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FROM THE EDITORS

In the volume **5 No. 1 of** – *TRANSBORDER ECONOMICS International Journal on Transborder Economics, Politics and Statistics* we would like to draw the Readers' attention to the transborder problems that are so different for the economies under analysis. Issues related to the startups market in Poland in perspective of young people, financial performance, agricultural changes, European Employment Services network and axiomatic approach to rankings techniques of decision analysis.

The article by Kinga Michoń and Joanna Piekarz entitled *Students startups in the national and international conditions. Manifestations of innovative entrepreneurship among young people* has the main objective to present the problems of startups, taking into account their basic characteristics, stages of development, major errors in their management. For the practical analysis of startups, examples of existing companies operating in national and international conditions were mentioned and discussed. For the purposes of this article, a survey was conducted among students of Polish academic institutions using an online questionnaire. It aimed to check the knowledge of the startup market and the potential path of its development. It was found that the Polish startup market is very popular, especially in the new technologies sector.

The paper by Andżelika Partyka examines the *Financial performance of SME enterprise as an engine of Polish entrepreneurship*. The aim of this paper is to present a classification of SME enterprises and the importance of this sector for the Polish economy. The aim of the paper is also to analyse the financial performance of the SME sector in Poland in 2015-2021. The paper uses the induction and deduction method, as well as structure and dynamics analysis. The results of the study led to the conclusion that, in the period 2015-2021, enterprises in the SME sector have, on average, a larger share of total revenue and costs and gross profit of non-financial enterprises than large enterprises. When analysing the data, it was also found that the SME sector is predominantly responsible for the creation of the value added and the value of production in the years under study over large enterprises.

Anna Szopińska's paper *State and changes in Podkarpackie agriculture on the basis of the Agricultural Censuses 2010 and 2020* is a case study of agricul-

ture in the Podkarpackie region which is characterised by a large number of small family farms, which limits its development and ability to compete on the national and international stage. The Agricultural Censuses 2010 and 2020 allowed to capture the changes that took place over the decade.

In the paper *EURES: facilitating occupational mobility across transborder areas* Anna Wójcik describes EURES, the European Employment Services network, which plays a crucial role in promoting labour mobility within the European Union (EU) and the European Economic Area (EEA). The findings shed light on the effectiveness of EURES initiatives in facilitating labour mobility and addressing the diverse needs of job seekers and employers in Europe. Data analysis presents large diversity of national labour markets. Imbalances of supply and demand side of labour market for several occupations are revealed. The occupational choice theories are outlined to indicate that it is a subject of substantial academic research.

Jarosław Napora and Agnieszka Giemza in their article *Axiomatic approach to rankings techniques of decision analysis* presents a short review of ranking techniques of multi-criteria decision-making. It makes conclusions about the common ideas shared among most of presented ranking techniques. Further, these common properties are expressed in terms of functional equations and inequalities. Finally, four properties of selected ranking techniques are investigated, namely: symmetry, scale-invariance, shift-invariance, and boundness. This article shed light on a new approach to developing ranking techniques, that is, axiomatic approach.

Prof. Elżbieta Feret
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STUDENT STARTUPS IN NATIONAL AND INTERNATIONAL CONDITIONS. MANIFESTATIONS OF INNOVATIVE ENTREPRENEURSHIP AMONG YOUNG PEOPLE

Kinga Michoń¹, Joanna Piekarz²

ABSTRACT

The global startup market is growing rapidly and is becoming more and more popular. This trend is visible, among others, in Poland, although the startup market is still not as big as in the case of the business power of the United States. A significant share of this market is held by young people, especially students, for whom creating a startup and finding an investor is an opportunity for success and further career development. The dream of many today's students is to become an entrepreneur, which consequently manifests itself in the formation of an increasing number of companies operating at universities. The article is theoretical and analytical. Its main objective is to present the problems of startups, taking into account their basic characteristics, stages of development, major errors in their management. For the practical analysis of startups, examples of existing companies operating in national and international conditions were mentioned and discussed. For the purposes of this article, a survey was conducted among students of Polish academic institutions using an online questionnaire. It aimed to check the knowledge of the startup market and the potential path of its development. It was found that the Polish startup market is very popular, especially in the new technologies sector.

Key words: startup, innovation, entrepreneurship, students.

JEL: M13, L26

1. Introduction

Startups are playing an increasingly important role in Poland and around. Due to their great popularity, it is becoming increasingly difficult to distinguish

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an idea in this market. Due to the great interest and needs, courses of study are created that allow you to learn how to introduce and maintain a startup on the market. Such a course was established, among others, in 2022 at the Wrocław University of Economics. Its name is Startup Leadership Program (Osowicz, P., 2022).

Startups currently play an important role among companies due to the fact that they are entities almost independently creating a new market. They take innovative solutions, which is why they are referred to as innovative companies, market pioneers, creating modern products, sometimes inventions. Startups test their solutions in the realities of economic reality, contribute to the creation of new lines of products and services, sometimes also new industries. Solutions used in startups are often used by other companies (Deloitte, 2016).

The strong growth of startups in countries such as the United States, China and the United Kingdom allows these countries to remain leaders in innovative products and services. Innovative business models modernise the economic structure of countries, increase competitiveness and create new jobs (Deutscher Startup Monitor, 2015). Startups contribute to creating and meeting needs, but their development is not possible without permanent sources of financing, which most often include: crowdfunding, venture capital funds, support for business angels, founders' equity, FFF (friends, family and fools), bank loans, funds from the European Union, funds from the employment office, support for business incubators (Cegielska, E., Zawadzka, D., 2017).

Although startups are often treated as small versions of large companies, they rarely achieve a strong market position, as they face relatively high operational risks and the need to find and apply different business methods to those that work for large companies. Today, it is possible to draw and exchange between startups and companies with established market position. All these entities have the same goal – seeking competitive advantage in order to achieve long-term profitability (Skala, A., 2017).

The world's leading startup researchers are Steve Blank, Silicon Valley entrepreneur and consulting associate professor in entrepreneurship at Stanford University, and Eric Ries, entrepreneur-in-residence at Harvard Business School. These researchers are the authors of the Lean startup management concept, which is a response to the need to create innovative products and services. This well-known concept involves shortening product development cycles and quickly checking whether the chosen business model is profitable. Management should be focused on minimizing waste and improving internal processes in the company. The concept of lean startup was popularized by Eric Ries, but S. Blank is considered to be the father of this line of thinking (Tomaszewski, A., 2018). Among Polish researchers dealing with the topic of startups, we can mention Agnieszka Skalska, who deals with the issue of complex definition of startups (Skala, A., 2017).

2. Characteristics of startups

2.1. Definition of startup

In the literature there are different approaches to defining a startup, but the often-mentioned feature is the high growth potential and innovation of this newly formed company. Related to the introduction of a new or improved product or service. The authors of the European Startup Monitor 2015 characterise startups as “companies under 10 years old, with innovative technologies and/or business models, aiming to significantly increase the number of employees and/or sales”. These features allow to distinguish startups from companies referred to as SMEs (Cegielska, E., Zawadzka, D., 2017).

Another similar definition of a startup can be found in the Management Encyclopaedia. According to it, a startup is an organization at an early stage of its life cycle. The main goal of creating a startup is to find a “repeatable and scalable business model”. The operation of a startup is associated with operating in an environment of extreme uncertainty, which is the most important difference compared to small and medium-sized enterprises operating in established and mature markets.

However, one of the most well-known definitions in the world is that of E. Ries (2011), who considers a startup to be a “human institution” whose task is to create a new product or service under conditions of extreme uncertainty. In this definition, E. Ries emphasises the focus of the startup’s activities on the extreme risks in which the organization operates.

2.2. Phases of startup development

The development of an innovative enterprise can be presented in the form of a certain model, including a fixed element. Of great importance in the selection of sources and financing strategy of a startup is paying attention to the phased development. There are different approaches to identifying the stages of development of startups. Usually, three types of division are distinguished depending on whether the development model refers to: customer development, product development or financing (Kowal, D., Kowal B., 2019). The latter category includes the concept of German entrepreneurs. S. Ripsas and S. Tröger highlight the following stages of startup development (Deutscher Startup Monitor, 2015):

1. Seed Stage – The first phase of development involves the formation of the startup through the implementation of the idea, the maturation of the business idea. At this stage, the concept is developed and the future entrepreneur is shaped. There is no sale yet, but the feasibility of the project is initially assessed, it is checked whether the solution will be interesting for potential users.

2. Startup Stage – Phase two is the early development of the startup. It consists in the completion of the concept development by the founders. Typically,

this phase generates the first revenue on the market and provides benefits to customers. The most important thing is to refine a product that will meet the needs of the target group. This is not yet a complete solution. Developers work with users to find out how they can improve the product. At this stage of development, a startup usually actively defines a business model.

3. Growth Stage – The next stage involves the slow transition of the company into the maturity stage. The startup has a ready market offer, realizes a strong growth in sales and an increase in the number of customers. This is a very important stage of startup development.

4. Later Stage – The fourth stage is the stage in which other companies, products or technologies are acquired or purchased in order to achieve faster growth. A startup is a mature company in which it is important to achieve a high income.

5. Steady Stage – The last stage of the startup's development involves an intended or unintended stabilization stage. Startups cease to show a significant increase in revenues and users. The stage ends with the sale of the startup to an industry investor or listing on the stock exchange. Those startups that manage to reach this stage of development usually become well-known organizations around the world. At this stage, it is difficult to describe them as startups, as their revenue, number of employees, processes and structure are closer to corporations than startups.

2.3. Mistakes in startup management

According to research by N. Patel (2015), as many as nine out of ten startups fail. Therefore, managing the development of a startup can be considered a particularly difficult task. It is therefore important to conduct research in order to better understand the specifics of their functioning and development, and in the longer term to minimize problems associated with functioning in the area of extreme environmental uncertainty and high risk (Tomaszewski, A., 2018).

K. Kowalewski lists the eight most common mistakes in startup management. Kowalewski's analysis of the practical sphere of startups' activity was based on the experience gained while working as a mentor of these types of companies within the "Hub of Talents" project. In connection with this project, a startup platform for new ideas for startups was created. Kowalewski considers the most serious mistakes that startup creators make: developing a startup individually due to unwillingness to cooperate; excessive belief in the correctness of assumptions; selection of unsuitable employees; incompetent raising of capital and ineffective financial planning; lack of coherent vision of development between partners; unprofessional marketing; lack of passion and perseverance in action; and shortcomings in strategic planning (Kowalewski, K., 2020).

These negative phenomena in the field of management hinder the functioning of startups. Identifying errors and working on them allows to improve man-

agement processes. It is important to be aware of the mistakes made and to see their consequences. Elimination of the above mentioned shortcomings gives managers the chance to significantly improve the effectiveness of management. Gathering knowledge, taking into account the decision areas and actions that most often cause problems, allows to avoid them in the longer term (Kowalewski, K., 2020).

2.4. Examples of student startups in Poland and around the world

Below are examples of existing companies operating in national and international conditions.

- **LEXLY**

LEXLY is an application that allows you to find legal aid. It allows you to obtain immediate legal aid by using the services of legal advisers and lawyers cooperating with the web application. Lexly is the first such application in the world. The author of the application is Mateusz Januś, a Polish student who in 2017 saw a problem in finding appropriate legal aid in Poland. Mateusz Januś created a startup that allows you to contact a lawyer or legal advisor within 15 minutes for a fixed rate via a mobile device, usually a smartphone (Polski start-up ułatwi znalezienie prawnika..., 2021). The app was launched on 4 October 2021 (LexU! App ogłasza przełom..., 2021).

- **Kebs&GO**

It is a startup of students of the Warsaw University of Technology, who constructed a machine for a dish popular especially among young people. The machine producing and selling kebabs was set up at the university in November 2017 (Kebaby z automatu hitem w Warszawie..., 2019). After great success, kebab vending machines were installed in several places in Warsaw, and in 2019 one of the vending machines could be used at Warsaw Modlin Airport. Despite the initial success, kebab vending machines have now been closed, which shows the high risk of long-term survival of startups (Kebs&GO profile on Facebook).

- **“Brewery UwaRzone”**

It is a startup of students of the University of Rzeszow created in cooperation with students and lecturers of the university. It is the first student company in the field of brewing in Poland with the characteristics of a microcorporation. The company is run by as many as 50 people from different institutes, thanks to which it combines the competences of journalists responsible for marketing and biotechnologists developing the brewery recipe. Students of dietetics and food technology are also involved in the work on the company. Currently Brewery UwaRzone is sold at special events and events. Currently, the brewery offers four types of beer and its points are located in eleven locations in Rzeszow and five outside the city (UwaRzone – pierwszy studencki browar w Polsce, 2023).

- **QPONY. PL**

Qpony. pl is a startup in the field of new technologies, mobile technologies, in particular mobile applications. Startup is an attempt to implement a business model popular in the United States using products and services in digital form. It was created as part of a project initiated by students of the Academic Business Incubators operating at Poznań University of Economics. The creators of the startup were inspired by the model of discount coupons popular in the United States. The beginnings of the startup date back to 2010 and are connected with the creation of a paper version of the catalogue with discount coupons. In 2012, the company launched a mobile app, and in 2018 it became the owner of apps such as Qpony, Blix and Healthy Shopping, which are used by millions of users. The apps make everyday shopping easier for users by providing the opportunity to get acquainted with the offer of retailers and information about promotions, as well as giving the ability to create shopping lists and check the composition of products (Nowak H., Łuczak K., 2019).

- **FACEBOOK**

One of the most popular examples of student startups is the social platform Facebook. The platform for communication via the Internet was created on the initiative of Harvard student programmer Mark Zuckerberg in collaboration with other students of the university. Before founding Facebook, he was successful in creating Play Synapse Media and CourseMatch. In February 2004, the first version of Facebook was created as an academic site at Harvard, which had a million users in less than a year. In December 2005, it was distributed worldwide as a public communication platform (Kowalska J., 2017).

- **LINGT LANGUAGE**

It is a platform for learning a foreign language created by students of Massachusetts Institute of Technology who had difficulty learning Chinese pronunciation. For this reason, they created a platform for both teachers and students who want to learn a foreign language. Through it, teachers create assignments using photos, texts and videos available on the platform. On the other hand, students have the opportunity to record their text and check its pronunciation and correctness on Lingt (Turek A., 2015).

- **GOOGLE**

The most popular and widely known internet search engine is also a startup created by students. In 1995, Sergey Brin and Larry Page met at Stanford University. At the university, they were engaged in indexing and cataloguing theses, and decided to use their skills with the help of the Internet. Google was supposed to be used to index web pages and sort and match data. The platform was established in 1998. The Stanford University student startup has been a huge success, as evidenced by the popularity of the browser, as well as its founders being on the list of the ten richest people in the world in 2022 according to Forbes magazine (Bartosiewicz D., 2022).

3. Purpose and description of the study carried out. Research material and methodology

This article is based on research conducted using an online survey. Two hundred people, who were students and graduates of academic institutions, took part in the study. The survey questionnaire was shared on social media. The survey consisted of respondents completing a questionnaire consisting of 12 main questions and three defining the study group. The study was conducted in July and August 2023 and involved 142 women and 58 men. Most of the respondents, as many as 83%, are young people under 25 years of age. The largest group of respondents were people living in rural areas. The aim of the study was to know the level of knowledge about startups in Poland and the opportunities offered by academic institutions for students who want to start their own startup.

4. Research results

The following part of the article contains a detailed description of the results of the survey, related to the answers of the respondents to the individual questions of the survey.

