was more relaxed from the start. The factors mentioned in the experimental group confirmed that the sound stickers evoke internal feelings easily, as shown by the phrases used by the participants: *"I'm used to it", I feel bad"," I felt obligated, but it's weird if I don't do it."* In addition, without the sound stickers, the participants' feelings were predominantly related to external factors.

Table 5. Feelings evoked by participants

How do you feel about separate waste collection? (inner feelings, motivation, or external factors)			
Without audio stickers		**With audio stickers**	
INNER	*"...Anyway, it's great, because I can do something for my environment, so that we can live in a cleaner environment..."*	INNER	*"...something that has grown on us, I don't feel that it makes me feel any particular emotion, but it feels like a general thing to do..."*
INNER + EXTERNAL	*"...I'm used to separate waste collection, now we have a blue bin like this at home, and we throw the bottles in it, we also take care of it in the dormitory, so I actually like it..."*	INNER	*"...it's been ingrained in our lives since birth, but I don't think everyone applies it regardless..."*
EXTERNAL	*"...I don't think we can do it as well as we should, and we can't do it as well as we should, and we still don't have the conditions to actually collect waste separately..."*	INNER	*"...that's the way we should all perceive it, so that we can make it a little bit better, so that in a few years we'll still be as healthy..."*
EXTERNAL	*"...obviously I try to pay attention to this, but, for example, where I come from, so where I live in a small village, they collected the recycling bins, so they were put out, and they decided not to continue..."*	INNER + EXTERNAL	*"...It's a completely positive thing I think, and it has as much impact on the environment as it does on society, and it doesn't take any longer than if you throw it in one place, because you usually have these bins next to each other."*
EXTERNAL	*"...but now I've somehow got to the point where, if I don't have it in me at the office level, but let's say at home, where I really have the possibility, because I have a separate bin for mixed and selective, a small bin for each..."*	EXTERNAL	*"...but there are still a lot of places where it's difficult to do this, for example in the countryside, or even in prefabricated buildings, where you have to carry it down, that it might be a problem for somebody."*

Source: own construction

9.2. Brainstorming

As a group work method, brainstorming can provide the additional result of more informal collective thinking compared to individual responses and reflection. It allows the participants to respond informally to a question written on a whiteboard and to write, organize and evaluate the ideas expressed on the whiteboard. In both focus group discussions, this method was used to gather information about good practices regarding responsible waste management in the participants' environment. The moderator wrote down on the flipchart the 3 levels (micro/household, meso/municipality, municipality/waste management body, and macro/government), where they perceive and see tangible efforts. During the discussion, we also examined the factors that hinder the separate collection of waste, building on the results of the previous World Café method. For methodological comparison purposes, we asked only open-ended questions in our first discussion to explore the barriers and enablers in the practice of selective waste collection. However, for the other group, the results obtained during the World Café were shown by the moderator on a flipchart and, based on the factors already identified, he asked the participants to give examples of these categories from their own lives. We then aimed to identify additional inhibiting and supporting factors in addition to those listed. A brainstorming activity was proposed for the question: who is responsible for what, when it comes to selective waste management? The participants then worked together to collect the tasks for the responsible actors on the micro, meso and macro levels.

Table 6. Comparison of the focus groups based on the results of the brainstorming

	Group 1	**Group 2**
Content diversity	Similar content in both groups	
Type of content shared	Diverse content, working on other ideas, reflecting on each other	
Group dynamics	Working in group, using a smart broad together in general boosted the eagerness of participation	

Source: own construction

The most important lesson learnt was that the two groups were similar based on content diversity, type of content, and group dynamics. The differences in the other tasks might be due to the application (or non-application) of the different methods, not the differences arising from the groups.

9.3. World Café categories

Pre-existing knowledge has been presented to one of the groups, and then the same question was asked from both focus groups: "Who is responsible for what, when it comes to selective waste management?" One group was presented with the World Café categories, while the other group was not. The group exposed to the categories exhibited a more structured and methodical approach in their responses. They seemed to engage with the provided categories, leading to a facilitated exchange of ideas and a more confident expression of opinions. However, this adherence to categories also

constrained their thinking, as participants got stuck within the predefined framework, limiting the exploration of alternative viewpoints.

Table 7. Comparison of the focus groups based on the WC category presentation

	Group 1	**Group 2 WC categories presented**
Content diversity	participants share exact examples of barriers	participants get stuck in the presented content.
Type of content shared	internal thoughts, real-life situations	more general thoughts, less examples of their own feelings.
Group dynamics	more half-hearted response according to the observer	presenting the WC categories supported the courage of expression

Source: own construction

In contrast, the group without predefined categories demonstrated more diverse and spontaneous responses. Participants were observed to provide more hesitant responses when no specific categories were provided. However, they shared feelings, private thoughts, real-life situations, and examples of barriers, enriching the discussion with a broader range of perspectives, and serving more our research objectives. The absence of categories allowed for greater flexibility in thinking and encouraged participants to freely express their opinions without being confined to predetermined frameworks. This distinction highlights the importance of carefully considering the use of structured approaches, such as World Café categories, in facilitating discussions and achieving research objectives.

9.4. Projective technique

By using the projective technique, we wanted to encourage respondents to express their feelings and views on the issue of separate waste collection. By using these techniques, respondents indirectly formulate their motivations and attitudes by interpreting the behavior of others in relation to a given situation. In marketing research, association, complementary, construction and expression techniques are used (Malhotra and Simon, 2017). The discussion was concluded in both groups by playing an association game and recalling personal stories. The students were asked to quickly, without thinking, write down on post-it notes five words that came to their minds about selective waste collection. After that they were asked to recount a personal experience related to waste selection. In each group, 21 of the thoughts expressed by the participants were positive and 3 negative, such as *"accumulation, problem"*.

Figure 4. Word cloud based on the free association games

Source: own construction (WordArt)

The other associations are related to the framework, the design, and material factors: *"dustbin, paper, collection, rubbish, colors, used items, plastic, etc."*. When looking at word frequencies, most associations were *"bin (4), collection (4), environment (3), recycling (3), plastic (3)"*. The result of the summary of the association ideas highlights the importance of the future for the young age group, with 21 positive mentions of this idea out of 50 associations: *"children, sustainability, important, earth, environment, solidarity, selective, nature, recycling, receptivity, circular, environment, environment, future"*.

We ended the talks by recalling personal stories. Respondents were asked to share with us any experiences or memories they had with the practice of separate waste collection. Four people recalled childhood experiences or memories. One such story was the following: *"We took a toy kitchen from a house during a waste clearance. I played with it for years afterwards, so it was useful."* The others remembered it as being linked to material factors, to the existence of conditions. One respondent described positive factors, but five participants listed mainly negative factors, events that annoyed them (lack of selective condition, lack of material condition, or non-exemplary attitude of the manager at work).

The respondent who recalled their positive experience also suggested the following on the subject: *"Otherwise, for me, the decisive factor was the visit to the yard. Here in the Springs, it was a very thought-provoking experience. I think that everybody should go there and see where the PET bottles that they throw away end up, or I don't know, the wine bottles that accumulate after an event, so I think that this should be made much clearer to people."*

10. Conclusion

In discussing the findings of the present study, it is important to align them with the multifaceted objectives we set out to achieve through the focus group discussions. Our primary aim has been not only to explore the factors promoting and inhibiting responsible waste management but also to rigorously test the methodology itself. We have aimed to examine the efficiency of the applied tools and methods, particularly

concerning target access and the efficacy of evoking meaningful responses from participants. Central to our study have been the research questions designed to assess the effectiveness of the stimuli, encompassing the tools and methods employed during the focus group sessions. We probed the extent to which these stimuli guided participants' responses towards the intended objectives, to understand whether predefined frameworks, such as the World Café categories, inhibited or enhanced outcomes. Specifically, we have investigated whether participants felt confined within given categories or if these categories stimulated further discourse and exploration of diverse viewpoints.

Our methodological approach includes the utilization of Atlas.ti and R-Studio (Biblioshiny) for content analysis and word co-occurrence analysis. Moreover, external observations were conducted to provide additional insights into group dynamics and participant engagement throughout the discussions. Through this methodology, we have aimed to gain comprehensive insights into the efficacy of different discussion methods and tools in achieving our research objectives. From our analysis it becomes clear that the choice of discussion methods and applied tools significantly impacts the depth and diversity of responses obtained.

The use of World Café categories tended to yield general ideas rather than real-life examples. It also placed limitations on the scope of discussion and failed to evoke new ideas beyond the predefined categories. Brainstorming proved to be highly effective in generating multiple ideas and fostering a relaxed atmosphere. This method facilitated the emergence of innovative ideas and encouraged a more open exchange of thoughts and opinions. The use of audio stickers encouraged participants to share real-life examples and express their emotions, contributing to a more relaxed atmosphere throughout the focus group discussion. Unlike the World Cafe categories, this method did not impose limitations on participants' thinking and made it acceptable to express negative ideas. When posing a single open-ended question, participants typically focused on a single factor. However, brainstorming emerged as an excellent method for evoking a wider array of ideas. The World Café categories, while providing structure, did not foster deeper exploration and often restricted responses. The use of audio stickers facilitated the sharing of personal examples and emotions, contributing to a more relaxed atmosphere throughout the discussion.

The insights gained from the pilot focus group discussions provided valuable lessons for future research. Building upon these findings, we plan to conduct additional focus groups, applying the lessons learned to refine our approach and deepen our understanding. These focus groups will encompass diverse demographic groups. Based on lifestyle, high school students, young adults entering the labor market, active labor market participants, and pensioners are going to be the focus of our future focus group discussions. By engaging with a broad spectrum of participants, we aim to capture a comprehensive range of perspectives on waste management behavior. Furthermore, drawing from the qualitative data collected in these focus groups, we will design a questionnaire, which will serve as a complementary tool to further explore and validate our findings on a larger scale. Employing a mixed-method research approach, integrating both qualitative and quantitative analyses, will enable us to triangulate findings, enhancing the robustness and depth of our research outcomes.

Our results highlight the importance of selecting appropriate discussion methods that align with the research objectives. While structured approaches like the World Cafe categories may provide some guidance, they can limit the depth and diversity of responses. In contrast, methods such as brainstorming and the use of audio stickers facilitate a more open and creative exchange of ideas, fostering a conducive atmosphere for exploration and insight generation. Moving forward, researchers should carefully consider the dynamics of different discussion methods to ensure optimal outcomes in data collection and analysis.

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Analysing selective waste collection habits using the World Café Method: A case study among the students at the University of Pannonia

Boglárka Konka – Attila Szűcs – Beáta Szentmiklósi – Zsuzsa Darida

In this study, one of the aims of applying the World Café Method (WCM) is to identify the barriers to selective waste collection among students at the University of Pannonia. According to the results, the most common barriers that influence selective waste collection behaviour are the lack of willingness, lack of infrastructure, and lack of credible information on separate waste collection. The second goal is to collect, together with the participants, suggestions for solutions to the problems identified, at three different levels.
The results of this study could contribute to strengthening a circular economy model that takes into account the interests of society and the economy, including the transformation of habits related to selective waste collection. It will also serve as input for further research and the development of educational content for impacting waste collection habits.

Keywords: selective waste collection; World Café Method; university students; habits

1. Introduction

Waste management has evolved significantly over the last decade as part of the circular economy, due to changes in its global trend (Durrani 2019, Karimi et al. 2023, Chintipalli et al. 2023). In Hungary, a new waste management system came into force on July 1, 2023, with a single concessionaire for the collection, treatment, and invoicing of municipal waste at the national level, replacing the current system of shared municipal and state waste management responsibilities with a centralized waste management system. The new system is aligned with EU recycling quotas: by 2040, 65% of total domestic waste should be recycled (Agovino et al. 2024). We aim to contribute to these targets through the work of our research team.

In the history of selective waste collection in Hungary, there has never been a uniform, national level of educational campaign, so in the current situation it may be of paramount importance to carefully establish its effectiveness. It is also significant that there is an opportunity and a need to develop coherent attitude-building programs linked to uniform collection.

Within the project Nr. 2022-1.1.1-KK-2022-00002, titled "Establishment of a competence center for waste management at the University of Pannonia", our task is to create educational content for the inhabitants related to selective waste collection, which will also lead to behavioral change. In other words, our sub-project aims to strengthen the commitment to separate waste collection. However, to develop appropriate educational content, it is necessary to understand the knowledge, behavior and habits of the population in relation to selective waste collection in Hungary.

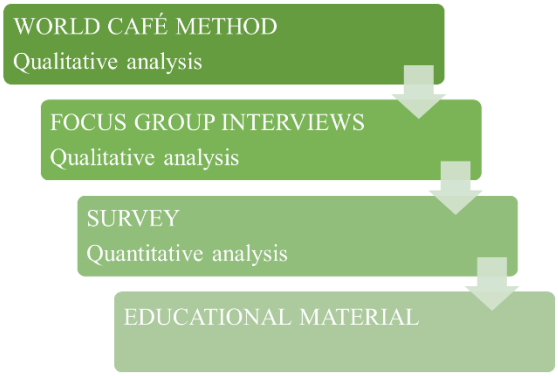
Therefore, as a first step, the goal of our subproject is to identify and understand the factors that keep the Hungarian population from collecting selective

waste. In this study, the World Café Method (WCM) was used. The WCM is an appreciated, inspiring and flexible participatory process, often used in combination with one or more other methods to identify emerging issues, gather best practices or suggestions, generate improvements or recommendations, and prioritize the implementation of projects or research agendas (Recchia et al. 2022).

In the application of the WCM, the obligations and opportunities for the public in relation to each waste stream are not yet known, especially with regard to individual, citizen responsibilities and legal requirements. No single education campaign is known for this period.

It should be stressed that the WCM and its results will be used as input for future research steps, such as focus group interviews and a questionnaire. The former method will provide deeper insights into the barriers to separate waste collection (Malhotra, 2009), while the questionnaire will allow us to understand the behavior of the population in relation to separate waste collection based on a large sample size. The interrelated studies are illustrated in Figure 1.

Figure 1. The research structure within the project



Source: own construction

One of the main advantages of this methodological triangulation (i.e. using several methodologies to analyze the same research question) is that we can check whether the results obtained with the different methods are correlated (Géring et al. 2014). The results of the WCM, the focus group interviews, and the questionnaire will help to scientifically substantiate the educational content related to selective waste collection and can effectively contribute to raising the awareness of the population and thus to increasing the amount of waste collected separately. This study presents the WCM related to selective waste collection and summarizes the results of our World Café rounds that have taken place up to the date of publication. The WCM for selective waste collection that we have developed has a dual purpose. The first objective (which is presented in the first part of our WCM) is to collect and group together the factors that hinder the selective collection of waste by the population. The second objective (which is in the second part of our WCM) is to gather together suggestions for solutions to overcome the barriers identified in the first part. In this phase of the research, the focus will not only be on good solutions that work, but also

on identifying and sharing innovative ideas. This paper starts with a literature review of the chosen method and continues with a description of the methodology and presentation of the results of our World Café rounds for selective waste collection. Finally, the main conclusions are summarized.

