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# Personnel Potential in Agribusiness Enterprises in the Context of an Innovation Economy

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## Abstract

The sustainability of social and economic development of countries and individual regions depends on various factors, one of which is the personnel potential shaping the labour market. In recent years, the number of people employed in agriculture has declined and has led to a shortage of agricultural personnel in the labour market. The aim of the research is to study the condition of human resources in agricultural enterprises under the conditions of pandemic and economic crisis and to identify ways of solving personnel problems. The object of the study is the personnel potential in agricultural enterprises in the example of the countries of the Eurasian Economic Union for the period from 2016 to 2020. The methods of comparative analysis, absolute and relative values, and abstract thinking served as a methodological basis for the study. The information base of the study was statistical data from the Eurasian Economic Union, and the works of scientists. The article analyses the dynamics of the urban and rural population in the countries of the Eurasian Economic Union, the number of the employed population by types of economic activity, including the agricultural sector. The main task of improvement of agricultural and industrial enterprises is to provide the industry with highly qualified personnel, solve which it is necessary to pay a lot of attention to agricultural education. Currently, many school graduates do not want to work in the agricultural sector due to the fact that it is considered unclaimed, non-prestigious, and low-paid. Therefore, various measures are needed within the states to attract graduates to the agricultural sector and to retain young professionals in rural areas. The article identifies and proposes the main ways of improving the training of in-demand personnel for agricultural and industrial enterprises based on conducted research.

## Keywords

Agricultural sector, employment, digital technology, pandemic, economic crisis.

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## Introduction

In recent years, urbanisation has been taking place throughout the world, with the movement of people, especially young people, from rural to urban areas, which has led to the problem of agricultural labour supply in the agrarian sector. This problem can, in turn, cause labour shortages in the agricultural sector of the economy and significantly affect its productivity. The problem of outflow of personnel from rural areas is addressed both by special commissions at the federal-state level and by relevant departments in the agricultural sector enterprises at the local level. The agricultural and industrial complex (AIC) is one of the main spheres and branches of the national economy and is of strategic importance for the economic development of all countries and regions (Dovgal et al., 2017). The main task of the agricultural and industrial complex is to provide the population of the country with food and raw materials for industry. The agricultural and industrial complex consists of the industries that produce agricultural products; the enterprises that process agricultural products; the enterprises that bring food products to the end consumer (Schetynina and Stenkina, 2019).

The development and improvement of agricultural and industrial enterprises largely depend on the provision of AIC with highly qualified agricultural personnel, which has an impact on the labour market. The qualitative composition of agricultural personnel forms the personnel potential of an agricultural enterprise, which is influenced by such factors as age of employees, education level, practical work experience, skills and abilities of employees, moral and material interest, ability to adapt quickly to the rapidly changing new economic conditions (Gusakova and Gusakov, 2020).

The problem of studying the personnel potential of various sectors of the economy, in particular the enterprises of the agricultural and industrial complex, is relevant and of high priority for ensuring the sustainable functioning and consistent development of social and economic systems of the agrarian sector of the economy and the state as a whole. As a central figure in the agrarian economic system, the AIC is called upon to systematise and optimise the staffing distribution and inflow locally in accordance with the actual needs of each particular enterprise, village, or agricultural and technical complex (Makhazhanova et al., 2022). At the same time, ensuring high rates of attraction of highly qualified personnel to the agricultural sector of the economy and the rational use of human resources for its dynamic and innovative development requires a constant diagnosis of the implemented personnel policy of agricultural organisations and identification of internal and external factors that affect its transformation (Akhmetzhanova et al., 2023). Young people, loose and often unemployed, or working in sub-optimal conditions, are best suited for working in the agricultural sector. However, special conditions are required to attract them. The employment rate of the working-age population is characterised by various factors, the main ones of which include: social and economic factors; technical and technological; structural; sectoral (Çera, 2022). The inflow of personnel into the sphere of rural employment is influenced by such factors as the standard of living in rural areas, the state of social protection of the rural population, development of the real economy, the rate of labour force growth, the share of the employed population in rural areas; the state of material and technical base of agricultural enterprises, the level of development of social infrastructure (Postnova et al., 2020).