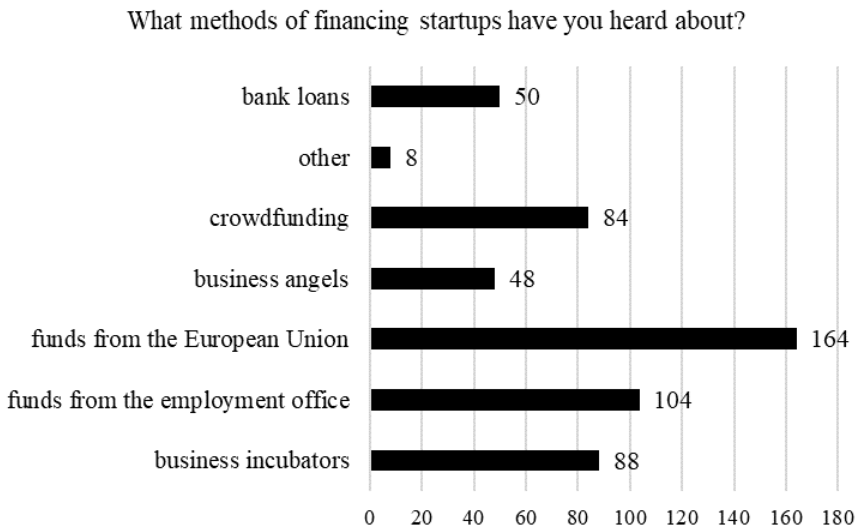


Figure 1. Methods of financing startups known by respondents

Source: own work.

The first question concerned the most well-known methods of financing startups. The most popular were funds from the European Union, which were chosen by 164 people, in second place were funds from the employment office chosen by 104 people, followed by business incubators chosen by 88 people and crowdfunding selected by 84 people. In addition, it was possible to choose other answers and additions, where 8 respondents mentioned, among others, bootstrapping and venture capital funds.

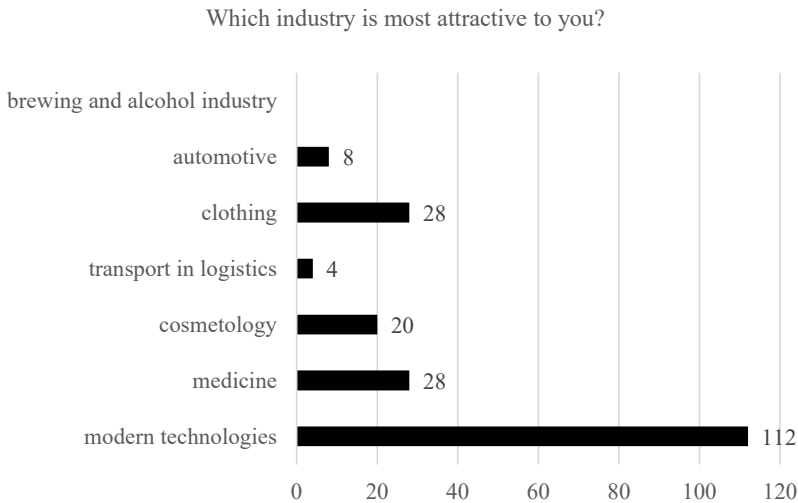


Figure 2. Industries with the most attractive startups

Source: own work.

The second question concerned the industries from which startups seem to be the most attractive for the studied group. The vast majority of respondents considered the most attractive startups in the field of new technologies, because as many as 112 people gave such an answer, which corresponds to 56% of respondents. Also popular were answers such as medicine and clothing chosen by 28 people each, and cosmetology, which 20 people consider to be the most attractive. The next places were automotive, transport and logistics. No one chose the brewing and alcohol industry.

What forms of support from academic institutions for startups are attractive to you?

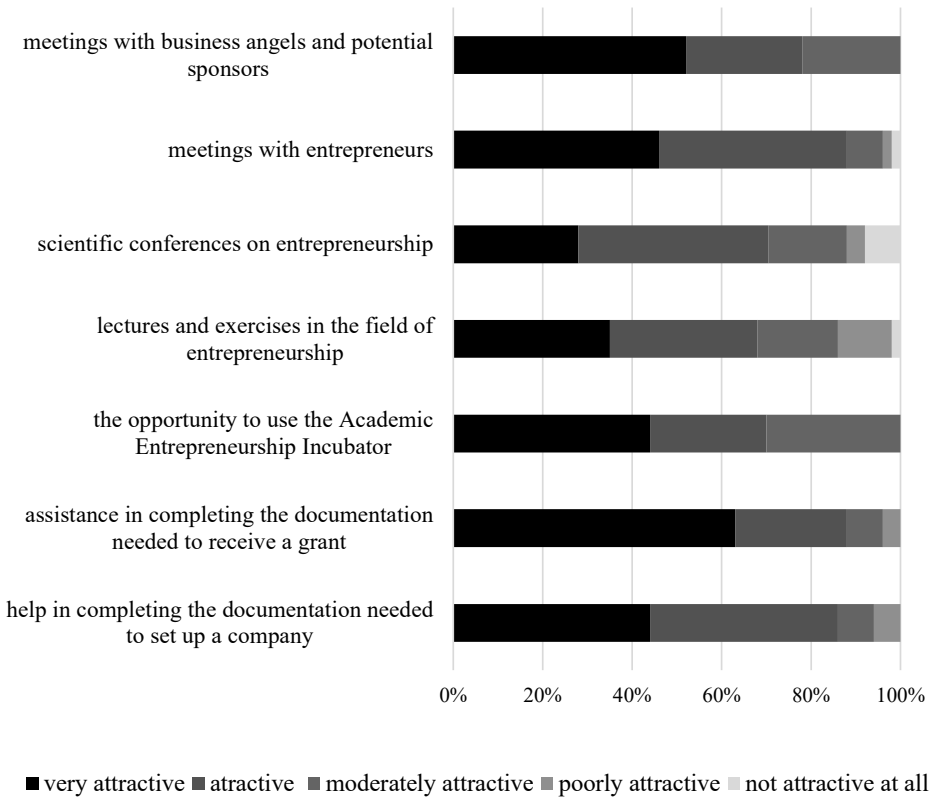


Figure 3. Attractiveness of forms of support from academic institutions for startups

Source: own work.

The third question concerned attractive forms of support for startups offered by academic institutions. Three activities turned out to be attractive or very attractive for more than 80% of respondents. These included meetings with entrepreneurs, assistance in filling out the documents needed to set up a business and support in filling out the documents for obtaining a grant.

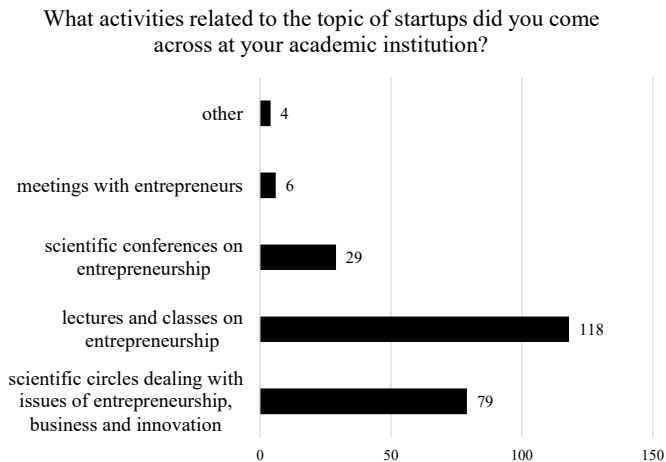


Figure 4. Activities taking place at academic institutions

Source: own work.

The next question was a multiple choice and was related to the activities of academic institutions that could contribute to the creation of startups by students. 118 people met with lectures and exercises on entrepreneurship. In academic institutions 79 respondents had the opportunity to get involved in the activities of scientific circles dealing with the issues of entrepreneurship, business and motivation. Less popular activities are scientific conferences on entrepreneurship and meetings with entrepreneurs. Four respondents indicated a different answer and wrote that their academic institutions did not offer any entrepreneurship activities.

Is there an Academic Business Incubator at your academic institution?

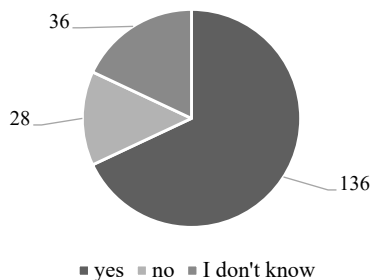


Figure 5. Academic Incubator of Entrepreneurship at Academic Institutions

Source: own work.

The following question concerned the Academic Entrepreneurship Incubator. More than 2/3 of the respondents, as many as 136 people, answered that the Academic Entrepreneurship Incubator operates at their academic institutions. 36 people did not know if their academic institution had an Academic Incubator of Entrepreneurship. Only 28 admitted that there is no such unit in their academic institution.

Have you ever thought about starting your own startup?

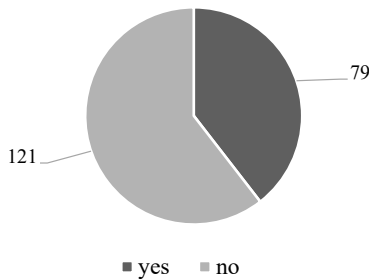


Figure 6. Desire to start a startup

Source: own work.

The next question was whether the surveyed respondents think about starting their own startup. Almost 40% of the people surveyed, i.e. as many as 79 people, are considering the possibility of starting a startup. 121 people did not think about starting their own startup.

What is your main motivation to start a startup?

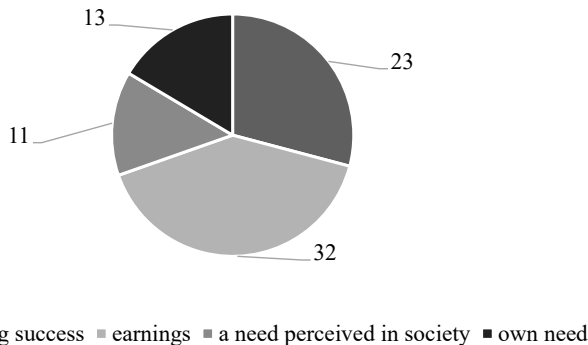


Figure 7. Motivation to start a startup

Source: own work.

The next question asked the respondents concerned their motivation to start a startup. The question was addressed only to 79 people who answered in the previous question that they had been thinking about starting their own startup. As many as 32 people consider the possibility of earning the most important motivation. Another 32 people think the most important thing for them is to achieve success. The following places included their own needs and needs perceived in society.

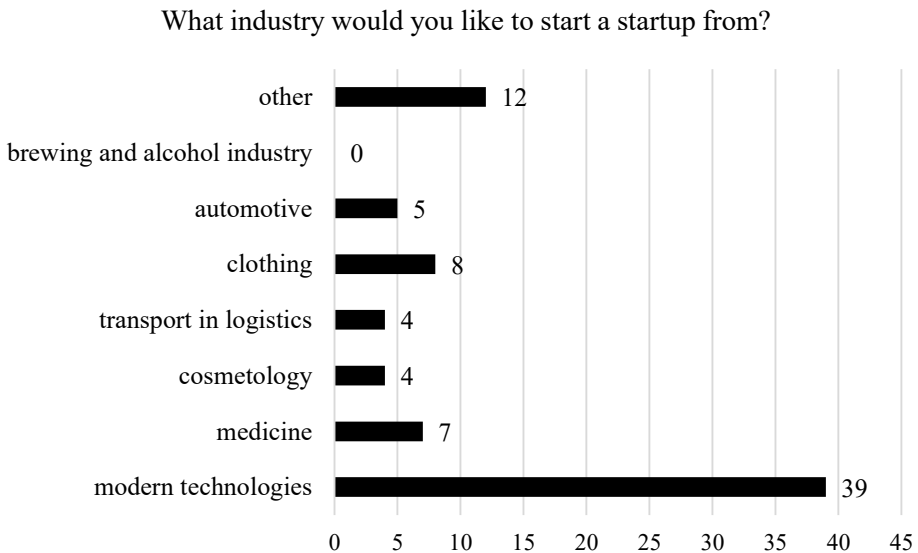


Figure 8. Potential startup industry

Source: own work.

The next question also concerned 79 people who are thinking about starting their own startup. Respondents chose the field in which they would like to start a startup. Almost half of the surveyed people think about starting a startup in the new technology industry. Respondents also selected clothing, medical, cosmetics, automotive, transport and logistics industries. Nobody thinks about starting a startup in the field of brewing and alcohol industry. 12 respondents responded differently, including sectors such as retail, education, coffee and real estate.

Have you heard about starting a startup by students at your academic institution?

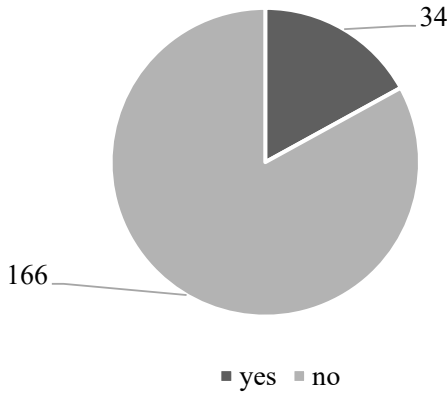


Figure 9. Startups founded by students that originated in academic institutions of respondents

Source: own work.

The penultimate question in the questionnaire concerned startups that were founded at the respondents' academic institutions. 34 people have heard about setting up startups at their academic institutions, which is 17% of respondents.

The last question asked in the survey was an open-ended question, which was answered only by people declaring that they had heard about setting up a startup at their academic institutions. 34 respondents mentioned the following industries: cosmetics, brewing, automotive, medical, modern technology, pop-ups, tourism and smart home systems. These were startups very diverse in terms of industries, but most of them were in the field of new technologies.

5. Conclusions

Startups are a popular form of setting up an innovative company in many industries. The presented examples show that both in Poland and around the world there are numerous initiatives of students who already take their first steps in business during their studies at academic institutions. Startups are also associated with huge risks, but opportunities for high earnings or success are factors that encourage young people to consider the decision to start a startup.

Research conducted for the purpose of this article shows that startups are very popular among students and graduates of academic institutions. Interest in the possibility of starting your own innovative business is constantly growing.

About 40% of respondents are thinking about starting their own startup. The popularity of startups may be associated with numerous activities of academic institutions, which transfer the knowledge needed to make it easier to open a business. Many of the academic institutions include courses in the field of entrepreneurship, enable active participation in circles dealing with broadly understood business topics or offer meetings with entrepreneurs, potential investors and business angels. Attractive forms that academic institutions that do not have one should consider in their offer are meetings with entrepreneurs, assistance in filling out documents needed to set up a business and to receive grants. The most attractive industry in which respondents believe it is worth running a startup or which respondents met at their universities is the sector of new technologies.

There are many initiatives that contribute to the popularization of startups. Both in Poland and around the world, events related to the startup market are organized, including competitions for the best startups, festivals for people thinking about their own startups, scientific conferences and business meetings. Due to the great popularity of startups, a new field of study at Wrocław University of Economics called Startup Leadership Program was created in 2022. Classes conducted within this field are aimed at providing students with knowledge of managerial skills, soft skills and learning how to run a business through classes in the field of marketing, finance and technology.

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FINANCIAL PERFORMANCE OF SME ENTERPRISES AS AN ENGINE OF POLISH ENTREPRENEURSHIP

Andżelika Partyka¹

ABSTRACT

The SME sector is one of the most important pillars of modern economies. Due to its large share in the creation of GDP, employment and the structure of Polish enterprises - the SME sector is referred to as the engine of the Polish economy. The aim of this paper is to present a classification of SME enterprises and the importance of this sector for the Polish economy. The aim of the paper is also to analyse the financial performance of the SME sector in Poland in 2015-2021. The paper uses the induction and deduction method, as well as structure and dynamics analysis. The empirical data comes from Statistics Poland. The results of the study led to the conclusion that, in the period 2015-2021, enterprises in the SME sector have, on average, a larger share of total revenue and costs and gross profit of non-financial enterprises than large enterprises. When analysing the data, it was also found that the SME sector is predominantly responsible for the creation of the value added and the value of production in the years under study over large enterprises.