2. Literature review

Since the introduction of WCM over a decade ago, more than 200 publications based on it have appeared in Scopus-listed journals. The researchers highlighted the effectiveness of this method. For example, positive results are reported by Ropes et al. (2022). They led a three-World Café study of 18 participants to analyze the social and cognitive aspects of their participation. Participants enthusiastically reported how well the method encouraged people to share knowledge. Others talked about organizing their own café or similar event based on the example. They agreed that the usual workshop format and other types of low-interaction events, such as a lecture, provide a less effective environment for knowledge exchange. The organizers of the WCM found that the method, when adapted to the context, is well suited to achieving the desired research objectives (Ropes et al. 2020). Additionally, WCM has been used effectively in analyzing barriers and opportunities (Bertotti et al. 2012, Cosby et al. 2019, Kavanagh et al. 2020).

Löhr et al. (2020) complement the two well-established methods of qualitative research, semi-structured interviews and focus group studies, with the WCM, to help explore and control themes. As a participatory method, it not only generates data for the researchers but also potentially benefits the participants by facilitating dialogue and mutual learning, thereby motivating their participation and response (Löhr et al. 2020).

The WCM is used in different scientific areas, for example in the field of library and information science. The methodological strength of the research used was demonstrated by the way it brought the 'voice' of participants to the center by bringing out their experiences and engaging them in collaborative work with librarians (Kitzie et al. 2020).

Molnár and Földvári-Uricska (1998) used the Police Café in their study, a structured method to organize an innovative discussion to explore the possibilities of increasing public safety in the Hungarian police. Del Mar Gómez-Sánchez et al. (2024) used the method to assess the self-reported perspectives of participants in an intervention to prevent childhood overweight and obesity. Tessaro et al. (2023) used World Café data from 15 startup customers and suppliers to identify seven factors that explain how startups attract suppliers, maintain relationships with them, and achieve preferred customer status.

In addition to the examples mentioned, WCM have been applied in many other areas, including education (e.g. McDermott et al. 2020, Estacio et al. 2016) or health (e.g. Recchia 2022, Albrecht et al. 2022, Teut 2013). However, we could not find any research linking waste management, or within it, selective waste collection, to the WCM. One of the closest topics to our research that has been addressed with the WCM was renewable energy. Ruppert-Winkel et al. (2014) conducted a WCM with a mixed group of local actors and practitioners to explore the challenges of

achieving renewable energy self-sufficiency. They concluded that the method used had several positive outcomes: on the one hand, it facilitated joint thinking and exchange of ideas between participants to solve region-specific problems, and on the other hand, it contributed to future joint work and the setting of guidelines (Ruppert-Winkel et al. 2014).

Another issue concerns food waste. Folsberg et al. (2023) analyzed whether the public can be involved in the development of innovations to eliminate food waste. To answer this question, they used the WCM and, as in the present study, they involved university students to better understand the attitudes and habits of the growing generation.

A further study reports that the WCM was used to identify the elements that hinder or facilitate the transition from a linear to a circular economy in the Romanian textile and clothing sector (Staicu–Pop 2018). Based on the studies cited as examples, the method can be widely applied as a stand-alone qualitative research method or complement traditional methods, depending on the areas under study.

Although WCM has not been used by researchers to map behavior related to selective waste collection, several studies have analyzed it with different methods in the national and international literature. Usually, the researcher used a questionnaire to examine the behavior or habits of the households or consumers regarding the separate waste collection (for instance, Cheng et al. 2024, Sarker et al. 2024, Cantillo et al. 2023). The articles related to this topic often analyze different types of waste, like food (like Hermanussen–Loy 2024, Kunszabó et al. 2022, Olah et al. 2022, Stancu et al. 2016) or e-waste (for instance, Sabbir et al. 2023, de Oliveira Neto et al. 2022, Shaharudin et al. 2020, Saphores et al. 2012), however in our study we focus on all waste categories of the selective waste collection.

In the Hungarian literature, for example Németh and Mészáros analyzed the waste collection of households in Zala county. Based on their results, the barriers to separate waste collection are infrastructure and lack of space, while the most common response in terms of incentives is to implement door-to-door collection (Németh–Mészáros 2022). They also analyzed the attitude of the population in Győr-Moson-Sopron County towards selective waste collection, the scope of waste collected and the further fate of waste, and in priority cases the possibilities for reuse and recycling (Németh–Mészáros 2021).

In the Hungarian literature, the researchers mainly focus, for example, on food waste. For instance, Kunszabó and his colleagues carried out a food waste survey in Hungarian households. Their results show that Hungarian households underestimate their food waste levels, however, they think that they are able to reduce their food waste (Kunszabó et al. 2023). Another study demonstrates that the composting barriers of Hungarian inhabitants are lack of space, fear of rodents, and lack of knowledge (Kunszabó et al. 2022).

3. The World Café Method (WCM) in selective waste collection

We have chosen the WCM as a community participatory data collection method, which is recommended for a large group of participants. In our experience, the large number of participants and the repeated data collection with different participants in

the same way, ensured not only the exploration of themes, but also their verification and confirmation, and helped to avoid facilitation as a research methodological problem (The World Café Community Foundation 2015).

Another important reason for choosing this method is the assumption that people already have the wisdom and creativity to face the most difficult challenges (Wen-Long–Shih-Ting 2015) and are able to identify the problems of residential selective waste collection that have been present in Hungary for decades and to propose solutions. Thus, it also collects the knowledge that exists among the population.

For our project, we plan to study several groups of different statuses (including high school students, university students, active workers in the labor market, and elderly people). In this paper, we present our pilot study among students at the University of Pannonia. In this paper, we introduce the WCM in general terms, then we describe our samples and data collection process. Finally, we represent the results of our World Café rounds: first, we summarize what kind of factors can block the participants in the selective waste collection; and second, we organize the micro level solution suggestions that can be used to promote and support selective waste collection.

3.1. The WCM in general

The WCM can be defined as an exploratory qualitative data collection method, where experts are gathered in a workshop to share their knowledge between several discussion tables, each focusing on a different aspect of the research. It is sometimes referred to as a 'conversation café', a viable modern form of accelerating data collection (Ramasubramanian–Yadlin-Segal 2016). The WCM can be seen as a specific form of focus group research, or more precisely as a 'circulating focus group' (Schiele et al. 2022).

The WCM, as a special type of focus group research, is a novel research method that has emerged in the last decade. In contrast to the classic focus group, the WCM has many variations, particularly in terms of its design which divides the bargaining questions into different tables, and then participants randomly rotate tables and discuss each sub-question in small groups one after the other. This allows for cross-pollination of ideas, leading to richer data collection (Schiele et al. 2022, Löhr et al. 2020, Estacio–Karic 2015, Fouché–Light 2011).

A further advantage of the WCM is that it can be not only informative as a method of participation, but also beneficial for the participants, as it facilitates dialogue and mutual learning, thus motivating their participation and responses (Silva–Guenther 2018). The method allows team members to apply logical thinking and focus on adopting new perspectives to maximize the impact of the discussion and ultimately share collective discoveries. The discussion is question-based, encouraging members to share their views and listen to others to explore the context and the problem from multiple perspectives (Dawkins et al. 2017). The participants often appreciated the dynamic and supportive environment that reduced anxiety while fostering knowledge-sharing (Pinto-Pinho et al. 2023).

In order to use the WCM, its seven principles for planning need to be considered, which are the following: creating a context, creating a welcoming space, formulating important questions to be explored, encouraging everyone's input, connecting the diverse perspectives of participants, listening collectively to ideas and insights, and sharing ideas (The World Café Community Foundation 2015). Diversity and homogeneity should also be taken into account when putting together a team. Up to four to six people can sit at a table so that all participants can actively participate in the discussions (Schiele et al. 2022). In the process of the WCM, the groups usually last 30-40 minutes, with participants being given a different problem for each round. Participants meet each problem set, ensuring full transparency of ideas. The method harnesses the energy of small group discussions and develops shared learning on an interesting topic. The opportunity for interactions between participants gives everyone room to express themselves, revealing information that is still unstructured and unresolved. It allows access to collective wisdom in a natural setting, involving a larger number of participants, prioritizing and selecting information, avoiding researcher bias (Schiele et al. 2022). The collaborative work concludes with a large team discussion – in which all participants take part – reflecting the collective knowledge of the whole group (Wiley et al. 2018).

To assist in the use of the available qualitative data analysis method, the literature recommends the use of moderator(s) to plan and lead the event. They encourage careful discussion and elaboration of key issues in a series of parallel discussions. Moderators clarify the purpose and broad parameters of the exercise and share the issues the group wishes to discuss. All participants are encouraged to contribute to the discussion, listen to the samples, share their insights and questions. The moderator is also the timekeeper who ensures that participants move between tables at the agreed time. After the table discussions are completed, the moderator leads a larger group discussion to collect summaries and often to identify areas for future action (Schiele et al. 2022).

In sum, the WCM as a research method of scientific inquiry is a combination of rigor, relevance, and speed (Schiele et al. 2022). It is typically seen as an informal, relaxed process through which groups of people have the opportunity to engage in productive and structured discussion (Brown–Isaacs 2005). This method exhibited a significantly higher positive effect compared with traditional strategy workshops (Chang–Chen 2015). Previous adopters and participants of the method have appreciated its knowledge-sharing nature, and the learning experience provided by innovative thinking (Schiele et al. 2022).

3.2. Participants: The university students included in the study

For the study at the University of Pannonia, we looked at the university's student population as a group that could be easily organized. We narrowed down the WCM to three diverse groups of students, in which an important criterion was the targeting of students from different courses. The sample of the present research is limited, but we plan to continue the data collection using the WCM after the completion of this study by including additional groups such as other university students, secondary school students, employed people, or retired people.

When selecting the study sample, we aimed to have a mixed composition of the selected groups, so we held the World Café sessions in three different types of groups on three occasions. The characteristics of the students in each group are given in Table 1.

One difference between the groups was the age gap. In the second World Café group, part-time students of the Faculty of Humanities, who are working while studying at university and thus have independent incomes and run their own households were interviewed. Some of the group members may be responsible not only for themselves but also for their families (children and/or parents). The age distribution of that group varies, but they are mainly of an older generation compared to the other two groups. Another difference is that the first World Café is a mixed group, as we invited full-time students from the Faculty of Business and Economics, Faculty of Humanities, and Faculty of Information Technology.

Table 1. The 3 groups of the WCM related to the selective waste collection

	W1	**W2**	**W3**
Date	October 17, 2023	November 11, 2023	December 13, 2023
Enrolment type	Full-time students	Part-time students	Full-time students
Faculties	Faculty of Business and Economics, Faculty of Humanities, Faculty of Information Technology	Faculty of Humanities	Faculty of Humanities
Number of students	26	30	17

Source: own construction

The method was applied in the months of October through December 2023, within the normal timetable of the university courses, in normal classroom conditions. This allowed us to avoid the need to examine motivational questions (under- and over-motivation, compliance, and optimized responses) and additional screening criteria, such as reporting by interest, which would have significantly biased the responses. Participation was voluntary, and students were given a briefing on the methodology, the short and long-term aims of the research, and the relevant GDPR regulatory issues before using the WCM. Students participated anonymously in the study.

A WCM guide has been prepared to apply a common methodology, which will ensure comparable results in future research. In the guide, we recorded the questions and instructions to be asked. Particular attention was paid to the role of the moderator, with internal training to identify and filter out facilitating questions and suggestive moderator communication due to inadequate responses. We considered these to be research methodological problems to be avoided, often mentioned in the literature on WCM (Schiele et al. 2022).

3.3. Data collection process

Data collection was carried out in 3 steps using the WCM. Each step involved a different working technique. The steps of the data collection process and the working methods used are presented in Table 2.

Table 2. Data collection process

Data collection steps		Form of work
1	Collecting barriers to separate waste collection	Individual work
2	Grouping and categorizing the barriers to separate waste collection and naming the resulting groups	Large group work (involving all students together)
3	Substantive processing of the jointly developed categories and collection of proposals to remove or reduce the barriers to separate waste collection	Small groups of 4-7 people

Source: own construction

The first step in the WCM scenario was to find out what the factors are that hinder students from selective waste collection. Research experience in other disciplines has shown that when respondents are asked to make negative statements about themselves, they bias or distort the results (Kuncel et al. 2005).

To avoid this bias, the research question was formulated in an extended way, allowing respondents to report not only on their own personal experiences, or to formulate their own personal experiences in a way that was independent of themselves. In order to achieve this goal, we asked respondents the following question: *"What are the factors that prevent you, your friends, people you know or people you do not know from collecting your selective waste separately from household waste or from placing it in a designated waste bin?"* Students gave the barriers to separate waste collection that they identified, one by one, on a separate post-it note (one barrier written on one post-it note).

In the second step, we collected post-its from the students. We asked the students to show, one by one, what they had written on the post-its and to explain what exactly the word or concept on the post-it meant. The word presented was then pasted on a board on the wall of the classroom. We tried to group words with similar meanings close to each other. Once all the post-its were on the board, the words that were close to each other were reviewed again, and checked, with the help of the participants, to see if they really belonged to the same group. Students were then asked to give the groups a category name. These groups were considered as the main categories of barriers to separate waste collection. The number of categories thus formed by consensus of the participants was not predetermined.

In a third step, the students worked with the resulting categories in small groups. After rearranging the study site and creating as many workstations as the number of separate waste collection categories identified, students were distributed proportionally between the workstations (with an attempt being made to have the same number of students per workstation).

The workstations were set up in a circle around the room. On each desk, we placed a flip chart sheet with the name of the category of barriers to separate waste

collection written on the top. Students worked with one category at a time per group. They had a short time (7 minutes) to complete the task. When that time was up, the flip chart sheets were left on the worktable, while the group members moved to the next table and continued the work started by the other group. The changeover between tables was done in a rotating stage style, group by group. Groups of students moved to the next table until they returned to their starting position (the workstation where they first worked) so that they could meet the groups working on each category.

The students' task at each station was to find the solution. They were asked to come up with ideas and suggestions to eliminate barriers to separate waste collection or to reduce the impact of these barriers at three different levels. The three suggestion levels were as follows:

- micro (individual, family)
- meso (narrow community, for example: institutions, employers, educational institutions, local government)
- macro (state or legislative level)

We concluded the data collection by allowing each team to review the content of the category they had first developed and the comments they had written on the sheet. After a short preparation period, each team representative summarized and presented the main suggestions to the whole community.

3.4. Categorization of the data collected

The results of the data collected with the help of the students as described in section 3.2 are presented below. After grouping the post-its, the categories in Table 3 were created by the participants.