Key words: SME sector, enterprise, financial performance, revenue, costs, profit, added value, production

1. Introduction

Small and medium-sized enterprises (SMEs) are entities with distinct characteristics and clearly defined boundaries of activity (Nesterowicz, 2020, p. 303). The criteria for the classification of micro, small and medium-sized enterprises have been defined by the European Commission and, following the EU criteria, the SME sector is classified by Polish law. The sustainable development of the SME sector is of critical importance for the country's socio-economic development, due to the large share of the SME sector in the structure of enterprises in Poland. In addition, the sector is responsible for the creation of about half of the

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country's GDP and is important for employment. Consequently, the SME sector is nowadays perceived as one of the most important pillars of the economy (Mempel-Śnieżyk, 2010, p. 125). The aim of this article is to explain the concept of the SME sector, as well as to present the importance of this sector for the Polish economy. In addition, the paper aims to empirically verify the financial performance of micro, small and medium-sized enterprises in terms of revenue, costs and gross profit in 2015-2021. The added value created by the SME sector and the value of production in the analysed period were also analysed. Deduction and induction methods were used to discuss and interpret the results, and structure and dynamics analysis was used. The data source for the analysis is Statistics Poland.

2. Definition and importance of the SME sector for the Polish economy

Entities defined as micro, small and medium-sized enterprises, despite the small scope of their activities, are the driving force of the Polish economy. Entities in the SME sector are most often sole proprietorships that are family businesses. Their activities are characterised by reference to tradition, high quality, a sense of social responsibility and very often assimilation with the region's inhabitants (Drożdżyński, 2021, p. 121). The range of potential customers of such entities is severely limited, as there is a lot of competition on the markets and the deciding factors for buying or using the services of these enterprises are often non-economic motives such as liking or habit - a behavioural approach (Sudol, 2006, pp. 55-57). For the SME sector, the lack of economies of scale is problematic due to the small number of customers. However, the strength of the SME sector is its high flexibility and ability to quickly re-brand and reorganise its organisational structure in the event of a crisis situation such as the COVID-19 pandemic, among others. Many entities in the SME sector, thanks to the creativity of the entrepreneurs themselves, took advantage of business development opportunities by re-branding in the era of the COVID-19 pandemic, while some enterprises had to take decisions to close down their business - which was reflected in the financial results of the SME sector.

Regarding the precise definition of SMEs, reference can be made to the European Commission's Recommendation, which distinguishes three basic groups of enterprises according to the number of persons employed and the enterprise's annual turnover or annual balance sheet total. On the basis of these three characteristics, the European Commission distinguished micro, small and medium-sized enterprises (Mempel-Śnieżyk, 2010, p. 126). The criteria for the clarification of SME enterprises are shown in Table 1.

Table 1. Criteria for the classification of SME's in the EU

	Micro-enterprise	Small business	Medium enterprise
Number of employees (in annual working units)	<10	<50	<250
Annual turnover (EUR million)	≤2	≤10	≤50
Annual balance sheet total (EUR million)	≤2	≤10	≤43

Source: *User's guide on the definition of SMEs, European Commission, Luxembourg 2015, p. 11.*

The European Commission's new recommendation of 6 May 2003 modified the 1996 recommendation's notion of small and medium-sized enterprise by introducing a definition of so-called micro-enterprises, i.e. enterprises employing fewer than 10 people on average, with an annual turnover of less than EUR 2 million (Ignatiuk, 2011, p. 9). A small enterprise, on the other hand, is one whose employment does not exceed 50 people and whose annual turnover or balance sheet total does not exceed EUR 10 million. The employment of a medium-sized enterprise must not exceed 250 people. The annual turnover and annual balance sheet total criteria for a medium-sized enterprise are not uniform. If annual turnover is the classification criterion, then it cannot exceed the level of EUR 50 million, while in the case of annual balance sheet total it should not exceed EUR 43 million.

In Poland, the division of enterprises into micro, small and medium-sized is made by the Act on Freedom of Economic Activity (Act of 2 July 2004 on Freedom of Economic Activity). The quantitative criteria for the classification of SME enterprises are the same as the EU criteria. A Polish entrepreneur, unlike an EU entrepreneur, when determining his or her status in the SME sector, has to fulfil the indicated conditions in one of the last two years (Tkocz-Wolny, 2015, p. 145). The concept of turnover has been specified adequately to Polish accounting standards as net turnover from the sale of goods, products and services, as well as financial operations. In order to determine the status of an entrepreneur, the classification criteria expressed in euro are converted into PLN at the average exchange rate announced by the National Bank of Poland on the last day of the financial year.

As statistical data show, the SME sector is of considerable importance for the domestic economy, as it constitutes 99.8% of all enterprises in Poland (Wasilewski, 2021, p. 50). The basic measures testifying to the SME sector's contribution to the country's economic development are: the share in the generated GDP and added value, and the share in the total number of business entities and in the number of employees (Murawiak, 2009, p. 52). The business sector generates 71.6% of GDP value, with SMEs generating almost every second zloty (43.6%). Micro-enterprises account for the largest share of GDP creation, at around 29.5%. The SME sector is also important from the perspective of job creation, as almost 6.9 million people, or 68% of the total number of employees

in the enterprise sector, were employed in SME enterprises in 2021 (PFR Report, 2023).

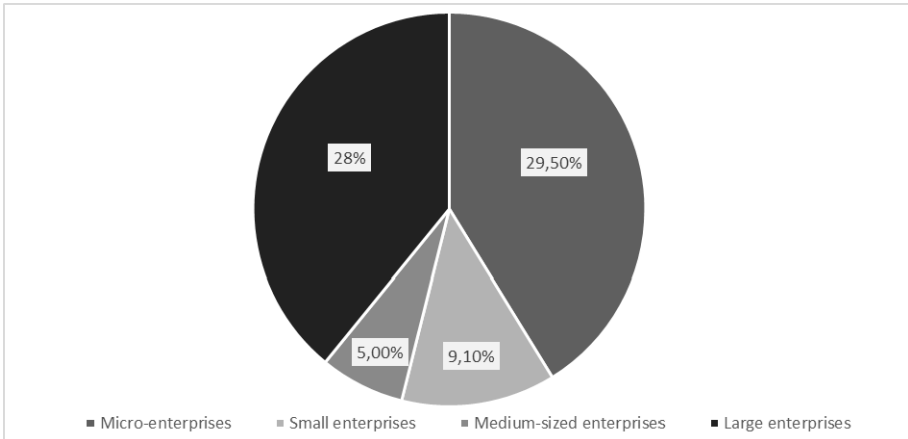


Figure 1. Share of businesses in the creation of GDP in 2020

Source: Own work based on Statistics Poland data.

Figure 2 shows the number of active enterprises in Poland by group by size for the period 2015-2021. Based on Figure 2, it can be concluded that there are more and more micro enterprises in Poland each year during the analysed period, while the number of medium and large enterprises remains stable. The number of micro-enterprises is increasing in favour of a decreasing number of small companies. Large enterprises constitute a small percentage of companies in Poland compared to the entire SME sector.

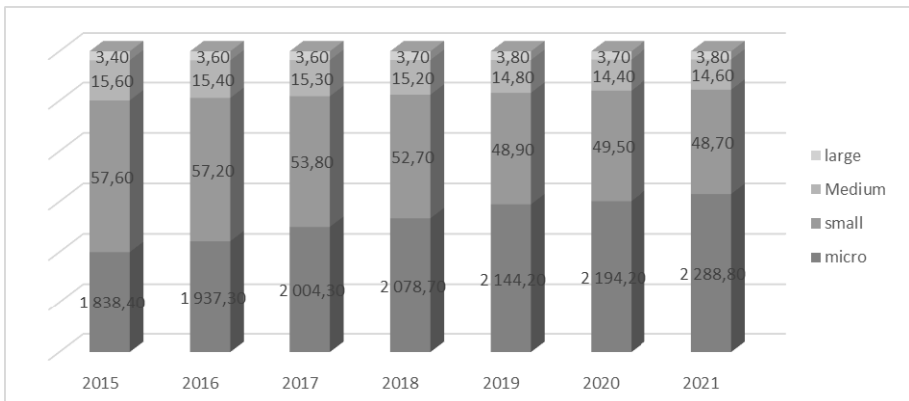


Figure 2. Number of active enterprises in Poland by size group 2015-2021 (in thousands)

Source: Own work based on Statistics Poland data.

An interesting issue is the structure of SMEs according to their primary area of activity, which is presented in Figure 3. As the SME sector accounts for 99.8% of enterprises in Poland, a conclusion can be drawn from the data in Figure 3 about the dominant area of activity in Poland. In 2021, the largest number of enterprises in Poland (53.90%) were engaged in offering services, followed by trade and construction. This structure indicates which areas are key in the creation of GDP and value added in the economy.

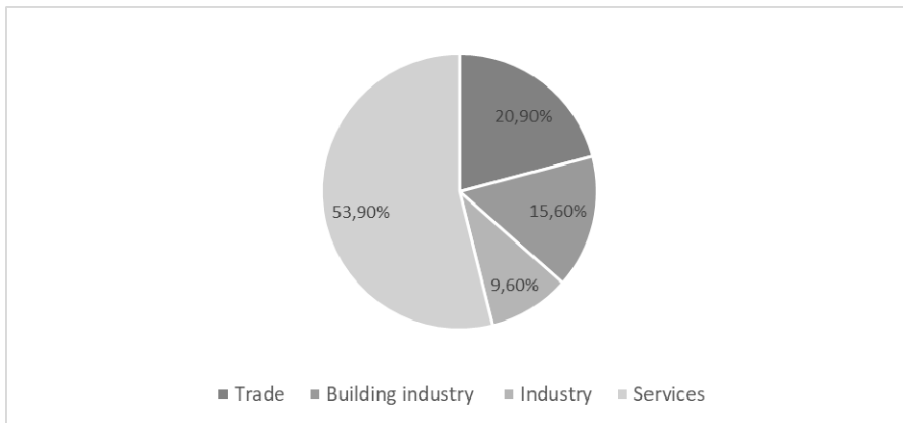


Figure 3. Structure of SMEs in Poland by core business area in 2021

Source: Own work based on Statistics Poland data.

According to data from Statistics Poland, which are presented in Table 2, the SME sector in 2021 was dominated by micro-enterprises, as they accounted for 97.15% of all enterprises in the analysed period. Large enterprises, i.e. those employing 250 people or more, account for a small proportion of all enterprises - just 0.16%. In turn, the SME sector employed a total of 67.87% of the total workforce as at 31 December 2021, while the average employment in 2021 in the SME sector was just under 4 million people. For large enterprises, the average employment in 2021 was more than 3 million people, while the number of employees at 31 December 2021 represents 32.13% of the total workforce. Another important aspect is the gross wages received by employees working in the various enterprises depending on their size. Based on the data presented in Table 2, it can be concluded that the gross salary is higher in large enterprises (51.29%) than in the SME sector as a whole (48.71%), so a better paid job can be obtained in a large enterprise. This finding is confirmed by the gross monthly salary per employee, as the average in 2021 for the SME sector was PLN 5224, while for large enterprises the gross monthly salary per employee in 2021 is PLN 6902.

Table 2. Basic data on enterprises by predominant type of activity and size classes in 2021

By number of employees	Total				
	number of enterprises	number of persons employed (as at 31 December)	average employment	gross wages and salaries in thousand PLN	Gross monthly remuneration per employee in PLN
total	2 355 980	10 229 943	7 034 516	500 849 309	5 933
up to 9 persons	2 288 844	4 344 332	1 521 407	70 193 525	3 845
10-49 persons	48 731	1 037 895	942 864	62 113 102	5 490
50-249 persons	14 618	1 561 162	1 468 635	111 661 470	6 336
250 or more persons	3 787	3 286 554	3 101 611	256 881 212	6 902

Source: Own work based on Statistics Poland data.

The small and medium-sized enterprise sector is the part of the economy that is developing most dynamically. Small and medium-sized companies are a very important element of the Polish economy and enable its faster development (Tomczyk, 2012, p. 160). Due to the significant share of SME sector enterprises in the creation of GDP in the Polish economy, it is reasonable to verify the financial results achieved by these enterprises.

3. Financial performance of SME companies 2015-2021

In analysing the financial performance of non-financial businesses in the SME sector from 2015 to 2021, the key aspects are total revenue, total costs and gross profit. Gross profit is a category that reflects the excess of revenues over costs and does not take into account tax charges, which can vary depending on the entity's form of taxation. In addition, the value added and production volume of non-financial enterprises from 2015 to 2021 were analysed.

The first aspect analysed is the total revenue of non-financial enterprises between 2015 and 2021. Based on the data in Table 3, it can be concluded that the SME sector, in total, has a larger share of total revenue of non-financial enterprises between 2015 and 2021 than large enterprises. Enterprises with up to 9 employees have the largest share of total revenue in the SME sector over the period under review, at an average of 23.78%.

Table 3. Total revenue of non-financial enterprises by number of employees in 2015-2021

Year	Total (PLN million)	By number of employees			
		up to 9 persons	10-49 persons	50-249 persons	250 or more persons
2015	4 076 488	21.97%	14.17%	19.67%	44.19%
2016	4 227 390	22.43%	13.59%	19.37%	44.62%
2017	4 572 742	22.84%	13.08%	18.84%	45.24%
2018	4 955 737	23.74%	12.55%	18.77%	44.94%
2019	5 262 556	25.27%	11.66%	18.36%	44.71%
2020	5 259 212	26.31%	11.61%	18.00%	44.09%
2021	6 287 651	23.90%	11.45%	18.91%	45.74%
Average	4 948 825	23.78%	12.59%	18.84%	44.79%

Source: Own work based on Statistics Poland data.

Next, total costs are an important category in the pre-investments, as when the level of total costs exceeds the level of total revenues, then the enterprise incurs a loss. The data presented in Table 4 show that large enterprises have the largest share of total costs for non-financial enterprises between 2015 and 2021; however, on average, the entire SME sector has a larger share of total costs than large enterprises during the period under review. Furthermore, within the SME sector, small enterprises with 10-49 employees have the smallest share of total costs.

Table 4. Total costs of non-financial businesses by number of employees in 2015-2021

Year	Total (PLN million)	By number of employees			
		up to 9 persons	10-49 persons	50-249 persons	250 or more persons
2015	3 817 914	20.31%	14.08%	19.83%	45.77%
2016	3 948 207	20.96%	13.75%	19.73%	45.57%
2017	4 246 797	21.35%	13.19%	19.34%	46.12%
2018	4 593 590	21.67%	12.65%	19.29%	46.39%
2019	4 897 922	23.28%	11.68%	18.88%	46.16%
2020	4 900 233	24.47%	11.59%	18.37%	45.57%
2021	5 718 315	22.01%	11.58%	19.41%	47.01%
Medium	4 588 997	22.01%	12.65%	19.26%	46.08%

Source: Own work based on Statistics Poland data.

Taking into account the categories of revenue and costs makes it possible to calculate gross profit from operations. From the data presented in Table 5, it can be concluded that enterprises employing up to 9 people had the largest share of the gross profit of non-financial enterprises between 2015 and 2021 - 47.40% on average. Moreover, the share of the entire SME sector in the gross profit of non-

financial enterprises in the period under review is significantly higher (71.7%) compared to large enterprises (28.3%).