Table 3. Original names of categories

Category	**W1**	**W2**	**W3**
Ignorance	x	x	x
Laziness	x	x	x
Motivation, lack of motivation, disinterest	x	-	x
Economic	x	x	-
Infrastructure	x	-	x
Doubts	x	-	-
Habit	-	x	-
Lack of space	-	x	-
Indifference	-	x	-
Lack of time	-	-	x
Attitude	-	-	x

Source: own construction

Note: 'x' indicates that the category appeared in the World Café round, while '-' indicates that the category was not involved in the World Café round. 'W1', 'W2', and 'W3' indicates the round of the WCM.

In the analysis, we reviewed each category again. We were looking to see if there were any categories that only had a different name depending on which WCM occasion they were defined in but had similar content. Based on the similarities, the categories were grouped. Taking into account the content, we aligned the groups named Doubts and Habit with Attitude, the group Lack of Space with Infrastructure, and Indifference with Lack of Motivation. After merging, the following categories emerged (see Table 4).

Table 4. Concatenated categories

Category	**W1**	**W2**	**W3**
Ignorance	x	x	x
Laziness	x	x	x
Motivation, lack of motivation, disinterest indifference	x	x	x
Economic	x	x	-
Infrastructure, lack of space	x	x	x
Lack of time	-	-	x
Attitude, doubts, habituation	x	x	x

Source: own construction

Note: 'x' indicates that the category appeared in the World Café round, while '-' indicates that the category was not involved in the World Café round. 'W1', 'W2', and 'W3' indicates the round of the WCM.

We continued by rethinking the naming of the categories. Since the groups were named by the students (lay people) who participated in the study, the analysis involved revisiting the content of the groups in each category and trying to give the group a proper name based on the words written on the post-its for that group. This resulted in the categories in Table 5.

Table 5. New category names

Old name of category	**New category name**
Ignorance	Lack of knowledge
Laziness	Laziness
Motivation, lack of motivation/ disinterest, indifference	Lack of motivation
Economic	Economic aspects
Infrastructure, lack of space	Lack of infrastructure
Attitude, doubts, habituation	False beliefs, habits
Lack of time	Lack of time

Source: own construction

3.5. Analysis of barriers to separate waste collection

The categorization was followed by the preparation of the content analysis. The words and phrases (keywords) written on the post-its were collected in a common excel sheet. In total, a list of 113 items was obtained.

In the keyword cleaning process, similar words were given the same name, e.g. *lack of information* and *lack of knowledge* were replaced by *lack of knowledge*. Keywords with multiple words were replaced by a single word (e.g. *lazy* instead of *lazy people*), synonyms were also merged (e.g. *habit* instead of *habitual*), and where it was not possible to clean up using the original words, new keywords were generated (e.g. *lack of time* instead or *lack of time* and *takes time away from other things*; *false belief* instead of *throwing away a piece of rubbish does not change the environment*; and *lack of infrastructure* instead of *few public waste bins*).

The results after cleaning the 113 original keywords are summarized in Table 6. The list of original keywords is given in Appendix 1. *Laziness*, *lack of infrastructure* and *lack of knowledge* have a significantly higher share than the other barriers.

Among the factors collected, there was a high predominance of *laziness*. The results of previous studies also show that the groups studied have a relatively high level of environmental awareness at a theoretical level, yet many do little in practice to help their environment (Greenfo 2009). Although people know what they should do, something prevents them from translating knowledge into action. A further research direction could be to explore what factors influence the decision to act and the translation of knowledge into action.

There are examples in the literature of a link between littering and laziness (Schenck et al. 2022, Muñoz-Cadena et al. 2012). We could not find any studies linking separate waste collection and laziness.

Table 6. Occurrence and proportion of keywords

Words	**Number of occurrences**	**Share (%)**
Laziness	21	18.58
Lack of infrastructure	20	17.70
Lack of knowledge	17	15.04
Lack of space	9	7.96
Indifference	7	6.19
False belief	6	5.31
Lack of time	5	4.42
Lack of commitment	4	3.54
Attitude	3	2.65
Comfort	3	2.65
Habit	3	2.65
Disaffection	2	1.77
Tiring	2	1.77
Inattention	2	1.77
Lack of financial benefits	2	1.77
You have to pay for it	2	1.77
Lack of motivation	2	1.77
Lack of resources	1	0.88
Insatiability	1	0.88
Absence of sanction	1	0.88
Total number of words	**113**	**100**

Source: own construction

The second most common barrier is the *lack of infrastructure*, such as the lack of separate waste collection points. It can, therefore, be concluded that the willingness to collect separate waste and the lack of infrastructure have a negative impact on the willingness to take active measures. This is in line with Domina and Koch (2002) and Halvorsen (2012), who show that convenience is an important aspect of separate waste collection (Domina–Koch 2002), that the availability of infrastructure and measures to increase accessibility can have a positive effect on the intention to collect waste, but that the lack of infrastructure can have a negative effect (Halvorsen 2012). The factor of infrastructure deficiencies is also mentioned in other papers (see e.g. Hansmann et al. 2017, Ahmad et al. 2016).

Based on the results of a study conducted in Hungary, it can be said that, in addition to the two factors mentioned above, the problem we have also identified, i.e. the lack of credible information, and misconceptions among the population, are also prominent (Szűcs–Hámori 2016). Szűcs and Hámori (2016) also found that misconceptions about waste collection (e.g. separated waste is poured into one container during transportation) influence waste collection behavior.

Lack of knowledge also occurs with a high frequency, as shown in Table 6. This means that it is not clear to residents which waste can be deposited in which collection containers. Their situation is also complicated by the fact that the list of types of waste that can be deposited in separate waste collection containers may vary from one municipality to another. Our results are in line with the conclusions of previous research, as knowledge has been repeatedly identified in the waste management literature as an important direct or indirect influencing factor (Rozana et al. 2023, Cudjoe et al. 2022, Wu et al. 2022). Interestingly, the literature often examines the role of knowledge not only for selective waste collection, but also for the environment (see e.g. He et al 2022), but this concept has not been addressed in the World Café roundtables.

In Table 6, the lines highlighted with the same color can be grouped into common categories. Lack of space (e.g. no space for more bins in an apartment) and lack of infrastructure (e.g. few public bins) are both about the *lack of material conditions for separate waste collection.* Lack of knowledge (e.g. not sure which bin to put the waste in) and false beliefs (e.g. throwing away one bin does not change the environment) are common sources of *lack of credible information on separate waste collection*. The third major group comprises psychological phenomena related to the individual (e.g. lack of motivation, lack of commitment, attitude, convenience, habituation, and disinterest). These phenomena are collectively referred to as the *lack of willingness to separate waste collection.* Two smaller groups remain, the first of which is called *lack of financial benefits*, the others *lack of time.*

Table 7. Main categories of the barriers

Primary mergers	**Number of mentions**	**Percentage of mentions (%)**
Lack of willingness to separate waste collection	45	39.82
Lack of material conditions for separate waste collection	29	25.66
Lack of credible information on separate waste collection	23	20.35
Lack of financial benefits	5	4.42
Lack of individual skills	5	4.42
Lack of time	5	4.42
Lack of sanctions	1	0.88
Total	**113**	**100**

Source: own construction
Note: The colors of the rows show the categories and the items related to Table 6.

According to the results summarized in Table 7, the greatest barrier to separate waste collection among the respondents of the present study (almost 40% of the barriers collected by the WCM) is the *lack of willingness to separate waste collection.* The other two significant factors influencing separate waste collection habits are the *lack of material conditions for separate waste collection* (25.66% of responses) and the *lack of credible information on separate waste collection* (20.35%). Other influencing factors are the lack of financial benefits (4.42%), lack of individual skills (4.42%), lack of time (4.42%), and lack of sanctions (0.88%). Interestingly, the lack of financial benefits has a relatively low prevalence, which suggests that further research may be worthwhile to investigate the extent to which financial rewards may be a strong motivating factor for selective waste collection in Hungary.

From a project perspective, the results of the World Cafés show that there is a need for educational content that provides credible and accessible information. At the same time, the development of educational content should also aim to take into account not only the sharing of knowledge but also the promotion of the willingness to collect waste selectively.

3.6. Micro-level solutions for each problem area

In the second part of our WCM, participants collected possible solutions within the categories they had developed, at three levels:

- micro level: what can individuals and their close environment (e.g. family members, friends, colleagues) do to remove or mitigate barriers to separate waste collection?
- meso level: how can local government and organizations tackle barriers to separate waste collection?
- macro level: what can the state do to reduce or eliminate barriers to separate waste collection?

Since the aim of our project is to shape social attitudes and to develop educational content that will change the individual's actions and waste collection habits in a positive way, we first analyzed the solutions proposed at the level of individuals and families – in this paper, due to the space limitations, we present the results of this analysis only. A total of 129 micro-level solutions were proposed in the 3 rounds of the World Café. Interestingly, more ideas were received at the meso level (148 solutions) and at the macro level (145 solutions).

The first step of the analysis is to clean the data, deleting micro-level solutions that are not related to the topic (e.g. less car use), belong to the meso or macro level instead of the micro level (e.g. cash-dispensing vending machines), or it was not clear from the brief wording what exactly the idea owner had in mind (e.g. cleaning concept). After cleaning, 118 micro-level solution suggestions remained. Next, the synonyms were combined to form small groups of micro-level solution proposals. In total, 27 groups were obtained, which are shown in the first column of Table 8. The most frequently mentioned solution suggestion is gathering information and receiving orientation (20 occurrences). For example, this includes watching David Attenborough's documentaries, or short films and videos about the environment, or gathering information about which product should be placed in which selective collection bin. This group further reinforces our finding that there is a need for easily accessible, understandable, and credible educational content. In particular, information sharing in video format (David Attenborough films, documentaries, non-stimulative films, 5 occurrences in total) were frequently mentioned, alongside social media (1 occurrence) and ppt presentations (1 occurrence).

The second most common group is the creation of individual conditions for separate collection in their own environment (11 occurrences), which includes solutions such as the use of a composter, creativity in waste storage, or a bin with several levels (to store several types of waste in the same place). These solutions are also significant because the second biggest problem in separate waste collection is the lack of material conditions for separate waste collection. At the national level, the most effective solution could be provided by the waste management company (e.g. more collection islands, more frequent emptying), but as our results show, the lack of physical conditions also implies the responsibility of the individual.

In the proposed solutions, a process can be detected, which we have identified in 3 separate phases based on our database (column 4 in Table 8): social influence, interiorization, and overriding individual habits. Thus, we categorized the participants' ideas according to these 3 stages.

Social influence is the second largest category in our database. Within this category are ideas that aim to influence the behavior of others. This category may raise further research questions: is the reason why this group of solutions is so significant because of its role that participants attributed to the subjective norm, i.e. they believe that individuals are significantly influenced by mainstream trends, social customs, and expectations? This issue will be explored through a questionnaire as the next step of the project.

At this point, a parallel can be drawn between our results and Ajzen's 1991 model, since in his Theory of Planned Behavior, too, social influence (subjective norms) results in changes in individual behavior. Based on the results published so far,

questionnaire surveys conducted in Pakistan and China based on Ajzen's 1991 model suggest that subjective norms have an indirect effect on behavior related to selective waste collection through intention (Li et al. 2023, Dong et al. 2023, Wang et al. 2022).

At the same time, in interpreting the impact on others, it can also be found that the individual, rather than acting on their own, would first look to others for guidance and correct behavior. That is, procrastination may also appear here. This could also be an interesting line of research to see to what extent procrastination plays a significant role in influencing behavior related to selective waste collection and whether people recognize their own responsibility in this area. Examples of research on procrastination can be found in the area of food waste (see Da Costa et al. 2021, Porpino et al. 2016), but not in separate waste collection. In any case, this approach also highlights the role of subjective norms.

Table 8. Summary of individual solution suggestions

Micro level solutions	Absolute frequency	Relative frequency	Category name	Absolute frequency	Relative frequency
Individual information gathering, orientation	20	16.95%	Overriding individual habits	49	41.53%
Creating individual conditions for separate collection in your own environment	11	9.32%			
Active action	5	4.24%			
Exploring recycling opportunities	5	4.24%			
Conscious shopping	3	2.54%			
Setting individual goals	2	1.69%			
Sole proprietorship for waste collection	1	0.85%			
Lifestyle change	1	0.85%			
Striving for self-sufficiency	1	0.85%			
Education in the family, shaping attitudes	8	6.78%	Social influence	37	31.36%
Rewards, positive reinforcement	6	5.08%			
Follow a role model or influencer	6	5.08%			
Setting an example	4	3.39%			
Penalty, negative reinforcement	3	2.54%			
Sharing the results with others	3	2.54%			
Awakening motivation in others	3	2.54%			
Attention	2	1.69%			
Exchange information with others	1	0.85%			
Initiating a community movement	1	0.85%			
Taking individual responsibility	7	5.93%	Interiorization	32	27.12%
Shaping mindsets	5	4.24%			
Exercising self-discipline	4	3.39%			
Self-development	4	3.39%			
Awakening motivation within ourselves	4	3.39%			
Developing a positive attitude in ourselves	4	3.39%			
Awareness	3	2.54%			
Realization	1	0.85%			
Total	**118**	**100%**		**118**	**100%**

Source: own construction

The next category is *interiorization*, also known as the internalization of personal factors, related to selective waste collection. Interestingly, this category was found to have the lowest relative frequency. Since the main problem with the factors that hinder separate waste collection is the lack of willingness to collect waste, it would have been expected that the factors related to willingness and personality would also appear more frequently among the suggestions for solutions. However, it may also show that further findings are needed to have a detailed understanding of the process of internalization. A starting point for this could be Ajzen's 1991 model, so the next step of our project could be to use this methodology in the questionnaire survey.

The category with the highest relative frequency is *overriding individual habit*, which covers the actions that it would be appropriate for an individual to take in order to separate waste. Factors such as collecting information, creating individual conditions for separate waste collection, taking active action, seeking recycling opportunities, or conscious purchasing are all factors that are considered here. The suggestions for solutions in this category also suggest that interiorization may be necessary, otherwise there will be no change in the individual's previous habits.

4. Summary

In this study, we have presented the results of 3 different studies in a group of 73 university students. The aim of the study has been to identify the barriers to separate waste collection and to collect suggestions for solutions to the problem in order to formulate measures to address these barriers in the future. The novelty of the study is that it was carried out using the WCM.

Among the respondents to this survey, the main barriers to separate waste collection have been shown to be the lack of willingness to separate waste collection, the lack of material conditions for separate waste collection, and the lack of credible information on separate waste collection. The latter barrier has confirmed for our project the need for credible, accessible educational content. However, our results have also shown that it is not enough to provide information, but that the willingness of individuals and its determinants should also be taken into account when developing educational content.