Table 5. Gross profit of non-financial enterprises by number of employees in 2015-2021

Year	Total (PLN million)	By number of employees			
		up to 9 persons	10-49 persons	50-249 persons	250 or more persons
2015	334 945	42.28%	14.16%	15.94%	27.63%
2016	347 081	43.34%	11.69%	14.45%	30.52%
2017	377 431	43.44%	11.93%	12.50%	32.14%
2018	430 610	50.18%	11.03%	12.10%	26.68%
2019	466 077	53.26%	10.36%	10.99%	25.39%
2020	517 170	53.71%	10.29%	11.44%	24.56%
2021	647 802	45.61%	10.08%	13.15%	31.16%
Medium	445 874	47.40%	11.36%	12.94%	28.30%

Source: Own work based on Statistics Poland data.

Table 6 presents the added value of non-financial enterprises by number of employees. It can be concluded that between 2015 and 2021, both the SME sector and large enterprises generated value added in the economy at an average of PLN 1,205,616 million. Within the SME sector, enterprises employing up to 9 people account for the largest share of value added generation in the years analysed. It can also be concluded that the SME sector is responsible for 56.11% of value added generation on average between 2015 and 2021, while in the same period for large enterprises the value added accounted for 43.89%, thus less than the entire SME sector. It is also worth noting that the structure of value added creation by non-financial enterprises in the years analysed is very similar for each type of enterprise depending on its size.

Table 6. Value added of non-financial enterprises by number of employees in 2015-2021

Year	Total (PLN million)	By number of employees			
		up to 9 persons	10-49 persons	50-249 persons	250 or more persons
2015	1 001 623	26.77%	11.31%	17.27%	44.66%
2016	1 038 419	28.02%	9.33%	16.99%	45.65%
2017	1 150 468	28.40%	10.94%	16.31%	44.35%
2018	1 188 744	28.57%	10.75%	16.81%	43.87%
2019	1 289 135	29.64%	10.29%	16.39%	43.68%
2020	1 322 255	28.54%	10.18%	16.35%	44.94%
2021	1 448 670	32.31%	10.15%	17.49%	40.06%
Medium	1 205 616	28.89%	10.42%	16.80%	43.89%

Source: Own work based on Statistics Poland data.

Table 7 presents the production value of non-financial enterprises by the number of employees in 2015-2021. Based on the data presented, it can be concluded that the highest production value is characterised by enterprises with up to 9 employees in the SME sector. On the other hand, against the background of all enterprises, it is large enterprises that achieve the highest production value in the analysed period. However, between 2015 and 2021, the SME sector on average achieves a higher production value (56.60%) than large enterprises (43.40%). It is also an important observation that in 2020, for micro, small and medium-sized enterprises, as well as for large enterprises, there is a decrease in the value of production compared to the previous year, which may have been influenced by the COVID-19 pandemic.

Table 7. Value of output of non-financial enterprises by number of employees in 2015-2021

Year	Total (PLN million)	By number of employees			
		up to 9 persons	10-49 persons	50-249 persons	250 or more persons
2015	3 075 326	886 571	335 382	541 240	1 312 133
2016	3 127 445	940 207	280 329	533 187	1 373 722
2017	3 478 338	1 042 893	366 075	574 040	1 495 330
2018	3 787 255	1 180 435	376 804	615 753	1 614 263
2019	4 020 161	1 275 125	382 035	638 274	1 724 726
2020	3 820 088	1 137 454	372 936	622 698	1 687 000
2021	4 662 005	1 428 184	420 299	749 351	2 064 170
Medium	3 710 088	1 127 267	361 980	610 649	1 610 192

Source: Own work based on Statistics Poland data.

In summary, between 2015 and 2021, on average, SMEs collectively accounted for a larger share of non-financial enterprises' total revenue and total costs and gross profit than large enterprises. Despite the largest share of large enterprises in total revenue and total costs of non-financial enterprises, it was micro-enterprises that accounted for the largest share of gross profit in the period under review. The largest share of micro-enterprises in the gross profit of non-financial enterprises in 2015-2021 may be conditioned by the fact that 97% of enterprises in Poland are micro-enterprises. In turn, the SME sector as a whole is more responsible for the creation of added value than large enterprises during the analysed period. Also, in the case of production value, the entire SME sector dominates large enterprises in the years under review.

Summary

Enterprises in the SME sector are the engine of the Polish economy. The structure of enterprises in Poland indicates that it is the SME sector enterprises which are mainly responsible for employment in the country. Despite the small size of business, which is specified by the criteria set out by the European Commission, micro, small and medium-sized enterprises are responsible for around half of the gross domestic product. Due to the great importance of the SME sector enterprises in Poland, a systematic verification of the financial results achieved by these entities is justified. The results of the analysis made it possible to conclude that, in the period 2015-2021, SME enterprises have, on average, the largest share of total revenues and costs and gross profit of non-financial enterprises. An important aspect is also the fact that the SME sector is predominantly responsible for generating value added and production value in the country. It is worth emphasising that due to the large share of SME sector enterprises in the structure of enterprises in Poland, it is the economic situation and the results achieved by these units that will determine the state of the Polish economy in the future.

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STATE AND CHANGES IN PODKARPACIE AGRICULTURE ON THE BASIS OF THE AGRICULTURAL CENSUSES 2010 AND 2020

Anna Szopińska¹

ABSTRACT

Agriculture in the Podkarpackie region is characterised by a large number of small family farms, which limits its development and ability to compete on the national and international stage. The Agricultural Censuses 2010 and 2020 allowed us to capture the changes that took place over the decade. The share of farms with 1-2 ha and 2-3 ha of agricultural land decreased, while the number of farms in the 30-50 ha area group increased. In farms, the average total land area increased to 5.93 ha and agricultural land to 5.03 ha. The area sown to rape and colza, ground vegetables and cereals increased, while the area sown to potatoes and sugar beet decreased. The consumption of mineral fertilisers increased by 19.3 kg per hectare of agricultural land, and of lime fertilisers by more than 4 times. The change in the sowing structure contributed to changes in the technical equipment of farm.

Key words: number of farms, farm size, land use structure, fertilisation

1. Introduction

Podkarpackie is the southeasternmost region of Poland. At the same time, it is a border region, the eastern border of the EU with many restrictions on the free movement of people, capital, goods. It is characterized by great diversity and high spatial differentiation of natural conditions (Ślusarz G., et al., 2022).

It is a sparsely urbanized area with one of the highest percentages of population living in rural areas at 58.9% (CSO, 2022), with large agricultural land resources and a high percentage of people working in agriculture. It is one of the peripheral areas due to its geographic location and low level of economic development (Ślusarz G., 2005). In addition, many municipalities are characterized by

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relatively poor spatial accessibility and poor housing conditions of the population, with an unfavorable demographic structure of residents (Rosner A., Wesołowska M., 2022).

In Podkarpackie Voivodship agriculture is of great importance, which is due to the historical, socio-economic and geographical conditions of the area. However, the agrarian structure and technical equipment are limiting factors for the productivity of farms, and changes may contribute to an increase in the importance of Podkarpackie agriculture. This importance is significant in relation to ensuring food self-sufficiency, sustainable development of rural areas, cultivation of cultural values, preservation of the landscape and protection of its selected resources. Agriculture remains a significant sector in the national economy. At the same time, this is accompanied by a steady increase in output and commodity economic surplus in agriculture, indicating that the agricultural sector is not declining (Bear-Nawrocka A., Poczta W., 2022).

The aim of the study is to present the status and changes that took place in agriculture in the Podkarpackie Voivodship over the last decade on the basis of the 2010 and 2020 agricultural censuses.

2. Number and area of farms

Podkarpackie Voivodship is characterised by a large number of small farms compared to other regions in Poland. There were changes in the number and size of farms over the decade. In 2020, the number of total farms decreased by 18.9% compared to 2010. This was influenced by a decrease in the number of farms covering an area of 1 ha to 10 ha, with the number of farms with an area of 1-2 ha decreasing by as much as 30.9%. On the other hand, in the area groups above 10 ha, an increase in the number of farms was recorded in a wide range from 4.7% in the 10-15 ha area group to 85.7% in the 30-50 ha area group.

Individual farms in Podkarpackie accounted for 99.9% in the total number of farms in 2010, and in 2020 for 99.5% (Table 1). There was a 19.2% reduction in the number of individual farms. The number of the smallest farms with an area of 1-2 ha decreased by 31.0%. On the other hand, the number of individual farms with an area of 50-100 ha increased by 85.9%.

Table 1. Number of farms in Podkarpackie by area group in 2010 and 2020

Area groups of agricultural farms	Total farms			Individual farms		
	2010	2020	2010=100	2010	2020	2010=100
	in ha		in %	in ha		in %
1	2	3	4	5	6	7
Total	140 465	113 873	81.1	140 293	113 326	80.8
up to and including 1 ha	2 470	2 630	106.5	2 466	2 610	105.8
1 - 2 ha	49 453	34 161	69.1	49 453	34 125	69.0

1	2	3	4	5	6	7
2 - 3	31 189	27 509	88.2	31 183	27 464	88.1
3 - 5	31 844	25 900	81.3	31 837	25 805	81.1
5 - 10	19 128	15 674	81.9	19 116	15 565	81.4
10 - 15	3 219	3 369	104.7	3 205	3 309	103.2
15 - 20	1 075	1 310	121.9	1 070	1 289	120.5
20 - 30	857	1 195	139.4	844	1 158	137.2
30 - 50	567	1 053	185.7	557	1 022	183.5
50 - 100	394	717	182.0	369	686	185.9
100 and over	269	355	132.0	193	293	151.8

Source: Own work based on Statistics Poland data.

The structure of farms (Table 2) continues to be dominated by farms with 1-2 ha of agricultural land, which accounted for 30.0% of total farms in 2020. Their share decreased by 5.2 pp compared to 2010. The second group of farms with the largest share in 2020 in the structure of total agricultural farms were farms with 2-3 ha of agricultural land - 24.2%. The increase in the share in this group was 2.0 pp. The share of farms with an area of 3-5 ha remained stable. The share of farms with an area of more than 5 ha of agricultural land increased over the decade by 0.1-0.7 pp, and the largest increase in the share was recorded in the 10-15 ha area group.

Individual farms were characterised by the largest share of farms in the 1-2 ha of agricultural land area group - 30.1%. In this area group of farms, as in the case of total farms, their share decreased in relation to 2010 by 5.1 pp. An increase in the share of individual farms was marked in the 3-5 ha and 5-10 ha area groups by 0.1 pp, 2-3 ha of arable land by 2.0 pp, and for farms in the 30-50 ha of agricultural land area group by 0.5 pp.

Table 2. Structure of agricultural farms in Podkarpackie by agricultural census 2010 and 2020

Agricultural area groups	Total farms		Individual farms	
	2010	2020	2010	2020
Total	100.0	100.0	100.0	100.0
up to and including 1 ha	1.8	2.3	1.8	2.3
1 - 2 ha	35.2	30.0	35.2	30.1
2 - 3	22.2	24.2	22.2	24.2
3 - 5	22.7	22.7	22.7	22.8
5 - 10	13.6	13.8	13.6	13.7
10 - 15	2.3	3.0	2.3	2.9
15 - 20	0.8	1.2	0.8	1.1
20 - 30	0.6	1.0	0.6	1.0
30 - 50	0.4	0.9	0.4	0.9
50 - 100	0.3	0.6	0.3	0.6
100 and over	0.2	0.3	0.1	0.3

Source: Own work based on Statistics Poland data.

The 2020 agricultural census showed an increase in the average size of total farms in Podkarpackie Voivodship (Table 3). Taking into account the total land, the size of an agricultural farm increased by 15.1% and amounted to 5.93 ha, while taking into account the total agricultural land, the average size of a farm increased by 15.9% to 5.03 ha. The largest increase in the area of farms took place in the case of agricultural land in good condition, which amounted to 0.86 ha, i.e. by 21.4%. Agricultural land in good condition in 2020 reached an average size per farm of 4.88 ha.

Table 3. Average farm size in Podkarpackie Voivodship in 2010 and 2020

Years	Total land	Total agricultural land	Agricultural land in good condition
total agricultural farms in ha			
2010	5.15	4.34	4.02
2020	5.93	5.03	4.88
2010=100	115.1	115.9	121.4
individual farms in ha			
2010	4.87	4.11	3.83
2020	5.68	4.83	4.68
2010=100	116.6	117.5	122.2

Source: Own work based on Statistics Poland data.

On individual farms, there was an increase over the ten years in the average total land area to 5.68 ha (by 16.6%), agricultural land to 4.83 ha (by 17.5%) and agricultural land in good condition to 4.68 ha (by 22.2%).

Analysing the structure of the number of farms in Podkarpackie in 2020 by the type of agricultural activity carried out, it was found that farms engaged exclusively in crop production accounted for 46.9% of all farms (Figure 1).

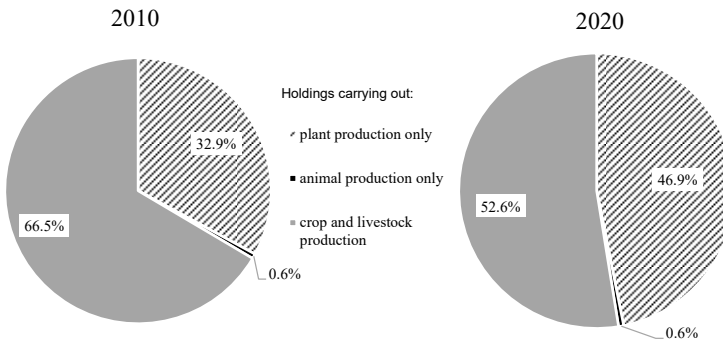


Figure 1. Structure of the number of farms by type of activity

Source: Own work based on Statistics Poland data.

Over the decade, there was no change in the share of farms involved only in livestock production, while the share of farms involved in crop and animal production decreased to 52.6% (by 13.9 pp).

Depending on the type of production carried out, the average size of the farm increased (Table 4). In Poland, there was an increase in total farm size to 11.4 ha, i.e. by 16.3% in 2020. This trend also took place in Podkarpacie, where the average farm size increased to 5.0 ha.

Table 4. Average farm size by type of production carried out

Specification	Total	Holdings carrying out		
		plant production only	animal production only	crop and livestock production
in hectares				
2010				
POLAND	9.8	8.3	3.8	10.9
PODKARPACKIE	4.3	4.2	2.4	4.4
2020				
POLAND	11.4	9.8	1.8	13.5
PODKARPACKIE	5.0	5.0	2.3	5.1

Source: Own work based on Statistics Poland data.

Farms with a plant production profile in Poland increased their average utilised agricultural area by 1.5 ha, i.e. to 9.8 ha, and those engaged in plant and animal production by 2.6 ha, i.e. to 13.5 ha. On the other hand, the area of farms involved only in livestock production decreased by 2.0 ha, i.e. to 1.8 ha.

In Podkarpacie, the average area of a farm engaged in crop production increased by 0.8 ha to 5.0 ha, and crop and livestock production by 0.7 ha to 5.1 ha. Farms carrying out only livestock production in Podkarpacie decreased their area to 2.3 ha.

3. Structure of agricultural land and sown area

In 2020, an increase in the share of land in good agricultural condition was recorded in the agricultural area to 96.9%. Compared to 2010, the increase was 4.3 pp. Sown area continued to occupy the dominant position in the structure of agricultural land, with their share increasing by 5.2 pp to 53.8% (Figure 2).

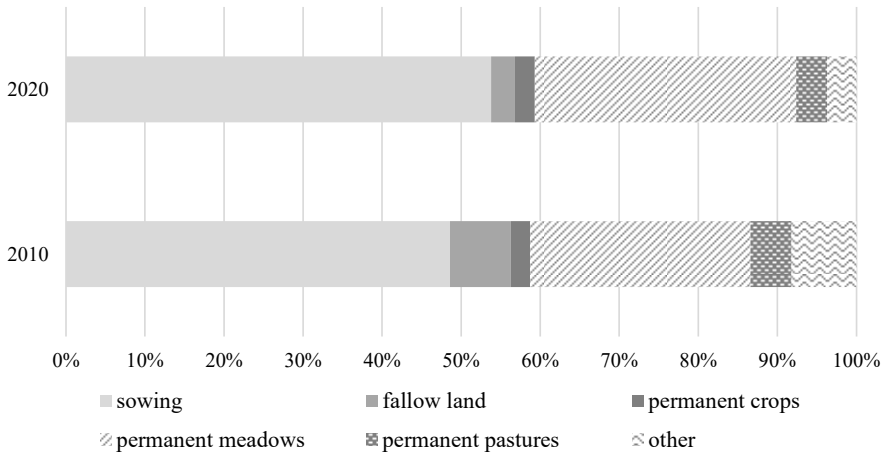


Figure 2. Structure of agricultural land

Source: Own work based on Statistics Poland data.

Permanent grassland was invariably in the second place in 2020, with its share increasing to 33.1%. An increase in the share of farmland in 2020 also took place for permanent crops to 2.5%. In contrast, the share of permanent pasture in agricultural land decreased by 1.3 pp to 3.9% and fallow land by 4.7 pp to 3.0%.

The sown area in Podkarpackie has increased by 4.1% over the ten years (Table 5). The largest increase in the area of sown crops took place in the case of rape and colza, by 62.5%, and ground vegetables by 36.0%. The area of total cereals also increased by 6.4%, with the area of basic cereals increasing by only 110 ha or 0.1%.

Table 5. Sown area by crop group in 2010 and 2020

Years	Total sown area	Of which					
		Cereals		potatoes	sugar beets	rape and colza	ground vegetables
		total	of which basic				
ha							
2010	296266	219277	169551	29760	4529	16094	2431
2020	308327	233354	169661	13659	3520	26156	3306
2010=100	104.1	106.4	100.1	45.9	77.7	162.5	136.0

Source: Own work based on Statistics Poland data.

In contrast, there was a reduction in the area under sugar beet and potatoes in 2020. The beet area decreased by 22.3% and the potato area by as much as 54.1%.

4. Fertiliser consumption in Subcarpathia

Over the ten years between 2010 and 2020, the consumption of mineral fertilisers on farms in general increased by 19.3 kg per ha of agricultural land (Table 6). Analysing the consumption of individual types of mineral fertilisers, the greatest changes were recorded for potassium fertilisers, the consumption of which increased by 10.9 kg and amounted in 2020 to 27.0 kg per 1 ha of agricultural land. Phosphorus fertiliser use increased in this period by 3.4 kg to 17.7 kg, and nitrogen fertiliser use by 5.1 kg to 39.8 kg per ha of agricultural land. On individual farms, total mineral fertiliser consumption increased at the same level as on farms in general. By type of fertiliser, the increase was for potassium fertilisers by 11.1 kg to 27.2 kg, phosphate fertilisers by 3.5 kg to 17.8 kg. Nitrogen fertilisers were applied at 39.6 kg per ha of agricultural land in 2020, an increase of 4.8 kg compared to 2010.

Table 6. Mineral and lime fertiliser consumption per ha of agricultural land in 2010 and 2020

Specification	2010		2020		2010=100	
	total	of which individual farms	total	of which individual farms	total	of which individual farms
	in kg					
Mineral fertilisers	65.1	65.3	84.4	84.6	129.6	129.6
Nitrogen	34.7	34.8	39.8	39.6	114.7	113.8
phosphorus	14.3	14.3	17.7	17.8	123.8	124.5
Potassium	16.1	16.1	27.0	27.2	167.7	168.9
Calcium fertilisers	17.0	15.9	69.8	70.3	410.6	442.1

Source: Own work based on Statistics Poland data.

The biggest change in the amount of fertiliser used in 2020 was for calcium fertiliser. On farms in general, consumption increased from 17.0 to 69.8 kg per ha of agricultural land (more than 4 times). On individual farms, consumption increased from 15.9 to 70.3 kg per ha of agricultural land (more than 4 times).

5. Tractors and agricultural machinery in farms of the Podkarpackie region

As the size of farms and the type of production carried out changed, the machinery on farms changed.

In 2020, tractors of 15-25 kW continued to dominate the structure of the number of tractors and obtained a share of 41.1% (Table 7). Tractors of 40-60 kW accounted for 22.4% and those of 25-40 kW for 20.1%. Tractors of 100 kW and above accounted for the smallest share. When analysing the share of agri-

cultural tractors in total farms, there was a decrease in the share of tractors up to 15 kW by 1.2 percentage points, 15-25 kW by 8.6 percentage points and 25-40 kW by 6.2 percentage points.

Table 7. Structure of the number of agricultural tractors by engine power in 2010 and 2020

Specification	2010		2020	
	total	of which individual farms	total	of which individual farms
Total tractors	100	100	100	100
up to 15 kW	6.4	6.4	5.2	5.2
15 to 25	49.7	49.9	41.1	41.3
25 to 40	26.3	26.3	20.1	20.1
40 to 60	12.8	12.7	22.4	22.3
60 to 100	4.1	4.0	8.6	8.5
100 kW and above	0.7	0.6	2.7	2.6

Source: Own work based on Statistics Poland data.

On the other hand, the share of tractors with a power output of 40-60 kW increased by 9.6 pp, 60-100 kW by 4.5 pp, as well as of 100 kW and above by 2.0 pp. On individual farms, tractors with a power output of 15-25 kW still accounted for the largest share, although this decreased by 8.6 pp compared to 2010, while the share of tractors with a power output of 40-60 kW increased by 9.6 pp and amounted to 22.3%. In 2020, one fifth of tractors on individual farms were 25-40 kW. Tractors with a power of 100 kW on individual farms accounted for the smallest share, at only 2.6%, but their share increased by 2.0 pp compared to 2010.

The number of agricultural machines equipped on farms in total changed, which is related to the nature of the changes in production and the acreage of individual crops in the sowing structure (Table 8).

Table 8. Number of agricultural machinery on farms in 2010 and 2020

Specification	2010		2020		2010=100	
	total	of which individual farms	total	of which individual farms	total	of which individual farms
	in pcs.					
Combine harvesters	5192	5068	6609	6542	127.3	129.1
Beet harvesters	586	580	242	236	41.3	40.7
Potato harvesters	2346	2336	2338	2330	99.7	99.7
Silisokombayns	206	191	102	95	49.5	49.7
Field sprayers	24253	24124	22629	22528	93.3	93.4
Orchard sprayers	1107	1093	802	791	72.4	72.4

Source: Own work based on Statistics Poland data.

In 2020, there was an increase in the number of combine harvesters on total and individual farms compared to 2010, by 27.3% and 29.1% respectively. There was a decrease in the number of potato harvesters, field and orchard sprayers, silage harvesters and beet harvesters compared to 2010 in both groups of farms. The dynamics of change of individual machines was at a similar level in total and individual farms. The greatest reduction was recorded in the number of beet harvesters, down by around 59%, and in the number of silage harvesters, down by more than 50%.

6. Summary

Over the ten years between the 2010-2020 Agricultural Censuses, there was an increase in the number of farms in area groups above 10 ha of agricultural land. An increase of 82.0% was recorded for farms with an area of 50-100 ha, which was reflected in the other agricultural production parameters of the region. The share of farms with 1-2 and 2-3 ha of arable land decreased, while the number of farms in the 30-50 ha of agricultural land area group increased. The average size of a farm increased from 5.15 ha to 5.93 ha when analysing the total area of land, and in the case of agricultural land from 4.34 ha to 5.03 ha. Individual farms in Podkarpackie Voivodship increased their average size to 5.68 ha for total land and to 4.83 ha for agricultural land. In Podkarpackie, the average size of farms engaged in crop production increased to 5.0 ha and crop and livestock production to 5.1 ha. In contrast, farms engaged in livestock production decreased in average size to 2.3 ha. Changes in the number and structure of individual farms promote differentiation in the economic sphere, as well as in the environmental sphere. On the other hand, the declining trend in the percentage of bi-directional farms, i.e. those combining crop and livestock production, and the reduction in the area of farms engaged exclusively in livestock production should be regarded as an unfavorable phenomenon (Zerag J.S., 2022). The above changes in agriculture in the Podkarpackie region had an impact on other aspects of agricultural production including the structure of agricultural land and the equipment of farms with tractors and agricultural machinery.

An increase in the share of sown land to 53.8 per cent and permanent grassland to 33.1 per cent was found in the structure of agricultural land. The share of fallow land and permanent pastures decreased. Analysing the sown area over the decade, an increase of 62.5% in the area under rape and colza and 6.4% in the area under total cereals was found. At the same time, the area under cultivation of staple cereals increased by only 110 ha, indicating an increase in the share of other cereals. The cereal whose cultivated area increased threefold in the analysed period was maize grown for grain, which is a result of a change in the livestock diet, involving a reduction in the feeding of potatoes to livestock (Slusarz G., et al., 2022).

The area under ground vegetables increased in Podkarpackie by 36.0%. However, the area under sugar beet decreased by 22.3% and the area under potatoes by 54.1% compared to 2010. The decrease in the area under root crops and the increase in the share of cereal crops in the sowing structure limit the possibilities for proper crop rotation and crop rotation. Soil productivity decreases, physical and chemical properties, water properties, biological activity deteriorate (Kiryluk A., 2016).

Over the decade, the use of mineral fertilisers on farms in general increased by 19.3 kg per ha of agricultural land, with the largest increase occurring in the case of potassium fertilisers by nearly 11 kg. There was also an increase in the use of calcium fertilisers to 69.8 kg per hectare of agricultural land on farms in general and to 70.3 kg per hectare of agricultural land on individual farms. The increase in the consumption of lime fertilisers is justified due to the acid reaction of 81% of soils in Podkarpackie Voivodship (Strategy for the development of agriculture and rural areas in Podkarpackie Voivodship until 2030). The increase in the consumption of lime fertilisers in 2020 was undoubtedly due to the introduction by the Voivodship Fund for Environmental Protection and Water Management of a priority programme entitled: 'Nationwide programme for environmental regeneration of soils through their liming' providing subsidies for lime fertilisers for farms, which was very popular with farmers (Report on the activities of the Voivodship Fund for Environmental Protection and Water Management in Rzeszów, 2020 and 2021).

Over the decade, the share of low-powered tractors (15-25 kW) decreased in Podkarpackie, although they still accounted for 41.3% in the structure of individual farms. However, the share of tractors with a power of more than 40 kW increased, which accounted for 33.7% in total farms and 33.4% in individual farms. In 2020, there was an increase in the number of combine harvesters on total and individual farms compared to 2010, by 27.3% and 29.1% respectively. This was due to an increase in the share of cereal and oilseed rape and colza area in the sowing structure over the years analysed. On the other hand, there was a decrease in the number of potato harvesters (by 0.3%), field sprayers (by 6.7%) and orchard sprayers (by 27.6%), silage harvesters (by 50.5%) and beet harvesters (by 58.7%). The above changes reflect an increase in the acreage of cereal crops and oilseed rape and colza, while at the same time a decrease in the acreage of potatoes and beet in the sowing structure. At the same time, service companies began to be engaged to a greater extent in harvesting crops. The decrease in the number of silage harvesters was the result of a decrease in the livestock population in the Podkarpackie region and a change in the livestock feeding technology (Slusarz et al., 2022).

Analysis of the state and changes in the agriculture of the Podkarpackie region over the decade indicate favorable changes manifested in a decrease in the number of the smallest farms, an increase in the average area of farms and farmland in good agricultural condition, an increase in calcium fertilization improv-

ing soil properties and an improvement in the technical equipment of farms resulting from the increasing specialization of production. On the other hand, the decrease in the share of bi-directional farms, the decrease in the share of root crops and the increase in mineral fertilization, which may worsen environmental conditions, are unfavorable. It seems necessary to apply various mechanisms, including financial and organisational ones, in order to reconstruct agriculture in Podkarpackie and improve its importance for the economy.

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EURES: FACILITATING OCCUPATIONAL MOBILITY ACROSS TRANSBORDER AREAS

Anna Wójcik¹

ABSTRACT

EURES, the European Employment Services network, plays a crucial role in promoting labour mobility within the European Union (EU) and the European Economic Area (EEA). Established in 1993, EURES facilitates the exchange of job vacancies and recruitment between European countries, connecting job seekers with employers and providing comprehensive support services. This article examines the initiatives and services offered by EURES to promote labour mobility, including its online job vacancy database, job mobility support, recruitment events, and support for employers. Additionally, the article analyses recent reports of European Commission as well as EURES database to provide insights into the supply and demand side of the labour market, required skills, education levels, and work schedules across different countries and NACE sectors. The findings shed light on the effectiveness of EURES initiatives in facilitating labour mobility and addressing the diverse needs of job seekers and employers in Europe. Data analysis presents large diversity of national labour markets. Imbalances of supply and demand side of labour market for several occupations are revealed. The occupational choice theories are outlined to indicate that it is a subject of substantial academic research. The role of occupational choice seems to be invaluable in terms of balancing labour market as well as in terms of its impact on other life domains.

Key words: EURES, Transborder Regions, Labour Market.

JEL: J24, J63, F15

1. EURES services and initiatives for labour mobility

EURES, which stands for "European Employment Services," is an EU-funded cooperation network that facilitates the exchange of job vacancies and recruitment between European countries. Established in 1993, EURES operates

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as a collaboration between the European Commission, national public employment services, trade unions, employers' organizations, and other stakeholders. Its primary goal is to promote labour mobility within the European Economic Area (EEA) and Switzerland, while also providing services to job seekers and employers outside of these areas.

EURES operates an online job vacancy database where employers can advertise job vacancies, and job seekers can search for opportunities across European countries. This database helps facilitate cross-border recruitment and mobility. EURES offers support services to job seekers looking to work in another European country, including information on job opportunities, living and working conditions, and administrative procedures. It also provides guidance on cross-border labour mobility, recognition of qualifications, and social security rights. Recruitment Events: EURES organizes job fairs, recruitment events, and networking activities to connect job seekers with potential employers across borders.

EURES provides support services to employers seeking to recruit workers from other European countries, including assistance with job postings, recruitment campaigns, and access to a pool of qualified candidates. EURES services to jobseekers and employers include:

- Matching job vacancies with CVs on the EURES portal.
- Providing information, guidance, and other support services for workers and employers.
- Offering information on living and working conditions in EU member states, covering aspects such as taxation, pensions, health insurance, and social security.
- Delivering tailored support services for frontier workers and employers in cross-border regions.
- Supporting specific groups through EURES Targeted Mobility Schemes.
- Assisting with dynamic recruitment events via the European (Online) Job Days platform.
- Offering information and access to post-recruitment assistance, such as language training and support with integration in the destination country.

The European Union's principle of free movement of workers is regarded as one of the most fundamental rights of EU citizens. It grants individuals the freedom to move to any EU Member State, as well as Iceland, Liechtenstein, Norway, and Switzerland, to seek and take up employment. However, leveraging this right may sometimes appear daunting and challenging. EURES aims to alleviate these challenges by providing support and assistance to jobseekers and employers alike.