In the current study, we have collected and analyzed micro-level solutions for changing waste collection habits, i.e. for the individual and his/her close environment. The most common solutions are related to individual information gathering, awareness raising, and the creation of individual conditions for selective collection in people's own environment. In the former, knowledge sharing in video format has been mainly highlighted by the participants. At the same time, the need for authentic, accessible educational content has been further confirmed for the sub-project. The high frequency of the category 'Creating individual conditions for separate collection in your own environment' is also a significant result, as it shows that solutions to the lack of material conditions for selective waste collection as a barrier to the selective waste collection can be found not only at the meso and macro levels but also at the micro level. This result also underlines the importance of individual responsibility.

In the process of categorizing the proposed solutions, three stages of a process have been identified: social influence, interiorization and overriding individual habits. These factors are in line with the conclusions drawn by Ajzen (1991), which suggests that future research could be directed towards the study of behavior related to selective waste collection using his theory of planned behavior. The results of this study suggest that social influences and norms may play a key role in the behavior associated with selective waste collection.

Based on our results, we see two areas of intervention for our project. The first is information dissemination, i.e. the transfer of material knowledge on selective waste collection to residents. In sharing information, attention should also be paid to ensuring that this knowledge is retained. The other area of intervention is behavioral modification, i.e. actions aimed at deliberately and purposefully changing individual behavior.

5. Future directions and limitations

This study is the first in a series of investigations. To ensure the generalizability of the data, it is necessary to increase the number of elements in the study sample and to select and include representatives of other socio-demographic groups. Therefore, as a further step in our research, we plan to conduct a WCM among high school students, retired people, employed people, and students from other faculties. A further line of action is to summarize and organize the proposals for solutions at the micro, meso, and macro levels, and to use them as a basis for proposing measures to decision-makers.

In addition to the wider use of the WCM, we will refine our findings in the future through focus group interviews and questionnaire research. Focus group research will allow us to explore and understand the deeper context of the phenomenon. The questionnaire survey will allow us to draw conclusions about the behavior of the population in relation to selective waste collection and its determinants based on Ajzen's 1991 model, using a larger sample size. The results of the three methods can contribute to the scientific basis of educational content.

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Appendix:

Appendix 1. Barriers to separate waste collection

Keywords on Post-it	**Cleaned keywords**
Bring the problem to the families, up to the level of physical availability	Lack of infrastructure
there are no facilities in the municipality	Lack of infrastructure
Will	Attitude
Not paying attention to your surroundings can also be an obstacle	Inattention
People are lazy	Laziness
The lack of time	Lack of time
Habit established	Habit
Candy wrappers where can they go? Toilet paper rolls go with the paper? And the spiral notebook?	Lack of knowledge
Just a conspiracy theory: it is not even recycled	False belief
Throwing away a piece of rubbish does not change the environment	False belief
I can't do anything with it alone anyway	False belief
Disinterestedness	Lack of commitment
Disinterestedness	Lack of commitment
Disinterestedness	Lack of commitment
Not available in village	Lack of infrastructure
Tiring for some people	Tiring
Inattention	Inattention
Physically, there is no well-designed system. Only for PET.	Lack of infrastructure
Negligence	Attitude
Lack of space	Lack of space
Lack of space	Lack of space
Lack of space	Lack of space
Lack of space	Lack of space
Lack of time	Lack of time
Lack of time	Lack of time
Takes time away from others	Lack of time
Insatiability	Insatiability
Lack of information	Lack of knowledge
Lack of knowledge (what can be collected separately and in which bin)	Lack of knowledge

Lack of knowledge. People do not know exactly how separate collection works	Lack of knowledge
Lack of knowledge	Lack of knowledge
Discourtesy	Indifference
Comfort	Comfort
few public waste bins	Lack of infrastructure
Few options	Lack of infrastructure
Few options for separate waste storage	Lack of space
Few recycling bins in public places	Lack of infrastructure
Indifference	Indifference
Indifference	Indifference
Indifference (not my problem/job)	Indifference
Far from home is only possible	Lack of infrastructure
Legends about waste management	False belief
I am lazy	Laziness
Lazy waste sorting	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Laziness	Laziness
Habit	Habit
Many selective islands have been eliminated	Lack of infrastructure
Because you have to pay to drop off your waste	You have to pay for it
Why collect when they do nothing in other major countries like Thailand	False belief
Lack of motivation	Lack of motivation
Lack of motivation	Lack of motivation
Not my problem	Lack of commitment
Not sure which one to throw in	Lack of knowledge
Lack of an appropriate collection method	Lack of infrastructure
Lack of an appropriate collection method	Lack of infrastructure
Non-established habits (elderly)	Habit
They don't care about the environment, so they don't collect separately	Indifference
I don't care attitude	Indifference
Carelessness	Indifference
Not nearby	Lack of infrastructure
Not enough money is invested in the processing of selective waste	Lack of resources
Not enough space at home	Lack of space
I don't have space for collecting multiple types of waste	Lack of space

No direct consequence or penalty	Absence of sanction
Not enough recycling bins	Lack of infrastructure
There are no large or small collection points in the city	Lack of infrastructure
Self-centeredness	Disaffection
Selfishness	Disaffection
Not enough space for more bins in a panel	Lack of space
Panel apartment	Lack of space
Automatic cash dispenser	Lack of financial benefits
Automatic cash dispenser	Lack of financial benefits
Bad experience	False belief
Haste	Lack of time
It is much easier to collect non-selectively (less time, energy, etc.)	Comfort
Delivery high fee	You have to pay for it
Lack of selective collectors (e.g. I don't remember seeing any in Pátka)	Lack of infrastructure
Lack of separate waste collection	Lack of infrastructure
Lack of separate waste collectors	Lack of infrastructure
Personal attitude	Attitude
Need to be sorted	Tiring
Ignorance	Lack of knowledge
Ignorance	Lack of knowledge
Ignorance	Lack of knowledge
Distance	Lack of infrastructure
No possibility in settlements	Lack of infrastructure
Ignorance	Lack of knowledge
Ignorance	Lack of knowledge
Ignorance	Lack of knowledge
Ignorance	Lack of knowledge
Ignorance	Lack of knowledge
Ignorance	Lack of knowledge
Ignorance	Lack of knowledge
Too far to the separate waste bin	Lack of infrastructure
Too much work	Comfort
Someone still doesn't know how to collect separately	Lack of knowledge

Source: own construction

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Clustering and education: A study on European schools

Claudia-Nicoleta Păun – Adrian Costea

The education standard is of utmost importance because it forms the basis of a country's future geoeconomic and socioeconomic progress and success. The study's main objective is to use cluster analysis to reveal the complex patterns, correlations, and relationships hidden between numerous education-related variables. The study uses clustering algorithms to group European nations with similar educational traits post-COVID-19. The selected variables – 44 European countries, Populations, GDP per capita, Scholars Enrollment Percentage, Number of Schools, and Successful Education Rate – combine to obtain a thorough framework for analysis. The study also explores the similarities and differences to predict the rate of successful schooling with statistical models. The clusters are vividly depicted in visualizations and tabular representations, which improves understanding of intricate data patterns. The categorization analysis opens doors to predictive modeling in the education sector, providing a potential tool for estimating academic achievements, notwithstanding some difficulties. These results highlight how analytics may improve the educational system.

Keywords: education, clusters, correlations, statistical analysis

1. Introduction

The rich mix of nations, cultures, and policies that make up Europe's educational landscape forms a fascinating area for investigation and research. The amount of funds allocated to a nation's educational sector directly relates to the future the country is headed towards. If the country invests in its people, prosperity is guaranteed, and the literacy rate and GDP increase. However, according to studies (Gundlach–Wößmann 2001), there may not be a clear correlation between educational expenditure and school performance. This leads to another theory that the school system is strongly important in seeing growth, and, therefore, investing in knowledgeable educators or building them professionally from the ground up is a must for any county. Other studies (Cefai et al. 2015) state that creating a resilience curriculum for Europe's primary and elementary schools is also necessary. Cefai et al. (2015) explore the curriculum's goal, conceptual understanding, and the six main subject areas. Developing a proper curriculum helps European countries who have deployed this system to transcend above their neighbors. The educational ecosystem of Europe can be uncovered using data analytics to see the idiosyncrasies, patterns, and trends that lie within.

The importance of this study rests in its potential to alter European countries' educational policies and decision-making. Not only is education an aspect of society, but it also serves as a significant catalyst for social cohesion, economic development, and personal fulfillment. These revelations may enable governments to allocate resources more efficiently, teachers to adapt their curricula to cater to the needs of their students, and citizens to push for data-driven policy changes.

This study also promotes a spirit of cooperation and knowledge exchange in a globalized environment where nations can learn from one another's triumphs and difficulties. The data was collected from many trustful sources, such as the World Bank, Eurostat, United Nations, Google Scholar, Wise Voter, etc. Ultimately, the clusters generated by the study will reveal that most of the European countries have a moderate educational rate boasting a generous population. Through these findings, European nations could collectively stride towards a bright future sharing information and sending students to each other's neighbors to study and strengthen bonds.

2. Literature Review

A nation develops its human capital mostly through education. People who have completed their education are prepared to make meaningful contributions to the workforce and society at large (Janks 2014). The core of a country's workforce is made up of highly educated people, who promote innovation, productivity, and economic expansion. European countries, most of which are labeled as developed nations, know the importance of this fact. This can be further backed up by research that has been done into this topic to further understand what makes European nations stand out. One such study points out that in Austria the educational system is decentralized (Hörner 2007). This means that the decision power is not centralized but is distributed across various levels. It emphasizes the value of a legislative framework that enables school administrators to develop and carry out their objectives (Ristea 2014). The most successful models give school managers the most autonomy, according to a comparison of the legal framework of four decentralized educational systems: Romania, France, Spain, and Finland. It suggests that giving freedom while providing a basic curriculum to work with can do wonders for the school system.

Economic development is said to be primarily fueled by education, which affects growth and productivity in a number of ways. According to the human capital theory, education improves people's abilities and knowledge, which raises economic output and productivity. Higher incomes and better economic performance are two ways that investments in education pay off (Psacharopoulos–Patrinos 2004). This theory has been validated by later research, which demonstrates that nations with higher levels of education have faster rates of economic growth (Barro 2002). Productivity and education levels are positively correlated, according to empirical study of the topic. An increase in the average number of years of education have been linked to higher labor productivity and economic growth, according to studies (Qutb 2017). Education promotes technical proficiency, creativity, and resource efficiency, all of which support general economic growth. Although there is a favorable association, some studies highlight obstacles and restrictions (Pritchett 2001). Critics contend that economic policies and institutional quality, for example, may mitigate the effect of education on economic growth. Furthermore, the return on investment in education may differ depending on the type and quality of education (Hanushek 2003).

The Education Index, also referred to as the Successful Education Rate, assesses a nation's educational system using a variety of metrics to help with policy evaluation (Yang–Hu 2008). A higher score indicates a more educated workforce, which promotes economic growth, innovation, and less inequality. But this connection

has many facets and is affected by factors like infrastructure, stability, and legislation. A wider variety of educational accomplishments, including higher education levels like primary, secondary, and tertiary education, are taken into account by the education rate, in addition to basic literacy (Kono 2018). This all-encompassing indicator provides information about the degree to which people may access and complete different educational levels (Petrakis–Stamatakis 2002). It also represents the general level of education within a population. In order to guarantee that all societal segments have equitable access to high-quality education (Ololube et al. 2016), this statistic is essential for demonstrating the collective progress made in education and pinpointing areas that require policy reform (Mok 2001). The Education Index helps in mapping out the education disparities among countries (Van Hiel et al. 2018). There are notable differences in educational achievement, especially in low- and middle-income countries, demonstrated clearly in research that uses the Education Index to compare educational outcomes between nations (Hay 2020). Although it provides insightful information, there are several criticisms of the Education Index. Its exclusive focus on years of schooling, some academics contend, oversimplifies educational quality, ignoring elements like learning quality and educational results (Hauser 1997). Conversely, others draw attention to the fact that the index fails to take into consideration differences between nations or demographic groupings, which can conceal large gaps in education.

The Education Index has a big impact on educational changes and policies around the world since it offers a thorough assessment of educational accomplishments (Saarinen 2017). For example, countries like Ireland and Northern Ireland can assess their educational systems with the aid of the International Education Index (IEI) (Clark et al. 2023), which consists of 54 questions spanning nine variables. In order to help policymakers and improve the quality and accessibility of education, the Education Index is an essential tool for evaluating educational accomplishments worldwide.

All the cluster analysis literature for education is focused on the internal educational system, and how students and teachers' relation affects it (Rodgers 2002). This study focuses on the bigger picture. This study relates how the population, the number of public schools, and government spending are clustered in response to the education index, which brings in the effects of the national government overall (Gerged–Elheddad 2020). However, clustering has been used in profiling countries against set metrics. Contextual considerations do not readily account for the complexity of leadership for learning approaches. According to research on leadership at the school and national levels, there are no regional, linguistic, or political clusters at the country level. Instead, across schools in most nations, five leadership profiles stand out (Veletić–Olsen 2021). This implies that leadership profiles at the school level may be more pertinent to comprehending and enhancing leadership practice globally. Similarly, students that are likely to experience behavioral or academic issues can be found using behavioral clustering. Once kids have been identified, interventions can be put in place to help them (Huberty et al. 2010). For instance, students in the "at-risk" cluster may profit from additional academic support or social-emotional therapy. A more structured and supervised learning environment may be advantageous for the "disruptive" cluster of students. Behavioral clustering (Park

2016) can also be used to guide practice and policy in education. For instance, schools may use the findings of cluster analysis to create tailored interventions for students who are at risk for behavioral or academic issues. Cluster analysis is another tool that schools can utilize to pinpoint weak points in their curricula or instructional methods.

Cluster analysis has been deployed in the education sector to analyze how different nations are distributed, or how their finances are distributed. Indonesia is a case in point: due to its decentralized educational system, which gives the local government significant decision-making power, the government has the challenge of equally dispersing instructors around the country (Widiyaningtyas et al. 2017). On the other hand, Likas et al. (2003) analyzed to solve this problem in clustering algorithms like k-means, and he provided a useful method for determining the distribution of teachers and identifying areas with surpluses or shortages (Likas et al. 2003). However, this approach depends on the accuracy of the data collected so the policymakers would make sure of the local resources to ensure that the budget is assigned and spent wholly and equally (Krueger–Kumar 2004). Additionally, according to Krueger–Kumar (2004), the USA focuses more on vocational and other training, and thus this keeps the country ahead of others.

The present study emphasizes the necessity of comprehending the many patterns seen within European educational systems (Baye et al. 2005) and the possibility for data-driven insights to guide decision-making. Other studies presented information on a variety of topics, including school clustering and classification (Santamouris et al. 2007), government funding, and the distribution of public schools. Furthermore, the emphasis on techniques, such as clustering algorithms and classification models, has highlighted the significance of data-driven approaches in educational research.

3. Methodology

The study follows clustering data analysis techniques to find out how European nations cluster against the variables necessary to the educational index. This implies using clustering as well as descriptive statistics to gouge the data for insights and build upon the analysis.