Despite its extensive network, EURES may have limited coverage in some regions or sectors, which can make it challenging for job seekers and employers

to find suitable matches. Cross-border recruitment and mobility can involve complex administrative procedures, including recognition of qualifications, taxation, and social security issues, which may deter some job seekers and employers from utilizing EURES services. Further, language and cultural differences can pose challenges for job seekers and employers participating in cross-border recruitment, potentially leading to miscommunication or misunderstandings.

2. Analysis of supply and demand side of labour market through EURES

EURES can serve as a database to derive some insights on labour shortages and surpluses (cf. European Labour Authority (2022), European Commission, (2023)). The recent reports state that the professions that predominated on the list of widespread shortages were primarily in the fields of software, healthcare, construction, and engineering crafts. Conversely, the occupations that featured prominently on the list of widespread surpluses were largely clerical roles, elementary occupations, and professional positions in the humanities and arts. Most of the shortage occupations, indicating a higher demand for these roles than the available supply of jobseekers possessing the necessary skills at the required location, were classified as shortages of significant magnitude. A longitudinal analysis reveals that many of these shortages have persisted over the last five years, suggesting a structural rather than transient nature to these shortages.

The aforementioned reports are based on data available before 2022. The following subchapters present an analysis of the data available on 30.11.2023.

2.1. Statistics available at EURES

EURES presents its own statistics on employers and jobseekers. Employers may be analysed through the job offers while the jobseekers can be analysed through their CVs uploaded on the platform and their search activity.

EURES received over 1.1 mln. of CVs. Among jobseekers, 30% have upper secondary education, 18% Bachelor degree or equivalent, 15% lower secondary education, and 11% Master degree or equivalent. Their most popular education field are business, administration and law, Information and Communication Technologies, and social sciences, journalism and information. Jobseekers may also express in their CVs a desired occupation. The most of them indicated general office clerks (111 ths.), shop sales assistants (106 ths.), waiters (60 ths.), cleaners and helpers in offices, hotels and other establishments (53 ths.), and civil engineering labourers (39 ths.). Jobseekers may list their skills with respect to ESCO, which stands for European Skills, Competences, and Occupations (ESCO). ESCO is part of the Europe 2020 strategy. The ESCO is a multilingual classification that identifies and categorises skills, competences, and occupations

relevant for the EU labour market and education and training. The next table presents the most common skills of jobseekers.

Table 1. Most common ESCO skills

ESCO skill	Count
Office software	94,271
Use word processing software	48,821
Merchandising techniques	44,949
Apply safety management	40,055
Debt collection techniques	39,156
Use spreadsheets software	31,896
Ergonomics	31,845
Use communication techniques	28,657
Security regulations	24,847
Project management	22,336

Source: EURES (date of access: 30.11.2023).

It may be noted that the most common skill pertains to office software, especially for working with documents and spreadsheets. Further, merchandising techniques are required and then safety management. Jobseekers can select multiple language skills. Among them, the most popular are English (567 ths.), French (525 ths.), Greek (275 ths.), Spanish/Castilian (162 ths.), and German (109 ths.).

Three thousand companies offer a job in over 3.3 ths. workplaces. It includes 1072 companies from Germany, 285 from Netherlands, 191 from Austria, and 156 from Denmark. There are 273 large enterprises (over 250 persons), 574 medium-sized enterprises (50-250 persons), 1068 small enterprises (10-50 persons) and 1092 micro enterprises (less than 10 persons). According to NACE classification, the most of companies represent Employment activities (515 companies), Computer programming, consultancy and related activities (221 companies), Food and beverage service activities (219 companies), Specialised construction activities (153 companies), and Human health activities (148 companies).

Finally, we are going to investigate the most desired occupations by jobseekers and the most frequently offered occupations by employers. Note that EURES statistics present only top 10 occupations in terms of jobseekers and top 10 occupations in terms of employers. Thus, we are not able to compare supply and demand side of labour market by exact number of CVs and vacancies whenever a given occupation is not present on one of these lists.

Table 2. Occupations on supply and demand side

Occupations	Desired by jobseekers	Offered by employers
Shop sales assistants	105,657	92,351
Waiters	60,388	-
Cleaners and helpers in offices, hotels and other establishments	52,964	42,012
General office clerks	110,619	-
Sales and marketing managers	27,908	-
Freight handlers	26,692	62,440
Cooks	29,298	-
Civil engineering labourers	39,398	-
Manufacturing labourers not elsewhere classified	32,326	49,901
Secretaries (general)	27,207	-
Nursing professionals	-	60,647
Agricultural and industrial machinery mechanics and repairers	-	56,139
Accountants	-	52,071
Building and related electricians	-	49,056
Social work associate professionals	-	42,518
Metal working machine tool setters and operators	-	38,276

Source: EURES (date of access: 30.11.2023).

Among the most desired occupations by jobseekers and the most frequently offered occupations by employers, there are only four occupations that are both in top 10 of both rankings: shop sales assistants, cleaners and helpers in offices, hotels and other establishments, freight handlers, and manufacturing labourers not elsewhere classified. The highest discrepancy occurs for freight handlers since there are 27 ths. CVs with that occupation and 62 ths. offers. On the other hand, supply and demand side is well-balanced in a case of shop sales assistants, cleaners and helpers in offices. Nursing professionals (61 ths.), agricultural and industrial machinery mechanics and repairers (56 ths.) are the most wanted by companies among those occupations which are not in the top 10 of occupations stated in jobseekers CVs while general office clerks (111 ths.) and waiters (60 ths.) are the most sought occupation by jobseekers which are not in the top 10 of occupations wanted by companies.

2.2. Exploratory analysis of job offers at EURES

EURES contains approximately 4.5 mln. job offers. Database enables several filters facilitating seeking for a job offer which meet desired criteria. It includes the following search criteria:

- country and NUTS 2 level region
- required experience
- education level
- sector according to NACE classification
- work schedule

For these criteria, summary statistics were derived with respect to the country. Since there is no obligation to fill up whole description of a given job offer, summary statistics are presented only for those countries that at least 20% of description of job offers has a given criteria description filled up.

Work schedule is filled up for 71.2% offers. Among them, 83% are full-time jobs, 12.5% are part-time jobs, and 4.8% are with flexible schedule. The next figure presents vacancies by work schedule with respect to the countries. Flexible schedule is very popular in job offers from Netherlands, where it stands for 69% and quite popular in Estonia (23%). Part-time jobs are the most frequent job offers in Lithuania (42%) and quite frequent in Norway, Sweden, Denmark, Estonia, Germany and Finland ranging from 18% to 21% of all offers.

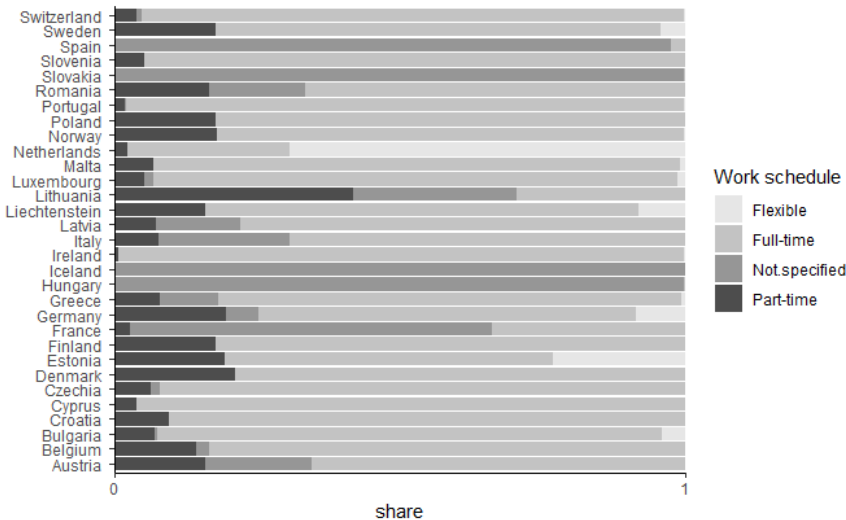


Figure 1. Vacancies by work schedule.

Source: own study, based on the data of EURES (date of access: 30.11.2023).

Contract type is filled up for 88% offers. Among them, over a half (53%) are contracts to hire and direct hire, 40.5% are temporary jobs, and 0.5% are offers for self-employed. Other contract, that is, internship, apprenticeship, volunteer, on-call etc. stands for 0.3% of offers. The figure 2 presents vacancies by contract type with respect to the countries. Contracts to hire are the great majority in Spain, Austria, Croatia, Malta and Cyprus. Temporary jobs stands for approximately 50% of offers in the remaining countries. The highest share (10%) of job offers for self-employed occurs in Romania while for others countries that share does not exceeds 1.7%. Remaining contract types including internship, apprenticeship, volunteer, on-call etc. with a share over 1% occur in Belgium, Sweden, Norway and France.

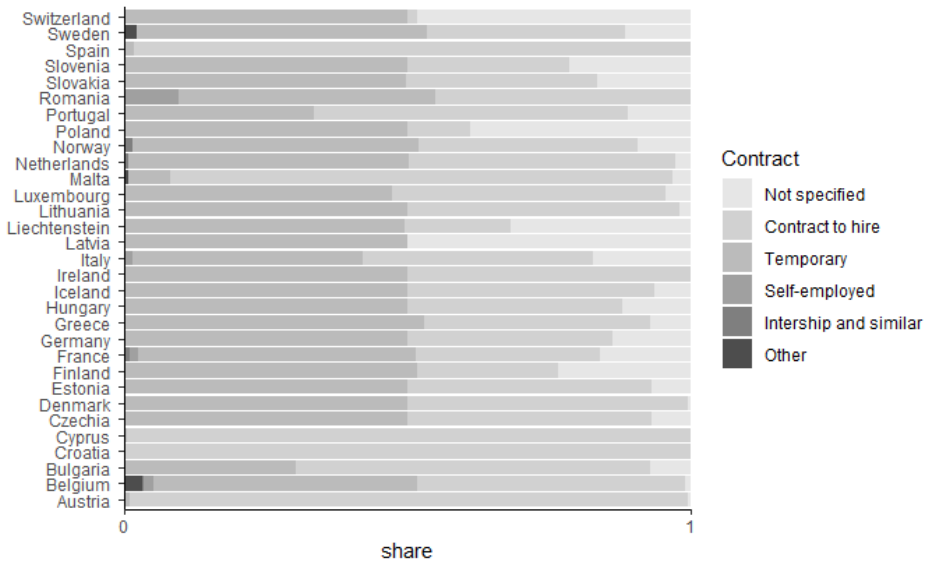


Figure 2. Vacancies by contract type.

Source: own study, based on the data of EURES (date of access: 30.11.2023).

Required education level is filled up only for 35.6% offers. More than half (54.1%) enterprises require secondary level of education, 26.5% require tertiary level of education and 6.9% primary level of education. The figure 3 presents vacancies by education level with respect to the countries. Nearly half of job offers in Luxembourg has tertiary level of education required. Approximately 30% with tertiary level of education required occurs in Belgium, Croatia and Slovenia. These vacancies are mostly in the sectors: administrative and support

service activities, information and communication, and professional, scientific and technical activities. On the other hand, primary education level is necessary for majority of job offers in Cyprus in the sectors: accommodation and food service activities, wholesale and retail trade; repair of motor vehicles and motor-cycles.

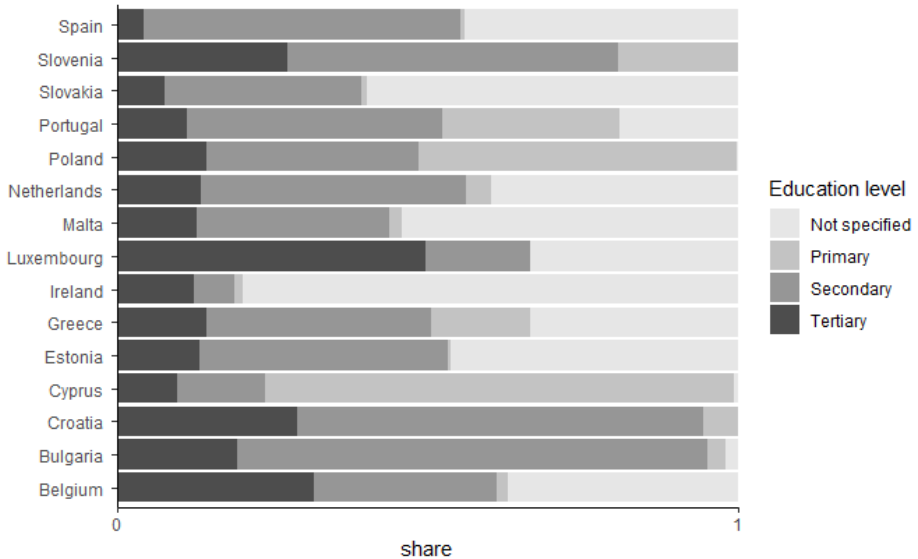


Figure 3. Vacancies by education level.

Source: own study, based on the data of EURES (date of access: 30.11.2023).

Similarly to education level, the required experience is filled up only for 31.4% offers. Concerning the other offers, for a half of jobs (49%) no experience is needed. Up to 2 years of experience is expected in approximately 40% of offers. The remaining ones expect at least 2 years of experience. The figure 4 presents vacancies by required experience with respect to the countries. More than 5 years of experience or 2 to 5 years of experience, among all countries in EURES, is the most frequently expected in Luxembourg. It is strongly connected with job vacancies in the country, of which 27.8% is in professional, scientific and technical activities sector, 15.5% is in administrative and support service activities sector, and 13.6% is in financial and insurance activities.

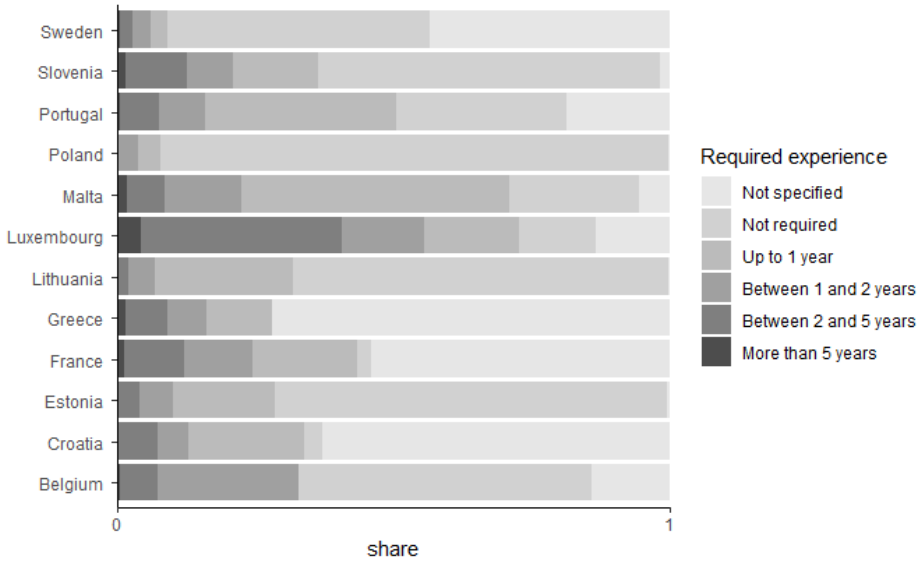


Figure 4. Vacancies by required experience.

Source: own study, based on the data of EURES (date of access: 30.11.2023).

There is also a possibility of advanced search that additionally may take into account: extra benefits, job title, employer’s name or even browsing job description. Only 2% offers specified extra benefits. Among them, 65.2% covers travel expenses, 17.5% includes accommodation, and 17.0% includes meals. Accommodation is in general included in some offers in Austria, Croatia, and Czechia (3 ths. of offers on average). Great majority of them are in the sectors: accommodation and food service activities, construction, manufacturing.

3. Occupational choice

Analysis of supply and demand side of labour market via EURES recent data and several European Commission reports revealed the high imbalance of job vacancies and job seekers for many occupations. It may stem from the lack of sound information flow between companies, universities etc. Occupational choice often is not a subject of concern on early stage of education.

Occupational choice theory explores the processes and factors that influence individuals' decisions regarding their careers and professions. It delves into the complex interplay of personal characteristics, societal influences, economic factors, and environmental circumstances that shape occupational preferences and outcomes. Several prominent theories have been developed to understand and explain occupational choice:

Trait-and-Factor Theory (Parsons, F. (1909)). It emphasizes matching individual traits and abilities with the requirements of specific occupations. It suggests that career decisions should be based on a thorough assessment of one's aptitudes, interests, and values, followed by a systematic exploration of potential career options.

Social Cognitive Career Theory (SCCT) (Lent et. al. (1994)). SCCT integrates principles of cognitive psychology and social learning theory to explain career development. It emphasizes the role of self-efficacy beliefs, outcome expectations, and personal goals in shaping career choices.

Theory of Vocational Personalities and Work Environments (Holland (1997)). Holland's theory proposes that individuals can be classified into six personality types (Realistic, Investigative, Artistic, Social, Enterprising, and Conventional) and that people tend to choose occupations that align with their dominant personality traits.

Social Cognitive Theory of Career Decision Making (SCCT-CDM) (Lent et. al. (2009)). SCCT-CDM extends social cognitive career theory by incorporating additional factors such as contextual influences, career decision-making self-efficacy, and goal intentions.

Recent research papers study an impact of occupational choice on other life domains. Brennan, Gallagher (2017) delve into the process of occupational choice, considering intrinsic and extrinsic influences. It focuses on gender and adolescence, examining how contextual factors shape occupational decisions. The research involved interviews with adolescent boys and girls aged 11-14 years. Findings reveal that gender plays a role in occupational choices through mechanisms like social systems, physical resources, institutional opportunities, and self-expectations. Szilagy et al. (2019) pointed out that while the impact of cancer and its aftermath on individuals is profound at the bio-psychosocial level, there remains a dearth of knowledge regarding the prevalence of professions among childhood cancer survivors. They analysed the primary factors influencing career choices and current occupations among former Austrian childhood cancer patients, with particular emphasis on occupations in the healthcare field. Kelly et al. (2014) explores the impact of work on people's lives. It highlights the significant time individuals spend working and its potential effects on health behaviours. For instance, they found out that blue collar work early in life is associated with increased probabilities of obesity, at-risk alcohol consumption, and smoking, and increased physical activity later in life.

These theories provide foundational works in the field of vocational psychology and career development, offering insights into the theoretical frameworks and empirical research underlying the theories of occupational choice. Recent research show that career development has a tremendous impact on many other life domains. Hence, more emphasis should be put on shaping and advising vocational choices of individuals.

4. Conclusions

EURES initiatives and services play a vital role in promoting labour mobility within the EU and EEA countries. By providing comprehensive support to both job seekers and employers, EURES facilitates the exchange of job vacancies and recruitment across borders, contributing to the EU's broader goals of economic integration and social cohesion. The analysis of EURES statistics highlights key trends in the labour market, including the distribution of job offers, required skills, education levels, and work schedules across different countries. While EURES has made significant strides in promoting labour mobility, data analysis revealed that significant imbalance of supply and demand side for several occupations persist. An introduction of complex system of tools enhancing sound occupational choice will be a challenge for Europe.

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AXIOMATIC APPROACH TO RANKINGS TECHNIQUES OF DECISION ANALYSIS

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ABSTRACT

Decision-making constitutes an integral part of human life, encompassing daily activities such as shopping and travel planning, as well as political elections. The decision-making process relies on the analysis of available options based on various criteria, enabling hierarchical ordering and the selection of the optimal alternative. In the case of decisions with long-term consequences, such as choosing the location of a production plant or investment strategy, spontaneity is unacceptable. With the increasing availability of information, the necessity of considering numerous potential options becomes a challenge.

In decision-making theory, various methods for evaluating objects have been developed, categorized as methods of total order or partial order, aligning with the mathematical concept of linear order. There are many natural, intuitive and desired properties of ranking techniques of multi-criteria decision-making. These properties can be expressed in terms of functional equations and inequalities. In such setting, the desired properties can be investigated with straightforward proof. With an approach of the functional equations and inequalities, ranking techniques can be evaluated in terms of the desired properties what enables a choice of an optimal ranking method for a given task.

The article presents a short review of ranking techniques of multi-criteria decision-making. It makes conclusions about the common ideas shared among most of presented ranking techniques. In final, four properties of selected ranking techniques are investigated, namely: symmetry, scale-invariance, shift-invariance, and boundness.

Key words: Multi-criteria decision making, Linear ordering, Ranking techniques, Functional equations, Functional inequalities.

Jel: C44, D81, D89, C64

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1. Introduction

In the recent years, decision-making process is more and more focused on time-effective and cost-effective decisions. It has various causes and may be related to broader social, technological, and cultural changes. It is particularly associated with efficiency and the need to achieve goals in the business world but leaves its mark on all aspects of human activity. During the decision-making process, we analyze available options based on various criteria, informally evaluating them. This allows us to organize possibilities from best to worst and make a choice. In many situations, spontaneous decisions are not feasible. For example, choosing the location of a manufacturing plant, supplier, or investment strategy may have long-term consequences. Furthermore, the increase in the amount of available information necessitates considering a greater number of potential options and their parameters in the decision-making process. We can distinguish several approaches to the decision-making process (Figueira,2005):

- Multi-Attribute Utility Theory (MAUT) (Von Winterfeldt, & Edwards, 1986): this approach involves assigning weights to different criteria and aggregating them into an overall utility score to compare alternatives.
- Analytic Hierarchy Process (AHP) (Saaty, 1994): this approach entails decomposing a complex decision problem into a hierarchy of criteria and alternatives, enabling decision-makers to assess and prioritize based on pairwise comparisons.
- ELimination and Choice Expressing REality (Elimination Et Choix Traduisant la Réalité) – ELECTRE (Roy,1996): this is a family of multi-criteria decision-making methods developed by French researcher Bernard Roy in the 1960s. It is a relatively popular tool in decision analysis, with various variants and extensions. Essentially, it involves evaluating alternatives based on their concordance and discordance with pre-defined criteria.

In the field of decision-making theory, numerous techniques for evaluating objects described by multiple parameters have been developed. These techniques can essentially be classified as methods of total order or partial order, directly related to the mathematical concepts of linear and partial order. Methods of total order provide a single real number for each analyzed object, typically interpreted as "the more, the better," naturally introducing a total order to the set of alternatives.

Many proposed evaluation techniques have been developed based on the researcher's intuition regarding desirable statistical properties. The choice of an evaluation technique constitutes an additional challenge that decision-makers must confront.

In this paper, we present an axiomatic approach to ranking based on natural postulates associated with data analysis. Axiomatic approach to decision-making process taking into account utility of alternatives has been introduced in the

beginning of 20th century. The classical and widely-known utility model, namely model of the expected utility, was introduced in von Neumann, Morgenstern (1995). Their approach was based on axiomatic formulation of properties of the preference relation, namely: translitivity, completeness, independence and continuity. Further, Quiggin (1982) using axiomatic approach formulated the rank-dependent utility model. Kahneman and Tversky in their joint works from 1979 and 1992 developed the prospect theory and the cumulative prospect theory. Such approach in the utility theory was used in works e.g. Schmeidler (1989), Prelec (1998). Axiomatic approach is getting more appeal also in other statistical areas. Atkinson (Atkinson (1970)) proposed an inequality measure which was derived from six axioms. These works were motivation to make a research on axiomatic approach to rankings.

Evaluation techniques for objects often prove effective in conducting linear ordering of objects, essentially yielding a ranking of these objects. We start with overview of ranking techniques. It turns out that most of them share the same desired properties stemming from postulates of data analysis. Further, we formulate these properties in a language of functional equation and inequalities. Finally, we investigate some very natural and desired properties of ranking techniques, that is symmetry, scale-invariance, shift-invariance, and boundness for three techniques: Simple Additive Ranking, Absolute Reference, and TOPSIS.

2. Overview of Ranking Methods

Ranking is a broader concept than linear ordering, which involves establishing a certain way of arranging elements of a set so that for any two different elements, it is possible to determine which one is greater, smaller, or equal to the other.

In mathematics, linear ordering is often used concerning ordered sets, for example, in real numbers, where their values can be compared, determining which is greater than the other.

The origins of mathematical linear ordering can be observed in the achievements of ancient civilizations such as the Babylonians and ancient Egyptians, who used simple methods to organize and order numerical data.

One of the key moments in the development of mathematical linear ordering was the introduction of the order axiom by the Greek mathematician Euclid, allowing for the formal definition of the order relation on numbers.

The development of algebraic methods for linear ordering significantly accelerated during the Middle Ages, particularly thanks to the work of Arab mathematicians who devised techniques for solving linear equations and inequalities.

Today, mathematical linear ordering is an integral part of many fields such as mathematical analysis, graph theory, and statistics, where it enables data ordering and analysis of relationships between them. The advancement of computer science

and algorithmics has also contributed to the development of mathematical linear ordering by creating effective methods for sorting data, which are widely used in modern computer systems.

Ranking methods can be categorized into several groups. Such distinction may be derived from

- the way what scale is used to treat decision-making criteria
- symmetric or asymmetric treating decision-making criteria

Rankings may be based on the ordinal scale. This group includes concordance analysis, dominance functions, and Hasse average ranking (Brüggemann, et al., 2005). These methods do not take into account exact difference between values of decision-making criterium. If the exact difference is essential to know, there are methods assuming interval or ratio scale of each decision-making criterium. Within that group, there are methods based on the assumption that for each variable, we individually select normalizing function $f_j: \mathbb{R} \rightarrow [0,1]$, which may generally differ between variables. Consequently, we cannot change the order of input variables. Ultimately, arithmetic or geometric mean, possibly considering variable weighting, is used for ranking. Examples of such methods include desirability functions and utility functions (Kahneman & Tversky, 1979).

Finally, there are also methods which involve the same normalizing function for each decision-making criterium. Among them, we can mention methods such as Simple Additive Ranking (SAR), Absolute Reference, TOPSIS (Zeleny, 1982). These methods, along with selected properties, are the subject of analysis in this article.

Let us recall some ranking techniques. Zdzisław Hellwig, the head of the Department of Statistics at the former Wrocław University of Economics, was one of the pioneers in introducing linear ordering. The method he proposed allows for establishing ranking of objects described in a multidimensional space of features, taking into account certain ordering criteria. Hellwig introduced key terms such as stimulants and destimulants, and proposed two variants of the method: Simple Additive Ranking, Absolute Reference also known as the method not utilizing a developmental pattern and the method utilizing a developmental pattern (Hellwig, 1968).

Let us assume we have n objects (indexed by i) and k variables (indexed by j). We may classify these variables into two groups:

- Stimulant – a variable for which high values are favorable for the phenomenon under study (the higher the value of this feature, the better).
- Destimulant – a variable for which low values are favorable for the phenomenon under study (the lower the value of this feature, the better).

The process of determining the ranking (ordering of multi-dimensional objects) using the non-reference Hellwig method (absolute reference) begins with

normalization to unify measurement units and scales. Typically, the method employs the transformation in the form of:

$$z_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (1)$$

for stimulants

$$z_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \quad (2)$$

for destimulants, where x_{ij} is a value of j -th variable for i -th feature.

Subsequently, it is necessary to calculate, for each object, the arithmetic mean of the transformed feature values. Based on these calculations, the objects are ordered (creating a ranking).

$$R_i = \sum_j^n \frac{z_{ij}}{n}.$$

The above formula can be modified using assigned weights to variables. In such a case, one should use a weighted average. The second linear ordering method by Hellwig utilizes standardization for normalization according to the formula:

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{\sigma_j} \quad (3)$$

for the stimulant set, where \bar{x}_j is the mean of values and σ_j is the standard deviation of the j -th variable,

$$z_{ij} = -\frac{x_{ij} - \bar{x}_j}{\sigma_j} \quad (4)$$

for the destimulant set.

After this transformation, each variable also takes on the nature of a stimulant. The next step involves determining the reference point $L_j = \max_i z_{ij}$.

Subsequently, for each object, the distance to the reference point is calculated (most commonly in the Euclidean metric).

$$d_i = \sqrt{\sum_j (z_{ij} - L_j)^2}$$

The determined distance is sufficient for establishing the ranking, although it is commonly practiced to calculate a measure expressed by the formula:

$$R_i = 1 - \frac{d_i}{\max_i d_i}$$

Currently, one of the most popular methods of linear ordering is TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution). It is a linear ordering method used in multi-criteria decision analysis. The normalization in this method can involve a transformation expressed by the formula:

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_i x_{ij}^2}} \quad (5)$$

Next, the reference pattern and anti-pattern are determined according to the formulas:

$$L_j^+ = \max_i z_{ij} \text{ for stimulant, } L_j^+ = \min_i z_{ij} \text{ for destimulant}$$

and the anti-pattern according to the formulas:

$$L_j^- = \max_i z_{ij} \text{ for destimulant, } L_j^- = \min_i z_{ij} \text{ for stimulant}$$

In the next step, the distance to the reference pattern (d_i^+) and the anti-pattern (d_i^-) is calculated in the Euclidean metric.

The ranking is then performed based on the calculated coefficient of the relative proximity of decision variants to the ideal solution:

$$R_i = \frac{d_i^-}{d_i^- + d_i^+}$$

The higher the value of this coefficient, the better.

In the hereafter, functions which transform values of the criteria to the same scale (according to the convention adopted by (Harrington, 1965)). We will call it as desirability function. In particular, desirability function are transformations (1)-(5).

3. Selected properties of chosen linear ordering methods

Desirability function should ensure that variables are consistently scaled, comparisons across variables are meaningful and make sure the analysis is less susceptible to the distorting effects of extreme values. It is expected that rearranging the order of input variables or changing units e.g. from to thousands to millions has no impact on the ranking. Such properties shall be called the symmetry and scale-invariance, respectively. It also a natural property that the distorting effects should be under the control. To this end, the boundness property is desired.

Our goal is to investigate the aforementioned properties of the described desirability functions. These properties can be expressed in the language of functional equations and inequalities. Let $f: \mathbb{R}^n \rightarrow \mathbb{R}^n$.

- 1) Function f is symmetric

$$\sigma(f(x_1, \dots, x_n)) = f(x_{\sigma(1)}, \dots, x_{\sigma(n)}) \text{ for } x_1, \dots, x_n \in \mathbb{R}$$
 and for every permutation σ of the set $\{1, \dots, n\}$
- 2) Function f is scale-invariant

$$f(ax_1, \dots, ax_n) = f(x_1, \dots, x_n) \text{ for } a \in (0, \infty), x_1, \dots, x_n \in \mathbb{R}$$
- 3) Function f is shift-invariant

$$f(x_1 + t, \dots, x_n + t) = f(x_1, \dots, x_n) \text{ for } t \in (0, \infty),$$

$$x_1, \dots, x_n \in \mathbb{R}$$
- 4) Function f is bounded, that is there exist $m, M \in \mathbb{R}$ such that

$$m \leq f(x_1, \dots, x_n) \leq M \text{ for } x_1, \dots, x_n \in \mathbb{R}$$

Let $x = (x_1, \dots, x_i, \dots, x_n)$ be a vector of a variable with n values, and x_i be the i -th value of this vector.

For the vector x , we will check whether properties 1)-4) hold for three desirability function of the form (1) which are part of the following ranking techniques: Simple Additive Ranking (SAR), Absolute reference and TOPSIS.