The accuracy and reliability of the data utilized in this study were carefully monitored throughout the data collection process. Given their well-established track record in assembling extensive datasets relating to educational and economic indicators, a wide range of reliable sources, including well-known international organizations like the World Bank, UNESCO, and Eurostat, were consulted. The solid foundation of the analysis was built through the careful sourcing of the data, ensuring that the conclusions are supported by accurate and current data. The data comprised 44 European nations. This data was collected in 2023, which means that the results concurred from the analysis are applicable.

Table 1. Descriptive Statistics

	Measurement	N	Min.	Max.	Mean	Std. Dev.
Population	Number of People	44	518	144,444,359	16,824,160.11	28,462,385.926
GDP Per Capita	USD	44	3,531	233,617	45,282.48	46,472.465
Government Education Financing	Percentage (%)	44	1.9%	8.1%	4.459%	1.3717%
Number of Public Schools	Count	44	4	40,000	5,702.16	9,110.582
Successful Education Rate	Percentage (%)	44	.56	.94	.8161	.09749
Valid N (listwise)		44				

Source: own calculations

The descriptive statistics provide an overview of the important dataset characteristics, illuminating the differences and diversity among the 44 European nations studied. The population ranges from 518 to 144,444,359, with a mean of roughly 16.8 million and wide variation. Similarly, GDP per capita values range greatly, from $3,531 to $233,617, with a mean value of $45,282. With a mean of 4.459% and a range of 1.9% to 8.1%, government funding for education exhibits substantial variation. Public school enrollment spans from 4 to 40,000, with noteworthy variations, and the average enrollment is 5,702.16. Finally, the successful education rate shows moderate variation in educational outcomes, with values ranging from 0.56 to 0.94 and a mean of roughly 0.8161. It is clearly indicated that population is not balanced in European nations, with a wide variation. In addition, this adds up to varying figures for GDP per capita.

3.1. Data variables and education index indicators

The study's educational attainment indicators comprise multiple critical variables that offer an all-encompassing perspective on the educational systems in 44 European nations. In order to compare educational measures in relation to the size of each country's populous, population acts as a contextual baseline. Economic success is reflected in GDP per capita, which affects the resources available for education and the standard of instruction provided. The amount of money the government spends on education is measured by the government education financing percentage, which shows how important and supported educational development is. In terms of accessibility and opportunity for students, the number of public schools indicates the presence of formal educational institutions. The successful education rate, which emphasizes the efficacy of educational programs and outcomes, evaluates the accomplishment levels within the educational system. When combined, these metrics offer a comprehensive picture of educational achievement and factors influencing it throughout the area.

3.2. Clustering and classification techniques

K-means clustering was used to identify latent patterns in the data, grouping the classification of countries into different clusters based on their shared characteristics. This method served as a data-driven magnifying glass, enabling the automatic grouping of nations that had similar characteristics in terms of population, GDP per capita, government education financing percentages, the number of public schools, and successful education rates. The investigation revealed hidden linkages and groupings that might not have been visible through manual assessment alone through K-Means clustering. This methodological decision was crucial in helping to provide a thorough grasp of the various educational environments present in different European nations, ultimately opening the door for more insightful classification and analysis.

Through K-means clustering we can cluster and classify nations accordingly to their respective groups, which can tell us how many nations are relatively focusing on education.

3.3. Cluster analysis limitations and mitigation

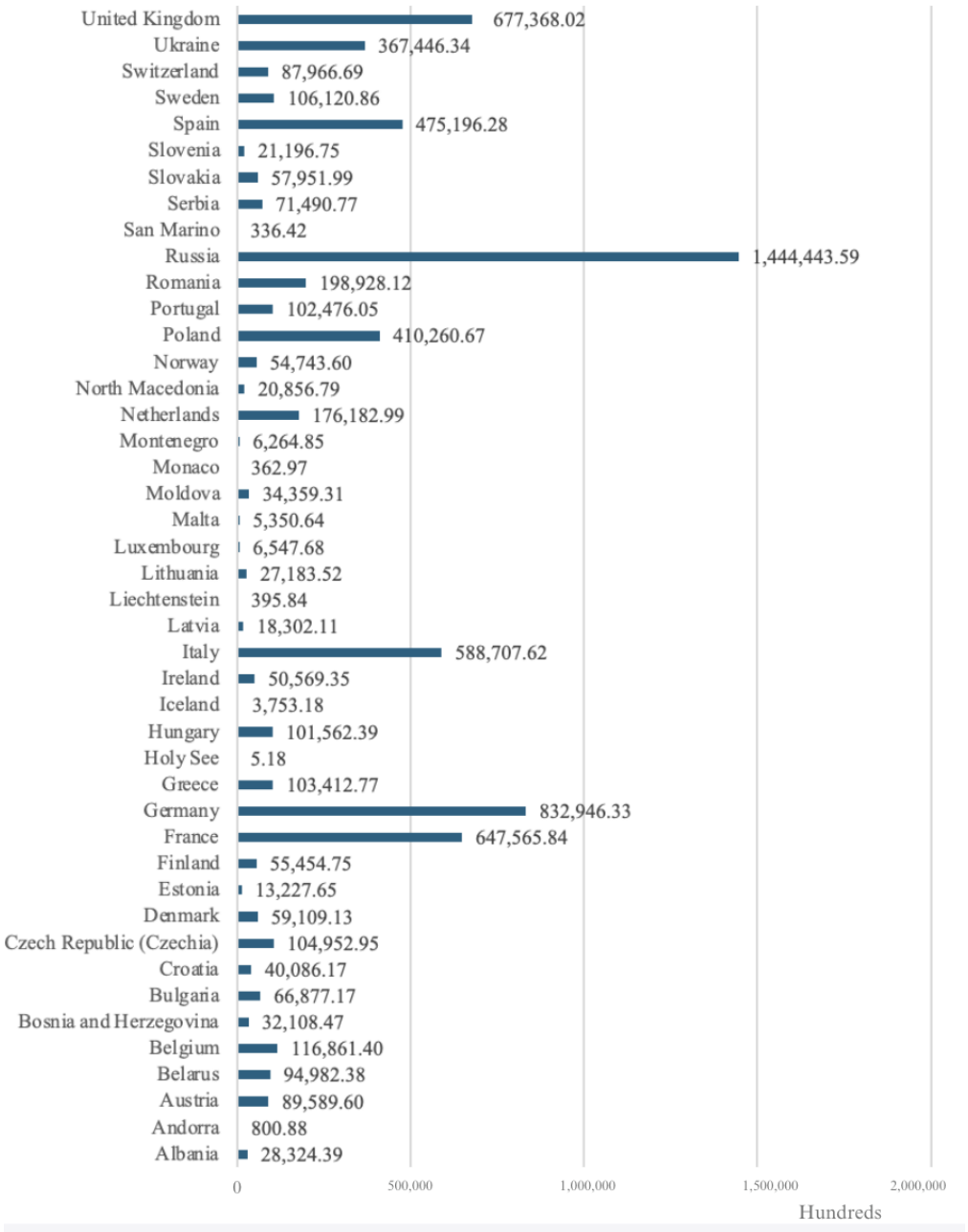
Although cluster analysis is an effective method for classifying related items, it has many common drawbacks and difficulties. Finding the ideal number of clusters is a major difficulty that can have a considerable influence on the validity of the findings. The elbow approach was used to solve this, enabling the visualization of the within-cluster sum of squares to pinpoint the point at which the benefits of adding more clusters reduce.

3.4. Distribution of the data variables

A total of 44 countries were chosen for the study due to their representation of a broad and comprehensive cross-section of Europe, which is essential for the effective application of cluster analysis to comprehend educational attainment. Moreover, the inclusion of a wide range of countries from various regions–Western, Northern, Southern, and Eastern Europe–allows for a more nuanced exploration of the various factors influencing educational outcomes across the continent.

All the different data variables contribute towards a nations' education index or education rate. Therefore, it is important to map out how all the other variables venture out in relation to this. All the countries listed are in Europe, located throughout the continent: Albania, Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic (Czechia), Denmark, Estonia, Finland, France, Germany, Greece, Holy See (Vatican), Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Russia, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, and the United Kingdom.

Figure 1. Simple bar mean of population by country/Europe



Source: own construction based on Eurostat (2023)

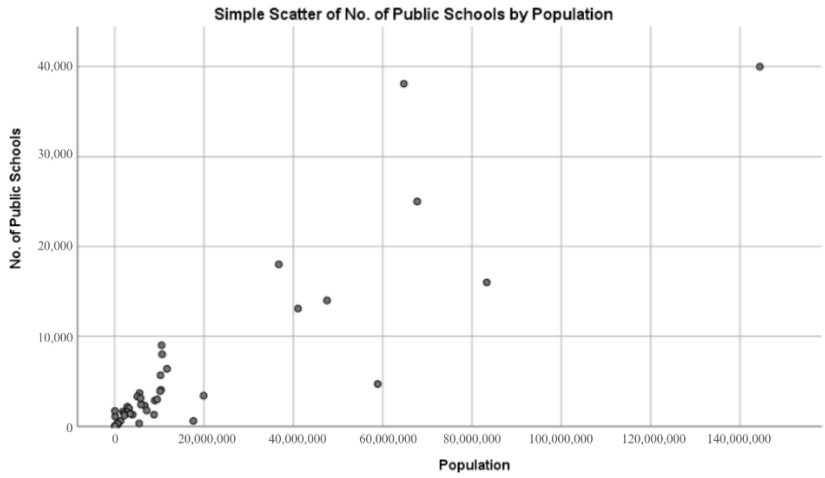
In Figure 1 the country with the largest population is Russia, with a population of about 143.4 million, while all the other countries are in the lower spectrum. This is a given, considering how Russia has been a superpower in the past, enjoying the economic advantages of such a sposition.

3.4.1. Relationship of public schools and the population

A range of variables interact dynamically to affect how many public schools there are in each location relative to its population. The first important factor is population size, with larger populations often requiring more public schools to meet citizens' educational demands. The inequalities between urban and rural areas also have an impact on this relationship, which is not only influenced by population size. Public schools are more concentrated in urban areas with higher population densities to meet local demand, but in rural areas there may be fewer but larger schools servicing a wider geographic area.

Figure 2 shows that as the population increases so does the number of public schools. But, it is notable in the figure that most countries have less than 10,000 public schools, entailing that they also have low population.

Figure 2. Scatterplot: Public schools by population

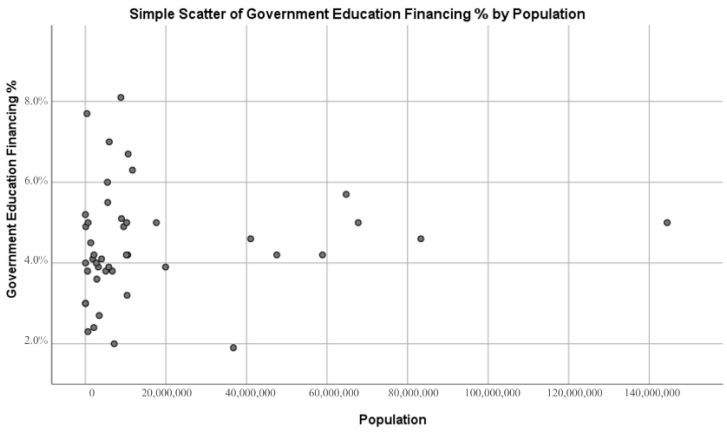


Source: own calculations

3.4.2. Government expenditure for education against population

People may guess that with increased population the government may increase their education budget. But, in the case of European nations, even small nations are mostly well off, as demonstrated in Figure 3. The figure indicates that even governments with low populations allocate a lot more budget than nations with more population.

Figure 3. Government education spending by population

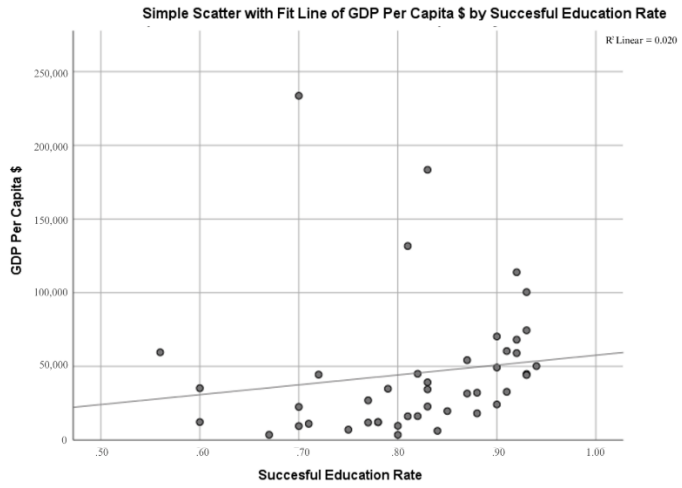


Source: own calculations

3.4.3. Relationship of successful education rate

A key tool for determining how well a nation's educational system is performing is the Education Index, which is frequently calculated as part of the Human Development Index (HDI). It includes a range of educational metrics, such as literacy rates, enrolment numbers for various educational levels, and overall educational attainment. A higher education index means that a large proportion of the population has access to high-quality education, which helps to create a competent and knowledgeable workforce. An educated workforce, in turn, often finds well-paying employment, stimulates innovation, and raises total production. Thus, nations with higher Education Index scores are more likely to achieve economic growth and prosperity.

Figure 4. Scatterplot: education rate vs. GDP



Source: own calculations

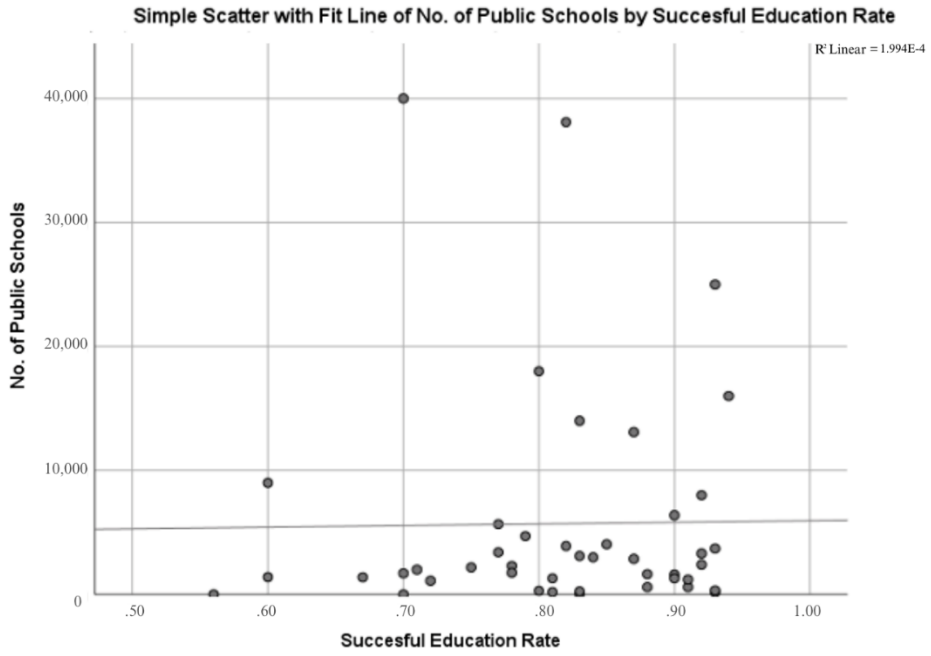
Figure 3 proves the point that with increased education rates the GDP per capita also increases, as indicated by the upward trend in European nations.