SAR method for the vector x uses the following desirability functions for standardizing features

$$f(x) = f(x_1, \dots, x_i, \dots, x_n) = \left(\frac{x_1 - \min(x)}{\max(x) - \min(x)}, \dots, \frac{x_i - \min(x)}{\max(x) - \min(x)}, \dots, \frac{x_n - \min(x)}{\max(x) - \min(x)} \right) \tag{6}$$

Firstly, we investigate a symmetry property.

Using properties of $\min(\cdot)$ and $\max(\cdot)$ function, for any permutation σ of $\{1, \dots, n\}$, the following equations hold:

$$\min(x) = \min(x_1, \dots, x_n) = \min(x_{\sigma(1)}, \dots, x_{\sigma(n)})$$

$$\max(x) = \max(x_1, \dots, x_n) = \max(x_{\sigma(1)}, \dots, x_{\sigma(n)})$$

First note that function f of the form (6) is affine transformation of x , that is $f(x) = ax + b$ with $a = \frac{1}{\max(x) - \min(x)} > 0$ and $b = \frac{-\min(x)}{\max(x) - \min(x)}$. Since such affine transformation preserves an order of x , we have

$$\sigma(f(x)) = \sigma\left(\frac{x_1 - \min(x)}{\max(x) - \min(x)}, \dots, \frac{x_n - \min(x)}{\max(x) - \min(x)}\right)$$

$$= \left(\frac{x_{\sigma(1)} - \min(x_{\sigma})}{\max(x_{\sigma}) - \min(x_{\sigma})}, \dots, \frac{x_{\sigma(n)} - \min(x_{\sigma})}{\max(x_{\sigma}) - \min(x_{\sigma})} \right) = f(x_{\sigma})$$

is true for any permutation σ of $\{1, \dots, n\}$.

The next step is to check whether the function f is scale-invariant.

Fix $i \in \{1, \dots, n\}$. The i -th coordinate of the function $f(x_i)$ has a form

$$f(ax_i) = \frac{a \cdot x_i - \min(a \cdot x)}{\max(a \cdot x) - \min(a \cdot x)}$$

We can use the property of functions $\min(\cdot)$ and $\max(\cdot)$ such as :

$$\min(a \cdot x) = a \cdot \min(x) \text{ and } \max(a \cdot x) = a \cdot \max(x)$$

Therefore

$$\begin{aligned} f(ax_i) &= \frac{a \cdot x_i - \min(a \cdot x)}{\max(a \cdot x) - \min(a \cdot x)} = \frac{a \cdot x_i - a \cdot \min(x)}{a \cdot \max(x) - a \cdot \min(x)} \\ &= \frac{a \cdot (x_i - \min(x))}{a \cdot (\max(x) - \min(x))} = \frac{x_i - \min(x)}{\max(x) - \min(x)} = f(x_i) \end{aligned}$$

In a result

$$f(ax) = f(ax_1, \dots, ax_i, \dots, ax_n) = f(x),$$

whence f is scale-invariant.

Next we examine shift-invariance. To this end, fix $t \in (0, \infty)$. Note that for fixed $i = 1, \dots, n$, we have

$$f(x_i + t) = \frac{x_i + t - \min(x_i + t)}{\max(x_i + t) - \min(x_i + t)}$$

Using the property of functions $\min(\cdot)$ and $\max(\cdot)$ such as :

$$\min(x + t) = \min(x) + t$$

and

$$\max(x + t) = \max(x) + t$$

we obtain

$$f(x_i + t) = \frac{x_i + t - \min(x_i + t)}{\max(x + t) - \min(x + t)} = \frac{x_i + t - \min(x_i) - t}{\max(x) + t - \min(x) - t} = \frac{x_i - \min(x)}{\max(x) - \min(x)} = f(x_i).$$

Thus, the function f is shift-invariant.

Boundness is the last property to be checked. We will demonstrate that the lower bound and upper bound are given by $m = 0$ and $M = 1$, respectively. Observe that the denominator is a positive since x non-constant. As $\min(x) \leq x_i \leq \max(x)$ for $i \in \{1, \dots, n\}$, we have

$$0 = \frac{\min(x) - \min(x)}{\max(x) - \min(x)} \leq \frac{x_i - \min(x)}{\max(x) - \min(x)} \leq \frac{\max(x) - \min(x)}{\max(x) - \min(x)} = 1$$

The standardization method used in the Absolute Reference method is given by the formula:

$$f(x_1, \dots, x_n) = \left(\frac{x_1 - \bar{x}}{S}, \dots, \frac{x_n - \bar{x}}{S} \right) \tag{7}$$

where \bar{x} is an arithmetic mean and S is a standard deviation of the variable $x = (x_1, \dots, x_n)$.

First, let us check the symmetry property. First observe that, for any permutation σ of $\{1, \dots, n\}$, it holds

$$\sum_{i=1}^n x_i = \sum_{i=1}^n x_{\sigma(i)} \tag{8}$$

First note that function f of the form (7) is affine transformation of x , that is $f(x) = ax + b$ with $a = \frac{1}{S} > 0$ and $b = \frac{-\bar{x}}{S}$. Since such affine transformation preserves an order of x , applying (8), we have

$$\sigma(f(x)) = \sigma\left(\frac{x_1 - \bar{x}}{S}, \dots, \frac{x_n - \bar{x}}{S}\right)$$

$$\begin{aligned}
&= \left(\frac{x_{\sigma(1)} - \frac{1}{n} \cdot \sum_{i=1}^n x_i}{\sqrt{\frac{\sum_{i=1}^n \left(x_i - \frac{1}{n} \cdot \sum_{i=1}^n x_i\right)^2}{n}}}, \dots, \frac{x_{\sigma(n)} - \frac{1}{n} \cdot \sum_{i=1}^n x_i}{\sqrt{\frac{\sum_{i=1}^n \left(x_i - \frac{1}{n} \cdot \sum_{i=1}^n x_i\right)^2}{n}}} \right) \\
&= \left(\frac{x_{\sigma(1)} - \frac{1}{n} \cdot \sum_{i=1}^n x_{\sigma(i)}}{\sqrt{\frac{\sum_{i=1}^n \left(x_{\sigma(i)} - \frac{1}{n} \cdot \sum_{i=1}^n x_{\sigma(i)}\right)^2}{n}}}, \dots, \frac{x_{\sigma(n)} - \frac{1}{n} \cdot \sum_{i=1}^n x_{\sigma(i)}}{\sqrt{\frac{\sum_{i=1}^n \left(x_{\sigma(i)} - \frac{1}{n} \cdot \sum_{i=1}^n x_{\sigma(i)}\right)^2}{n}}} \right) \\
&= f(x_{\sigma})
\end{aligned}$$

is true for any permutation σ of $\{1, \dots, n\}$. In a result the function f is symmetric.

Next, we want to check if function f is scale-invariant. Fix $i \in \{1, 2, \dots, n\}$. Then

$$\begin{aligned}
f(a \cdot x_i) &= \frac{a \cdot x_i - \frac{1}{n} \cdot \sum_{i=1}^n a \cdot x_i}{\sqrt{\frac{\sum_{i=1}^n \left(a \cdot x_i - \frac{1}{n} \cdot \sum_{i=1}^n a \cdot x_i\right)^2}{n}}} = \frac{a \cdot x_i - \frac{a}{n} \cdot \sum_{i=1}^n x_i}{\sqrt{\frac{\sum_{i=1}^n \left(a \cdot x_i - \frac{a}{n} \cdot \sum_{i=1}^n x_i\right)^2}{n}}} \\
&= \frac{a \cdot \left(x_i - \frac{1}{n} \cdot \sum_{i=1}^n x_i\right)}{\sqrt{\frac{\sum_{i=1}^n \left(a \left(x_i - \frac{1}{n} \cdot \sum_{i=1}^n x_i\right)\right)^2}{n}}} \\
&= \frac{a \cdot \left(x_i - \frac{1}{n} \cdot \sum_{i=1}^n x_i\right)}{\sqrt{\frac{\sum_{i=1}^n a^2 \left(x_i - \frac{1}{n} \cdot \sum_{i=1}^n x_i\right)^2}{n}}} \\
&= \frac{a \cdot \left(x_i - \frac{1}{n} \cdot \sum_{i=1}^n x_i\right)}{\sqrt{\frac{a^2 \sum_{i=1}^n \left(x_i - \frac{1}{n} \cdot \sum_{i=1}^n x_i\right)^2}{n}}} = \frac{a \cdot \left(x_i - \frac{1}{n} \cdot \sum_{i=1}^n x_i\right)}{a \sqrt{\frac{\sum_{i=1}^n \left(x_i - \frac{1}{n} \cdot \sum_{i=1}^n x_i\right)^2}{n}}} \\
&= f(x_i)
\end{aligned}$$

which proves that the function f is scale-invariant.

Next step is to verify whether desirability function is shift-invariant. Notice that for any $t > 0$, it holds

$$\sum_{i=1}^n (x_i + t) = n \cdot t + \sum_{i=1}^n x_i,$$

Therefore

$$\begin{aligned} f(x_i + t) &= \frac{x_i + t - \frac{1}{n} \cdot \sum_{i=1}^n (x_i + t)}{\sqrt{\frac{\sum_{i=1}^n \left(x_i + t - \frac{1}{n} \cdot \sum_{i=1}^n (x_i + t)\right)^2}{n}}} \\ &= \frac{x_i + t - \frac{1}{n} \cdot (n \cdot t + \sum_{i=1}^n (x_i))}{\sqrt{\frac{\sum_{i=1}^n \left(x_i + t - \frac{1}{n} \cdot (n \cdot t + \sum_{i=1}^n (x_i))\right)^2}{n}}} \\ &= \frac{x_i + t - t - \frac{1}{n} \sum_{i=1}^n (x_i)}{\sqrt{\frac{\sum_{i=1}^n \left(x_i + t - t - \frac{1}{n} \sum_{i=1}^n (x_i)\right)^2}{n}}} \\ &= \frac{x_i - \frac{1}{n} \sum_{i=1}^n (x_i)}{\sqrt{\frac{\sum_{i=1}^n \left(x_i - \frac{1}{n} \sum_{i=1}^n (x_i)\right)^2}{n}}} = f(x_i) \end{aligned}$$

which proves that the function f is shift-invariant.

Finally, we shall show that the function f does not have a property of boundness.

Fix $m \in \mathbb{R}$. Put $x = (x_1, x_2, \dots, x_n)$, such that $x_1 = x_2 = \dots = x_{n-1} = 0$, but $x_n = 1$. Hence, $\bar{x} = \frac{1}{n}$ and $S = \sqrt{\frac{1-\frac{1}{n}}{n}}$. Let $n > m^2 + 1$. Then $\sqrt{n-1} > m$, which gives $\frac{n-1}{\sqrt{n-1}} > m$. Thus

$$\frac{\frac{n-1}{n}}{\frac{1}{n}\sqrt{n-1}} > m$$

and so

$$\frac{1 - \frac{1}{n}}{\sqrt{\frac{1}{n} - \frac{1}{n^2}}} > m.$$

In a result, we obtain

$$f(x_n) = \frac{1 - \frac{1}{n}}{\sqrt{\frac{1 - \frac{1}{n}}{n}}} > m.$$

In a consequence the function f is not bounded.

Desirability function in TOPSIS method is a transformation given by the formula

$$f(x) = f(x_1, \dots, x_i, \dots, x_n) = \left(\frac{x_1}{\sqrt{\sum_i x_i^2}}, \dots, \frac{x_i}{\sqrt{\sum_i x_i^2}}, \dots, \frac{x_n}{\sqrt{\sum_i x_i^2}} \right) \quad (9)$$

The first property we want to examine is the symmetry of the function f . First note that function f of the form (9) is linear transformation of x , that is $f(x) = ax$ with $a = \frac{1}{\sqrt{\sum_i x_i^2}} > 0$. Since such linear transformation preserves an order of x , applying (8), we have

$$\begin{aligned} \sigma(f(x)) &= \sigma\left(\frac{x_1}{\sqrt{\sum_i x_i^2}}, \dots, \frac{x_n}{\sqrt{\sum_i x_i^2}}\right) = \left(\frac{x_{\sigma(1)}}{\sqrt{\sum_i x_i^2}}, \dots, \frac{x_{\sigma(n)}}{\sqrt{\sum_i x_i^2}}\right) \\ &= \left(\frac{x_{\sigma(1)}}{\sqrt{\sum_i x_{\sigma(i)}^2}}, \dots, \frac{x_{\sigma(n)}}{\sqrt{\sum_i x_{\sigma(i)}^2}}\right) = f(x_{\sigma}) \end{aligned}$$

Therefore, function f is symmetric.

Secondly, we need to check if the f function is scale-invariant. For fixed $i \in \{1, \dots, n\}$, we get

$$f(a \cdot x_i) = \frac{a \cdot x_i}{\sqrt{\sum_i (a \cdot x_i)^2}} = \frac{a \cdot x_i}{\sqrt{\sum_i a^2 \cdot x_i^2}} = \frac{a \cdot x_i}{a \cdot \sqrt{\sum_i x_i^2}} = \frac{x_i}{\sqrt{\sum_i x_i^2}} = f(x_i)$$

That proves the scale-invariance of the desirability function.

Next, we shall that the shift-invariance property does not hold.

Notice that for any $i = 1, \dots, n$, we have

$$f(x_i + t) = \frac{x_i + t}{\sqrt{\sum_i (x_i + t)^2}} = \frac{x_i + t}{\|x + t\|}$$

To this end, let us show first that for any positive numbers a, b and k , where $a < b$, the following inequality holds

$$\frac{a+k}{b+k} > \frac{a}{b} \tag{10}$$

Since $a < b$ and $k > 0$, we get $ak < bk$. Hence

$$b(a + k) = ab + bk > ab + ak = a(b + k)$$

Dividing both sides of above inequality by $b(b + k)$, we obtain (10). Define $\|x\| = \sqrt{\sum_i x_i^2}$. Since $\|\cdot\|$ is the norm, it holds $\|x + t\| < \|x\| + \|t\|$ for any $x \neq 0$ and $t \in (0, \infty)$. Hence, using (18), we can observe that

$$f(x_i + t) = \frac{x_i + t}{\|x + t\|} > \frac{x_i + t}{\|x\| + t} > \frac{x_i}{\|x\|} = f(x_i)$$

for $i = 1, \dots, n$. Thus, the function f does not have a shift-invariance property.

The boundedness of the function can be proven by starting with the obvious inequality

$$0 \leq x_i^2 \leq \sum_i x_i^2$$

for $i = 1, \dots, n$. And so

$$-\sqrt{\sum_i x_i^2} \leq x_i \leq \sqrt{\sum_i x_i^2}$$

hence

$$-1 \leq \frac{x_i}{\sqrt{\sum_i x_i^2}} \leq 1.$$

In this way we proved that the lower bound and upper bound are given by $m = -1$ and $M = 1$, respectively, which proves the boundedness of the function f .

4. Conclusions

Incorporating the functional equations and inequalities enabled to express the very intuitive and desired properties of ranking techniques, namely: symmetry, scale-invariance, shift-invariance, and boundedness in a clear and neat way. Straightforward proofs revealed which properties hold in a case of three

investigated ranking techniques. In a result, a decision-maker can evaluate each of them and choose the optimal one for a given problem.

Investigating the properties of ranking techniques is essential to ensure the consistency of data, compatibility with analysis algorithms, meaningful comparisons, robustness against outliers, interpretability of results, avoidance of biases, and effective communication of findings in the context of data analysis. It is a critical step toward conducting reliable and valid analyses.

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