3.4.4. Public schools and education rate

Public schools are a pillar of accessible education and are often funded and run by the government to educate a large portion of the population. A nation's dedication to provide its inhabitants with educational opportunities can be gauged by the number of public schools in that nation. Increased enrollment rates, better access to education, and perhaps superior educational achievements are frequently associated with an increase in the number of public schools.

However, Figure 5 suggests that even countries with a high education rate have a low number of public schools and vice versa is also true. This means that countries need to strengthen their system either through decentralization or cluster-based learning.

Figure 5. Number of Schools



Source: own calculations

3.5. Correlation

The educational index is a matric used to tell whether a country is on an educational success trajectory or not. Through correlation analysis the variables that impact the index can be analyzed.

Table 2. Correlations

		Population	GDP Per Capita, $	Government Education Financing, %	No. of Public Schools	Successful Education Rate
Population	Pearson Correlation	1	-.166	.087	.885**	.044
	Sig. (2-tailed)		.281	.575	.000	.776
	N	44	44	44	44	44
GDP Per Capita $	Pearson Correlation	-.166	1	.202	-.158	.140
	Sig. (2-tailed)	.281		.187	.307	.363
	N	44	44	44	44	44
Government Education Financing %	Pearson Correlation	.087	.202	1	.101	.523**
	Sig. (2-tailed)	.575	.187		.513	.000
	N	44	44	44	44	44
No. of Public Schools	Pearson Correlation	.885**	-.158	.101	1	.014
	Sig. (2-tailed)	.000	.307	.513		.928
	N	44	44	44	44	44
Successful Education Rate	Pearson Correlation	.044	.140	.523**	.014	1
	Sig. (2-tailed)	.776	.363	.000	.928	
	N	44	44	44	44	44

**. Correlation is significant at the 0.01 level (2-tailed).

Source: own calculations

Table 2 indicates that there is a significant positive correlation between population and public-school enrollment (0.885**), indicating that as a nation's population rises, so does the number of public schools. Furthermore, a notable positive association between Government Education Financing (%) and Successful Education Rate emerges (0.523**, highly significant at the 0.01 level), suggesting that countries that allocate a larger share of their budgets to education typically have better educational outcomes. Though statistically insignificant ($p = 0.513$), the link between Government Education Financing (%) and the quantity of public schools is only marginally favorable (0.101). These relationships provide important insights by highlighting the complex interactions between population size, educational funding, and educational achievement rates.

From the above findings it is clear that the only variable affecting the successful education rate is Government Education Financing (%). This means that the greater the budget allocated to education by a government, the higher the educational index of the country, which thus increases the GDP as indicated in Figure 4.

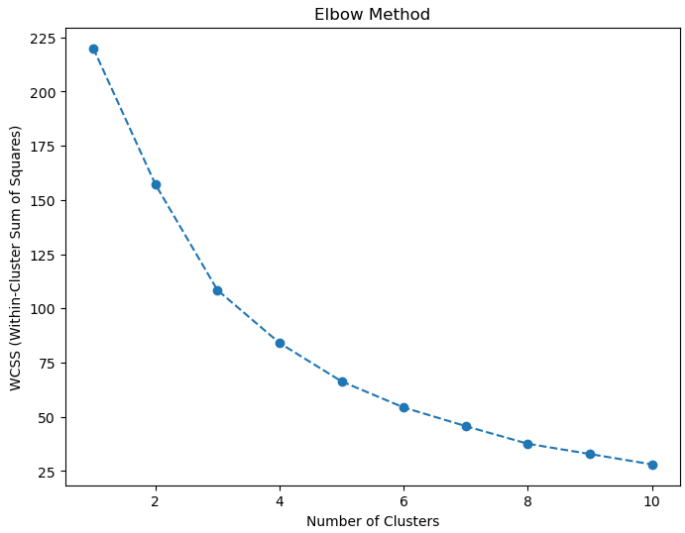
Cluster analysis is used in the methodology to find factors impacting education rates by analyzing educational data from European countries. Normalization and other pre-processing stages handle data variability and outliers, and the elbow approach is used to find the ideal number of clusters. By confirming cluster stability and relevance, the method guarantees reliable and understandable results.

4. Results and Findings

4.1. Finding the clusters: The Elbow Method

Before analyzing any k-means cluster techniques, the optimum number of clusters must be found to represent the data. When employing clustering methods like K-means, the Within-Cluster Sum of Squares (WCSS) and the Elbow Method are crucial steps in figuring out the ideal number of clusters. In order to determine how compact a cluster is, WCSS calculates the sum of squared distances between each set of data points. In contrast, the Elbow Method is charting the WCSS for various cluster counts and locating the point on the graph where the rate of reduction abruptly changes, mimicking an "elbow." This point denotes the ideal cluster count since it is a compromise between reducing intra-cluster distance and avoiding excessive fragmentation. These techniques are useful tools for cluster analysis, aiding decision-making regarding the number of clusters to utilize by data analysts. Figure 6 demonstrates that the optimum number of clusters for the given data is three.

Figure 6. The Elbow Method



Source: own calculations

4.2. K-means cluster and findings

With the help of the elbow method, we found out that three clusters can be made for our data. By using k-means the following three clusters were made. Table 3 represents the centers of each of the three clusters.

Table 3. K-means cluster

Cluster	1	2	3
Population	57,135,587	5,440,822	144,444,359
GDP Per Capita $	35,479	48,182	9,510
Government Education Financing %	4.3%	4.5%	5.0%
No. of Public Schools	18,412	2,278	40,000
Successful Education Rate	.85	.81	.70

Source: own calculations

Cluster 1: Moderate GDP, High Population

Population: Cluster 1 has a median population of about 57.1 million people, which suggests that the nations in this cluster have generally average-sized populations. *GDP Per Capita*: The average GDP per capita in this cluster is relatively high, at roughly $35,479, indicating that countries in this cluster have a significant economic production per person. *Government Education Financing Percentage*: With an average government education financing percentage of 4.3%, these nations devote a respectable portion of their GDP to education. *Number of Public Schools*: There are typically 18,412 public schools in Cluster 1, which indicates a moderate degree of infrastructure. *Average Success Rate in Education*: The average success rate in education is 0.85, showing a comparatively high degree of academic success.

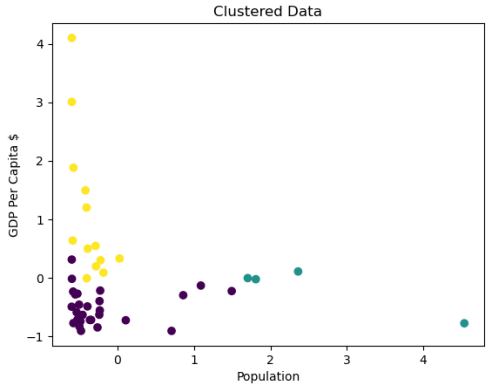
Cluster 2: High GDP, Small Population

Population: With an average of only 5.4 million people, Cluster 2 has a significantly smaller population than Cluster 1, showing that the countries in this cluster typically have a smaller total population. *GDP Per Capita*: This cluster's average GDP per capita is relatively high, at roughly $48,182, indicating significant economic affluence per person. *Government Education Financing Percentage*: The average government financing percentage for higher education is 4.5%, which is reasonable but significantly higher than Cluster 1. *The average number of public schools* in Cluster 2 is around 2,278, which suggests a less developed infrastructure for public education than in Cluster 1. *Successful Education Rate*: This cluster has a reasonably high degree of educational performance, with an average successful education rate of 0.81.

Cluster 3: Low GDP, Very High Population

Population: With an estimated 144.4 million people, Cluster 3 has the greatest average population size, indicating that the nations in this cluster have sizable populations. *GDP Per Capita*: At $9,510 on average, this cluster's GDP per capita shows lower economic prosperity for everyone. *Government Education Financing %*: These nations devote a larger proportion of their GDP to education than the other groups, with an average government education financing percentage of 5.0%. *Number of Public Schools*: Cluster 3 has an average of almost 40,000 public schools, which suggests a comparatively robust public-school infrastructure. *Successful Education Rate*: This cluster has a lower level of educational success than the other clusters, with an average successful education rate of 0.70.

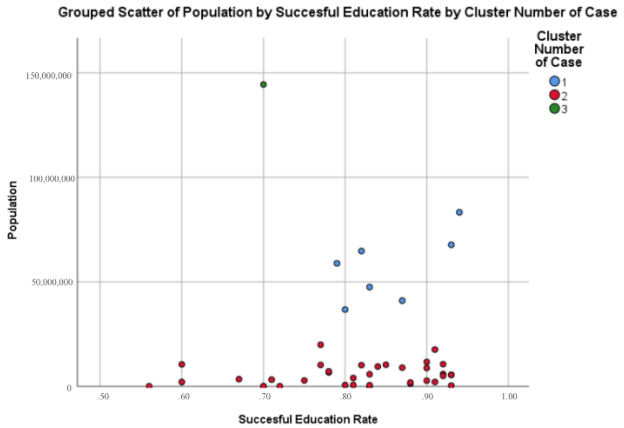
Figure 7. Plot of clusters in relation to GDP and population



Source: own calculations

In conclusion, Cluster 1 includes nations with average population sizes, high GDP per capita, average educational funding, average numbers of public schools, and average levels of academic accomplishment. Cluster 2 contains nations with smaller populations, high GDP per capita, slightly greater education financing, fewer public schools, and relatively high levels of educational accomplishment. Cluster 3 includes nations with sizable populations, lower GDP per capita, higher education financing, a sizable number of public schools, and lower levels of educational success. These clusters offer insights for additional investigation or policy concerns by classifying nations according to socioeconomic and educational traits.

Figure 8. Cluster distribution



Source: own calculations

Figure 7 shows the scatter plot distribution of cluster points. Apparently, most of the countries center around the second cluster. This is also obvious from the above figure. The second cluster has low population as well as a high education rate.

Each cluster's variability is exposed via the descriptive statistics for the clusters. In the first cluster, the standard deviations of the population (16,459,779.98), GDP per

capita (15,446.39), government financing of education (1.1838%), the number of public schools (10,588.04), and the successful education rate (0.06079) are all measured. In Cluster 2, there are 2,186.40 public schools, a successful education rate of 0.10172, GDP per capita of 50,477.72, government financing of education at 1.4348%, and population standard deviation of 5,020,486.92. Cluster 3 statistics are left out because all of the factors remain constant.

Table 4. Variability of the data variables with the clusters

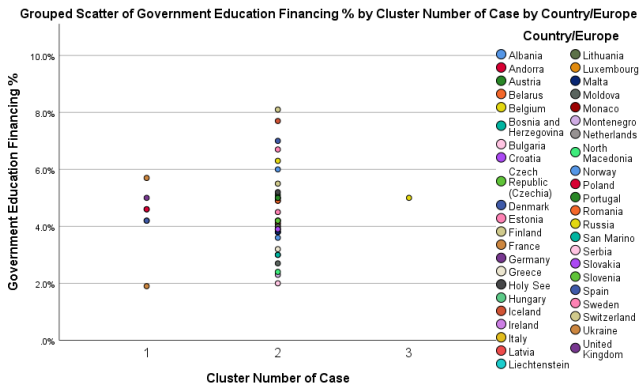
Descriptives[a,b,c,d,e]			
Cluster Number of Case			Statistic
Population	1	Std. Deviation	16,459,779.975
	2	Std. Deviation	5,020,486.920
GDP Per Capita $	1	Std. Deviation	15,446.393
	2	Std. Deviation	50,477.720
Government Education Financing %	1	Std. Deviation	1.1838%
	2	Std. Deviation	1.4348%
No. of Public Schools	1	Std. Deviation	10,588.039
	2	Std. Deviation	2,186.399
Successful Education Rate	1	Std. Deviation	0.06079
	2	Std. Deviation	0.10172
a. Population is constant when Cluster Number of Case = 3. It has been omitted.			
b. GDP Per Capita $ is constant when Cluster Number of Case = 3. It has been omitted.			
c. Government Education Financing % is constant when Cluster Number of Case = 3. It has been omitted.			
d. No. of Public Schools is constant when Cluster Number of Case = 3. It has been omitted.			
e. Successful Education Rate is constant when Cluster Number of Case = 3. It has been omitted.			

Source: own calculations

4.3. Classification of countries according to clusters

The countries are divided among the clusters as follows:

Figure 9. Countries distribution according to clusters



Source: own calculations

The countries in the various clusters are listed in Table 5. Cluster 1 consists of 7 countries, Cluster 2 consists of 36 countries, and Cluster 3 consists of 1 country only.

Table 5. Distribution of countries against their cluster number

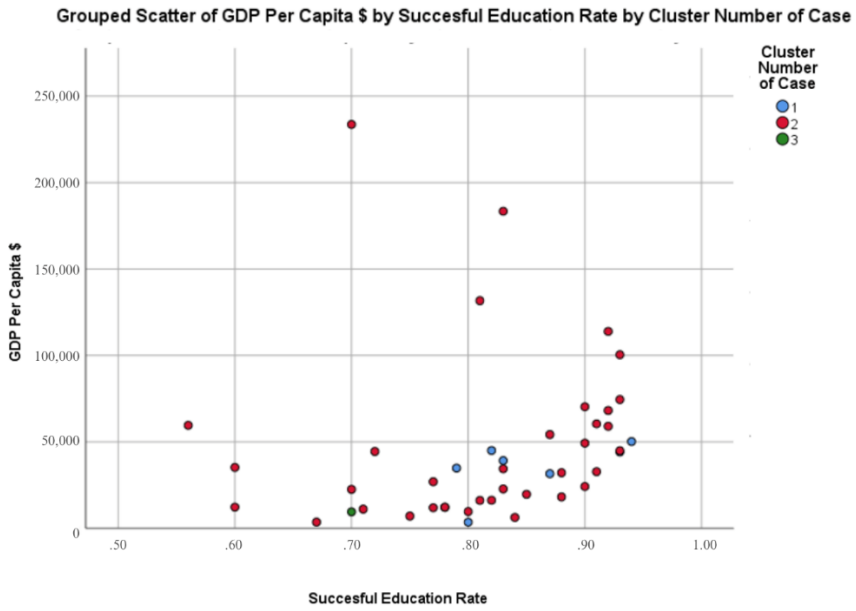
Cluster Number of Case	1	2	3
Country/Europe	France	Albania	Russia
	Germany	Andorra	
	Italy	Austria	
	Poland	Belarus	
	Spain	Belgium	
	Ukraine	Bosnia and Herzegovina	
	United Kingdom	Bulgaria	
		Croatia	
		Czech Republic (Czechia)	
		Denmark	
		Estonia	
		Finland	
		Greece	
		Holy See	
		Hungary	
		Iceland	
		Ireland	
		Latvia	
		Liechtenstein	
		Lithuania	
		Luxembourg	
		Malta	
		Moldova	
		Monaco	
		Montenegro	
		Netherlands	
		North Macedonia	
		Norway	
		Portugal	
		Romania	
		San Marino	
		Serbia	
		Slovakia	
		Slovenia	
		Sweden	
		Switzerland	
Total	7	36	1

Source: own calculations

Table 5 clearly shows that most of the European nations have smaller populations, high GDP per capita, slightly greater education financing, fewer public schools, and relatively high levels of educational accomplishment. However, some

have large populations, the anomaly being Russia, as it has the largest population out of all the European nations.

Figure 10. GDP distribution by clusters



Source: own calculations

Figure 10 further validates the k-means cluster. The nations belonging in the 2nd cluster have education rates along with high GDP per capita.

5. Discussion

The clustering analysis of European countries offers an organized technique to comprehend the diversity of educational and economic environments on the continent. Using these clusters as a resource, European countries may cooperate to strengthen their educational systems, spur economic expansion, and promote a more prosperous and equitable future for all.

The clusters can provide important insights for the continuous growth of European nations. As an illustration, the clusters can be used by European policymakers to guide the creation of specialized economic and educational policies. Nations in Cluster 1 can offer insights on how to achieve both economic prosperity and high rates of educational success to other clusters by sharing best practices.

Governments can deploy resources more effectively if they are aware of the unique difficulties and advantages of each cluster. For instance, Cluster 2 nations may profit from higher public education spending or focused efforts to raise educational standards.

Collaboration between countries with comparable features can be facilitated by the clusters. This cooperation may also include commercial alliances, cooperative research projects, and educational exchanges.

5.1. Further research

The results of this study suggest several intriguing directions for further investigation and analysis in the areas of education and economics in Europe. A more thorough examination of the exact elements influencing the performance of the nations in Cluster 1, which display high GDP per capita and good schooling rates, is one promising direction of research. To identify the laws, customs, and instructional methods that have produced such favorable results, researchers could carry out case studies or surveys. For other European countries attempting to attain comparable results, this might offer useful insights.

5.2. Limitations and data improvement

Recognizing the limitations of the current study is essential for future research. One shortcoming is that the analysis was based on a small number of variables, and additional variables like cultural elements, teacher-to-student ratios, and infrastructure could have a considerable impact on educational and economic outcomes. To provide a full understanding of the topic, in a future study including a wider range of variables would be useful.

6. Conclusion

The delicate link between education and economic development in European nations has been clarified by this detailed study. Through the use of clustering and classification algorithms, various clusters have developed, each of which represents a particular fusion of educational and economic traits. These clusters shed important light on the various difficulties and triumphs that European countries have encountered in their quest for socioeconomic prosperity.

Cluster 1, which has a high GDP per capita and high success rate in education, provides an example of how to implement effective public policy and educational techniques. The nations in this group may help their peers succeed economically and academically by imparting invaluable knowledge. To close the disparities in economic development and educational quality, Cluster 2, which is dealing with these issues, needs targeted interventions and creative strategies.

The results also highlight the significance of including a wider range of factors in future study to provide a more thorough understanding of the complex relationship between education and economic development, including cultural factors, infrastructure, and political stability. The dynamics of these clusters through time can also be better understood via longitudinal research and evaluations of outside influences.

In conclusion, this study offers politicians, academics, and educators all around Europe a useful starting point. Nations can develop well-informed strategies, improve their educational systems, and promote sustainable economic growth by

utilizing the insights gained from these clusters. This research contributes to the ongoing effort to advance human development and prosperity in Europe. The pursuit of excellence in education and economic development is a lifelong journey.

Acknowledgements

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Consumer behavior factors in green purchasing of food and agriculture products in Hungary

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In the contemporary world, the considerable increase in population, followed by the rise in food consumption and industrial production to meet the needs of society, results in environmental destruction. Since large industries carry out the majority of production with a monopoly on the market, the importance of paying attention to this issue is felt more by these companies to boost client satisfaction and green sales. In this study, consumer behavior factors in green purchasing of food and agriculture products in Hungary is discussed. The experts in this study include management and economics professors in Hungarian universities, scientific experts, and active managers in food and agricultural industries in Hungary. Based on the opinion of these experts, it is determined that 35 sub-final factors and 6 final factors can be considered by the managers of food and green agriculture production units to improve sales and increase customer satisfaction in Hungary.

Keywords: green purchasing, consumer behavior, food and agriculture products

1. Introduction

Nowadays, due to the increase in population and daily consumption, and air and environmental pollution from industrial production, environmentally friendly products have become more important. Since large industries carry out 75% of production with a monopoly on the market, the importance of paying attention to this issue is felt more by these companies, and customers expect a lot from these big businesses. Since the late 80s, the concept of green marketing has been used among companies to improve their position in the market, differentiate the company's philosophy, and provide green value propositions to attract satisfaction and retain customers for a long time (García-Salirrosas–Rondon-Eusebio 2022). Green marketing pays attention to the process of selling products and services, especially environmentally friendly products, and in general, the implementation of all processes based on environmental benefits and their effects on the health of society. This marketing model is used by companies that are committed to the environment and hold themselves responsible for environmental and social health (Chandra Sekhar et al. 2022). Green marketing is an emerging strategy for protecting society and the environment with a long-term vision for the future (Roh et al. 2022). Humans realized in the past that they had to take care of the environment to continue their survival, and not taking care of it would lead to their destruction. With the progress of industry and economy, despite the progress in income and standard of living, the environment has been significantly damaged, and the existing order in it has been endangered by the pollution created by products. To prove this claim, attention should be paid to the increase in the average global temperature of the environment that air pollution and reduction of natural rainfall are its results. These issues caused attention to be drawn to the preservation and care of the environment (Javidi Kermaninezhad et al. 2020,

Ahmed et al. 2023). Green shopping is a suitable solution in developed and developing countries. On the other hand, due to the stated problems, the attitude and behavior of consumers towards green shopping and environmentally friendly goods have flourished more than ever, so most of today's customers prefer to buy green goods from companies supporting the green environment that provide green services (Quach et al. 2022). In recent years, especially in the last decade, marketers have been adopting the philosophy of green marketing according to the environmental concerns of customers, so this attention to their concerns has created a competitive advantage in today's highly competitive market (Ahmed et al. 2023). From the studies on green marketing, it can be seen that it is divided into topics such as green distribution, green supply chain, green packaging, green advertising performance, green human resources, and green organization performance (Sun et al. 2021, Jermsittiparsert et al. 2019). Organizational performance is related to market share, profitability, customer satisfaction, customer loyalty, and long-term competitive advantage, so it is suggested that companies use environmentally friendly long-term strategies (Yusiana et al. 2021, Chen–Chang 2012). Researchers talk about the existence of a triangle including manufacturing companies, consumer society, and governments; these three sides are involved in the purchase of green products, and each of them has specific challenges. Governments and companies have an important role in preserving the environment, but it seems that customers and consumers have a more important role in preserving the environment, so raising awareness in this field is very important for customers (Dalir–Ghasemi 2020, Rahbar–Wahid 2011, Paul et al. 2016).

Therefore, according to the growing concerns and attentions of individual and industrial customers and society, as well as producers in all the links in the supply chain, from raw material producers to final producers, in this study – with the help of library and academic resources – we attempt to identify and investigate the effective factors of consumer behavior in buying green products in Hungary, to help to improve the performance of green product producers in sales, profit, and consumer satisfaction and to meet needs.

In this paper, we first provide an overview of studies about green consumers, purchase behavior, and green food and agriculture products. Then, previous studies are discussed to elaborate on purchasing behavior factors. After outlining the methodology and its stages, we describe our findings. Ultimately, we conclude what factors can affect consumer behavior in buying green agriculture and food products in Hungary.

2. Theoretical framework

2.1. Green consumer

The increase in environmental pollution and the endangering of the environment and the future of humanity – in the reduction of natural rainfall, the destruction of forests, air pollution, the increase in the temperature of the earth, as well as the destruction of the ozone layer – cause that a new type of concern in the decision making of customers in buying the goods has created (Javidi Kermaninezhad et al. 2020). Consumers are an essential element for the survival and growth of any service product in today's competitive market. In the past years, consumers did not know much about green

products. However, changing times, culture, and global relationships such as social networks, as well as increasing imports and exports, have created opportunities for green consumption in all parts of the world. Nowadays, customers are exposed to information, and manufacturers are well aware of their needs. Dissemination of information has created awareness of dos and don'ts. Broadly speaking, the support of eco-friendly systems and the environment has been aimed at achieving a sustainable future, and governments and policymakers have been obliged to implement this positive action to achieve customer satisfaction (Rutkowska et al. 2021).

Environmental concerns led to the introduction of a new concept called green consumers in recent decades. Green consumption is a thought and belief that is aimed at expressing a relationship between consumption and various factors including socio-demographic, psychological, attitudinal, and behavioral factors (Ogiemwonyi et al. 2019, Singh 2023). Green consumption has increased in developed and developing economies, and it means environmental protection by all classes of society, the current and future generations, like the use of organic products, clean and renewable energy, and products that have the least adverse effects on the environment, as well as low use of fossil fuels. Hence, this attention to the environment is the result of the green customer's attention (Haba et al. 2023). Green consumers are people who care about quality and price as well as brands and manufacturers that adopt environmental protection measures and respond to concerns (Martínez et al. 2020, Haba et al. 2023). Mulyono et al. (2023) believe that these consumers buy and consume goods based on their desire and opinion, not their needs. This means that, in general, ordinary customers buy goods without any reasonable and behavioral considerations and only based on the pleasure, need, and feeling of shopping. Researchers who first investigated green consumers classified them using sociodemographic factors such as gender, age, education, and income. They believed that the level of education and income is key in the acceptance of this issue, so it was believed that green consumers have a high level of education (i.e. university degrees or higher), and/or their household income is above average. Also, from a psychological and sociological point of view, these people have the characteristics of active self-control resource, perceived consumer efficacy and altruism, and from the perspective of attitudinal factors, they have environmental concerns and perceived environmental responsibility more than the general public (Lee–Haley 2022).

Green consumer efforts have important effects on the environmental performance of producers and help to achieve environmental sustainability, and for this reason, the main agenda of green marketing is to maximize sales and consumption of green products as well as green customer satisfaction (Martínez et al. 2020, Ogiemwonyi et al. 2019). Haba et al. (2023) believe that active managers in the green products industry should conduct research on green consumers and sustainability aspects, including environmental marketing and green consumption under sustainability to better identify green consumers.

2.2. Green purchase behavior

Due to the harmful effects that can be seen due to the uncontrollable consumption of goods and irresponsible behavior towards the environment, the balance of the ecosystem

and human life has been affected, so humans, as an essential part of this world, should have the responsibility of protecting the earth against any exploitation and unreasonable misuse of the environment. Therefore, the need to change habits from standard to green shopping is strongly believed to reduce the negative environmental impact. In recent years, green shopping behavior has received much attention due to its positive effect on the environment (Jaini et al. 2020, Moazzam et al. 2023). Green shopping behavior is called a behavioral and practical philosophy resulting from complete discretion by the customer, which affects the environment and ecology (Tawde et al. 2023, Lim–Lady 2023). Green shopping behavior is the purchase and consumption of environmentally friendly products, which are protective of the environment and can be kept and even recycled. This product is sensitive to environmental concerns and issues; in this case, customers have no problem paying more for these products; their environmental needs cause this behavior, and it is done based on the principles of sustainability, forward-looking, and social benefits (Liu et al. 2022, Setiawan et al. 2022, Sheikh et al. 2023, Mustikasari 2023).

The philosophy of green shopping behavior is mainly the attitude of consumers towards, the intention to buy, and the willingness to pay for a green product; these customers have a complete understanding of the environmental issue and the effects of the product they buy (Liu et al. 2022). Examples of green shopping behavior can be summarized as buying low-consumption products, avoiding over-packaged and non-biodegradable products, wanting to use recyclable products, and any activity that leads to pollution reduction (Sheikh et al. 2023, Lim–Lady 2023). Green purchasing behavior was considered in the agriculture and food sectors. The philosophy of green procurement behavior is mainly the attitude of consumers towards the intention to buy and the willingness to pay for a green product; these customers completely understand the environmental issue and the effects of the product they buy (Liu et al. 2022). The philosophy of green purchase behavior is strongly influenced by consumers' commitment and motivation to advance goals in the intention-behavior link, and this behavior or conscious intention eventually becomes their purchasing choice (Setiawan et al. 2022, Lim–Lady 2023, Tawde et al. 2023). On the other hand, primary research on green purchase behavior shows that consumers pretend that they intend to buy and keep buying throughout their lives. They try to convert intentions into behavior as well as convert it into action (Tawde et al. 2023). Green shopping behavior starts with intention. Purchase intention is influenced by several factors, including cognition, which includes knowledge and concern, as well as collectivism, environmental concerns, and the perceived effectiveness of the consumer (Mustikasari 2023). Based on the conducted research, green shopping behavior has a series of theories, including the theory of planned behavior, value-belief-norm theory, and attitude-behavior-context theory (Goh–Balaji 2016, Yadav–Pathak 2017, Chaudhary–Bisai 2018, Jaini et al. 2020). Its proponents have shown that beliefs about consequences, responsibility, and personal norms are critical factors that affect human behavior. Therefore, personal values, beliefs and norms are expected to be considered drivers of consumers' green purchasing behavior (Jaini et al. 2020). A person with a positive attitude towards green products is influenced by the social norms that support the desire to consume green products, is

aware of the positive factors surrounding this issue, and has a positive attitude towards this issue (Sheikh et al. 2023).

After using the green product, these consumers evaluate the product. Consumers will feel the benefits of products with green values, which, of course, play an essential role for consumers and the environment, and relate to their previous perceptions. This value is an essential factor that affects the purchase intention. When consumers feel that the product's value is high and can satisfy them, it positively affects their purchase intention; in contrast, when the value is low for consumers, it leads to reluctance. As a result, companies should be able to maintain the green value of new products and improve them to meet customer expectations or even exceed them so that consumers trust these products (Simamora–Graciafernandy 2023).

2.3. Green food and agriculture products

Food is one of the main constituents of human life and has an immediate and abundant impact on human health. The important parameters that show that a food is called green are the following. The raw materials are green, which means that green and organic methods and norms are used in production, cultivation, and harvesting techniques. In terms of agriculture, what can be mentioned is the reduction in the use of plants that require a lot of energy, water, and fertilizer. In the processing and distribution sector, reducing the use of preservatives and finally disposing of waste and reproducing are decisive. In terms of packaging, the rules of green packaging should be used, which can be called the use of environmentally friendly raw materials in packaging (Jindoliya–Nagra 2020). In recent years, the production of green products, especially in the agricultural and food sectors, has increased significantly due to the great increase in the demand for these products. The quality and safety of agricultural products and food are closely related to the health of human life. Green agriculture and its development will reduce agricultural pollution and improve the quality of food. In the field of market economy, the desire of consumers to buy agricultural products and green foods causes the increase of producers' motivation to develop and promote green agricultural products, and on the other hand, to improve the production technology in this field and increase competition in diversity and Production quality. These factors have caused managers to pay more attention to improving their brand image to increase customer satisfaction and meet their expectations. Therefore, it is very important to help companies create a good brand image for green agricultural products to improve the consumption intention of green agricultural products, promote green consumption, and achieve sustainable development (Yang et al. 2023).

3. Empirical evidence

Javidi Kermaninezhad et al. (2020) determined and obtained the variables influencing customers' green buying behavior by a systematic literature review on green purchase behavior to highlight its significance. All publications pertaining to this particular topic between 2000 and 2017 were included in the sample. Six main components, including psychological, personal, value–belief, marketing mix, sociocultural, and

product-related factors, and 59 sub-factors were extracted and categorized as factors influencing consumers' green purchase behavior.

Witek and Kuźniar (2020) investigated the effects of gender, age, education level, personal financial situation, and the number of children in the family on purchasing behavior toward green products. To achieve the goal, a survey among 650 Polish consumers was conducted. Findings suggest that all of the above-mentioned sociodemographic variables have an impact on awareness and purchasing behavior towards green products. Moreover, the results show that female consumers have more positive attitudes towards purchasing green products than male consumers. Young consumers are skeptical about green products. A positive relationship was established between education and the acknowledgment of the dominance of one's own needs over the needs of the environment. The better the personal financial situation, the more likely it was that people expressed their intention to buy green products.

Hasnain et al. (2020) investigated the effects of eco-labels and environmental attitude along with the moderating of gender to examine the impact of customer personality traits regarding their propensity for green purchases. They used survey method data from a sample of 434, which has been collected through a structured questionnaire distributed among employees of the different national and multinational companies. The results indicate that consumers' intentions to purchase environmentally friendly products are significantly influenced by the mediation of ecological labels, environmental attitude, and gender moderation.

Sobuj et al. (2021) evaluated the variables that affect young Bangladeshi consumers' purchase decisions for eco-friendly clothing. Data were collected through a survey among 198 respondents in Bangladesh in terms of consumer attitude, subjective norm, perceived behavioral control, environmental concern, environmental knowledge, and purchase intention. They stated that purchase intention is substantially influenced by attitudes, subjective norms, environmental concerns, and environmental knowledge of consumers.

Alavi Foumani et al. (2022) tried to determine factors influencing the implementation of green purchases behavior. Using purpose foul and snowball sampling methods, semi-structured interviews were conducted with 13 experts from among business researchers and environmental activists. The interviews revealed that causal categories (environmental belief, health concern, green attitude, and mental norm), causal categories (green purchase behavior), background categories (economic indicators, government support for capital Eco-friendly investments, the country's environmental policies, and the impact of green consumption culture), interventionist category (distribution of green products, financial and economic constraints of households and promotion, and encouragement to green purchase), strategies (Indian market strategies, prices, and innovation), and the consequence (at the macro-level including increasing the level of health in society, development, and growth of organizational performance and promoting green lifestyle, while at the micro-level including preference to buy environmentally friendly products and increase the repetition of purchases behavior) impact on the implementation of green purchases behavior.

Boca (2021) investigated factors influencing consumer behavior in sustainable fruit and vegetable consumption in Maramures County, Romania. For this

purpose, a questionnaire was applied to a sample of 1230 people from Maramures County, Romania. This study evaluates consumer behavior and attitudes toward sustainable healthy food consumption; determining factors of consumer behavior are established as the needs, knowledge, selection of quality products, and the degree of culture and education in health diet issues. This study has revealed that consumer behavior is not influenced by age, gender, and education.

Majeed et al. (2022) investigated the influencing factors on consumers' choice behavior and their environmental concerns while purchasing green products in Pakistan. This study aims to investigate the influencing factors on consumers' choice behavior for green products by applying the theory of consumption values in Pakistan. The data was collected from the consumers of green products in four metropolitan cities of Punjab Province (e.g. Lahore, Islamabad, Multan, and Faisalabad) using a structured self-administered questionnaire. The random sampling technique was employed. Based on the 480 responses, the empirical findings revealed that functional value-quality, emotional value, conditional value, and epistemic value have a positive impact on consumers' choice behavior and their environmental concerns. In contrast, the functional value-price, social value, and environmental concerns have a negative impact on consumers' choice behavior.

4. Methodology

To obtain the factors affecting consumer behavior in green buying in Hungary, we use research by Javidi Kermaninezhad et al. (2020), who identified the likely factors and investigated 407 papers related to this subject. Of the 407 initial results, 61 were examined, and 6 main components (namely psychological, personal, value–belief, marketing mix, sociocultural, and product-related factors), and 59 sub-components were identified as factors affecting the consumers' green purchase behavior. We utilized the fuzzy Delphi technique to screen the factors by distributing a semi-structured questionnaire with Likert scoring in one step. Experts who answered the questions are university professors of management sciences and economics active in Hungary and managers and specialists working in large factories producing agricultural and food products in Hungary. The fuzzy Delphi technique is a collaborative method to gather experts' opinions in a specific field, such that a group of experts in a specific field are selected as panel members and express their opinions on a specific issue using fuzzy concepts. It is a mathematical logic for modeling uncertainty and ambiguity in data and information. The snowball sampling method was used to identify research experts. A semi-structured questionnaire with a five-point Likert scale (very low = 1, low = 2, medium = 3, high = 4, and very high = 5) was sent to 20 experts. Excel was used to extract the results. Based on this method, all the sub-factors with a diffusion score of 0.7 or higher were considered verifiable factors, and the factors with a score lower than the specified number were excluded (Habibi et al. 2013).

Table 1. Triangular fuzzy numbers equivalent to a 5-degree Likert spectrum

Linguistic variable	Fuzzy number	Triangular fuzzy number
Very unimportant	1	(0,0,0.25)
Unimportant	2	(0,0.25,0.5)
Moderately important	3	(.025,0.5,0.75)
Important	4	(0.5,0.75,1)
Very important	5	(0.75,1,1)

Source: Habibi et al. (2013)

5. Findings

A total of 6 main indicators and 59 secondary indicators used as the likely factors affecting consumer behavior are demonstrated with the title of Main Factor and Secondary Factor in Table 2. Based on fuzzy score, 35 sub-factors out of 59 sub-factors under 6 main factors were accepted and confirmed (Table 3).

All sub-factors of marketing mix indicators are effective, including green product design, distribution, price, promotional activities, and green marketing. Perceived quality, brand name, convenience and durability, performance, safety and health, and green brand image are impressive as related product's sub-factors. In sociocultural factors, all of them, including social effects, peer group influence, environmental effects, reference groups, government stimuli, and culture are influential. Among psychological factors, attitude towards green product, emotions, attitude towards green packaging, trust in the green brand, environmental attitude, awareness of the green brand (green product), and environmental concern are effective. This means that around 30 percent of plausible psychological factors are substantial in Hungary. Price sensitivity, environmental protection, environmental awareness, environmental pragmatism, and saving resources, as the personal factors, affect green consumer behavior to buy agriculture and food products. All sub-factors of belief-value indicator are effective, including consumer opinions, values, collectivism-individualism, mental norms, freedom (liberalism), and religious beliefs.

Table 2. Fuzzy score of main factors and secondary factors

Main Factor	Secondary Factor	Fuzzy Score	Defined Symbol	Result
(1) Marketing mix factors	(1) Green product design	0.7333464345	C1	Acceptable
	(2) Distribution	0.7884179955	C2	Acceptable
	(3) Price	0.845739819	C3	Acceptable
	(4) Promotional activities	0.701675275	C4	Acceptable
	(5) Green Marketing	0.7004806065	C5	Acceptable
(2) Product-related factors	(1) Access	0.5440699155	*	Unacceptable
	(2) Perceived quality	0.7884179952	S1	Acceptable
	(3) Brand name	0.7237976105	S2	Acceptable
	(4) Convenience and durability	0.718407627	S3	Acceptable
	(5) Environmental label	0.578616642	*	Unacceptable
	(6) Loyalty to the brand	0.1079285195	*	Unacceptable
	(7) Packaging	0.5292101725	*	Unacceptable
	(8) Performance	0.759954526	S4	Acceptable

	(9) Safety and health	0.9001075515	S5	Acceptable
	(10) Green brand image	0.752161424	S6	Acceptable
	(11) Green image of the organization	0.4617225695	*	Unacceptable
(3) Sociocultural factors	(1) Social effects	0.707935498	P1	Acceptable
	(2) Peer group influence	0.749528934	P2	Acceptable
	(3) Environmental effects	0.7321418365	P3	Acceptable
	(4) Reference groups	0.7355546345	P4	Acceptable
	(5) Government stimuli	0.7538983225	P5	Acceptable
	(6) Culture	0.708149641	P6	Acceptable
(4) Psychological factors	(1) Attitude towards green product	0.7192244945	DS1	Acceptable
	(2) Perceived risk	0.526635018	*	Unacceptable
	(3) Perception	0.5931906545	*	Unacceptable
	(4) Emotions	0.710491857	DS2	Acceptable
	(5) Attitude towards green packaging	0.7360875135	DS3	Acceptable
	(6) Trust in the green brand	0.7139038835	DS4	Acceptable
	(7) Consumer's perceived value	0.5780185647	*	Unacceptable
	(8) Environmental attitude	0.730056252	DS5	Acceptable
	(9) Awareness of the green brand (green product)	0.72044894	DS6	Acceptable
	(10) Perceived behavioral control	0.540436536	*	Unacceptable
	(11) Perceptual importance of problems	0.573920173	*	Unacceptable
	(12) Doubts and doubts about buying green products	0.11727158	*	Unacceptable
	(13) Waiting	0.6938277815	*	Unacceptable
	(14) Perceptual environmental responsibility	0.5653060755	*	Unacceptable
	(15) Perceived effectiveness	0.530293083	*	Unacceptable
	(16) Worrying about impressions (personal image)	0.5443761805	*	Unacceptable
	(17) Attitude based on marketing activities	0.4588048795	*	Unacceptable
	(18) Environmental concern	0.739362329	DS7	Acceptable
(5) Personal factors	(1) Interpersonal effects	0.5088055655	*	Unacceptable
	(2) Previous experience	0.5222983965	*	Unacceptable
	(3) Environmental knowledge	0.3871537245	*	Unacceptable
	(4) Being thrifty	0.5352611665	*	Unacceptable
	(5) Conscious behavior	0.621020713	*	Unacceptable
	(6) Intention to buy green	0.5235297645	*	Unacceptable
	(7) Demographic factors	0.337120786	*	Unacceptable
	(8) Price sensitivity	0.7311088045	M1	Acceptable
	(9) General environmental behavior	0.6350735205	*	Unacceptable
	(10) Environmental protection	0.741900463	M2	Acceptable
	(11) Environmental awareness	0.7369485205	M3	Acceptable
	(12) Environmental pragmatism	0.717756953	M4	Acceptable
	(13) Saving resources	0.735587291	M5	Acceptable
(6) Belief-value factors	(1) Consumer opinions	0.721643235	F1	Acceptable
	(2) Values	0.72720843	F2	Acceptable
	(3) Collectivism and individualism	0.759949464	F3	Acceptable
	(4) Mental norms	0.7258738755	F4	Acceptable
	(5) Freedom (liberalism)	0.7495835645	F5	Acceptable
	(6) Religious beliefs	0.7129035815	F6	Acceptable

Source: own construction

Table 3. 35 sub-factors out of 59 sub-factors under 6 main factors

Main Factor	Secondary Factor
(1) Marketing mix factors	(1) Green product design
	(2) Distribution
	(3) Price
	(4) Promotional activities
	(5) Green Marketing
(2) Product-related factors	(1) Perceived quality
	(2) Brand name
	(3) Convenience and durability
	(4) Performance
	(5) Safety and health
	(6) Green brand image
(3) Sociocultural factors	(1) Social effects
	(2) Peer group influence
	(3) Environmental effects
	(4) Reference groups
	(5) Government stimuli
	(6) Culture
(4) Psychological factors	(1) Attitude towards green product
	(2) Emotions
	(3) Attitude towards green packaging
	(4) Trust in the green brand
	(5) Environmental attitude
	(6) Awareness of the green brand (green product)
	(7) Environmental concern
(5) Personal factors	(1) Price sensitivity
	(2) Environmental protection
	(3) Environmental awareness
	(4) Environmental pragmatism
	(5) Saving resources
(6) Belief-value factors	(1) Consumer opinions
	(2) Values
	(3) Collectivism and individualism
	(4) Mental norms
	(5) Freedom (liberalism)
	(6) Religious beliefs

Source: own construction

6. Conclusion

This study has aimed to investigate the existing literature in the field of factors affecting consumers' green purchasing behavior and to determine the influencing factors on consumer behavior in green purchasing of food and agriculture products in Hungary. In this research, the fuzzy Delphi technique was used via distributing a semi-structured questionnaire with Likert scoring in one step. Finally, 35 sub-factors out of 59 sub-factors under 6 main factors were accepted as influencing factors. Health and safety, price, distribution, perceived quality, and performance have the highest importance among the approved sub-factors, and all of them belong to the two main factors of marketing mix factors and product-related factors. The marketing mix factor

shows to managers that every business knows its potential better and guarantees its success by formulating an efficient strategy and preparing a detailed business plan. The product-related factor demonstrates that customers pay attention to the quality of product production first when buying a green product.

This study was conducted in Hungary, and the results can be utilized by firms in this country to pay more attention to consumer behavior and attitudes towards their products and to identify new innovative technologies for future products. This study offers opportunities for future research into consumer behavior and attitudes toward sustainable consumption of different products, suggesting companies and traditional producers develop and implement new market strategies. The approaches that managers and producers of green products can apply to guide the norms of customers and increase their productivity are as follows: (i) creating awareness among customers about the benefits and importance of green products and emphasizing their environmental effects; (ii) encouraging customers to perform positive environmental behaviors such as waste separation, saving energy, and supporting green-label products; (iii) providing solutions for participation in environmental protection and encouraging customers to feel social responsibility towards the environment and society; (iv) providing a positive and satisfactory shopping experience for customers of green products; and (v) establishing continuous and active communication with customers, better understanding their needs and expectations, and providing appropriate answers.

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