## Materials and methods

The theoretical and methodological basis of the study was built on the works of leading academic economists in the field of studying the problems of development and improvement of the agricultural and industrial complex, and the issues of formation of agricultural human resources. In the course of the study to determine the current state of market potential, and the need for agricultural personnel, the method of expert survey was applied, which was conducted in the online format and included the participation of graduates of agricultural universities. In Russia, the urban population for 2020 was 109562.5 thousand, compared to 109032.4 thousand in 2017, an increase of 530.1 thousand. According to statistics, the number of the rural population compared to the urban population in the Eurasian Economic Union (EAEU) countries has decreased in recent years, except for Kyrgyzstan and Kazakhstan. Thus, in 2020 the rural population was 52345.6 thousand people, while in 2017 it was 52962.9 thousand people, a decrease of 617.3 thousand people is observed. The rural population in Russia has decreased by 585.5 thousand in recent years from 37772.0 thousand in 2017 to 37186.1 thousand in 2020. In the EAEU, the urban population in 2020 is 131928.3 thousand, the rural population 52345.6 thousand, the share of the rural population concerning the urban population is 39.7%, while the share of the urban population is 60.3%. In Russia the share of the rural population in 2020 is 33.9%, urban population 66.1%. In Kazakhstan, the share of the rural population in 2020 is 70.4%, while the share of the urban population is 29.6% (Polevaia, 2019; Gagiyev et al., 2020).

The aim of the research is to study the condition of human resources in agricultural enterprises under the conditions of pandemic and economic crisis and to identify ways of solving personnel problems. The object of the study is the personnel potential in agricultural enterprises in the example of the countries of the Eurasian Economic Union for the period from 2016 to 2020.

## Results and discussion

### Ways to improve the agricultural sector

In spite of high performance in higher education, the majority of graduates demonstrate a deficit of self-confidence, self-sufficiency, and emotional stability. They have excellent knowledge

of economic terminology, technical, agronomic, veterinary, and other knowledge, but the share of entrepreneurial initiative, in general, does not exceed a tenth of the respondents (Gagiyev et al., 2020). To develop and improve the agricultural sector, one of the priority tasks is to retain young professionals in rural areas, for the solution of which the state should develop necessary measures to improve the level and quality of life in rural areas. The main priority is to develop state-level rural youth employment programmes. There is currently an acute shortage of qualified personnel in agriculture, while many young specialists are not employed. The main reasons are as follows:

1. The low level of qualifications of agricultural personnel, which makes them uncompetitive in the labour market.
2. Low wages for agricultural personnel, which is unattractive to young professionals.
3. Harsh working conditions that are not paid decently.

All of these reasons can lead to young people having difficulty finding work for long periods of time and an increase in unemployment. The consequences of unemployment lead to the fact that young people lose interest in work, their skills are lost, and their moral and psychological state deteriorates, which can lead to serious consequences, in particular, it can lead to drunkenness, crime, and other negative phenomena (Holovenchyk, 2019). And therefore, to prevent all these negative consequences, it is necessary to work on moral and material incentives for rural youth. For the agricultural sector to be attractive, it is necessary to work on the improvement of villages and infrastructure, the creation of natural landscapes, the improvement of ecology, etc. To attract young specialists and to retain them in rural areas, it is necessary to carry out a set of measures at the state level, which will entail costs from the budget, but the incurred costs will pay off and bring their benefits (Liasnykov and Romanova, 2019; Herasimov et al., 2020). Basic measures to retain young people in the countryside:

- the payment of a placement allowance for young professionals on arrival at their place of work;
- providing young professionals with housing;
- the creation of good working conditions, i.e., the provision of jobs;
- ensuring a decent wage;
- development of social infrastructure in rural areas;
- providing opportunities for career development.

One of the new directions of increasing the attractiveness of rural areas is the development of agricultural tourism, as many rural areas are located in favourable climatic conditions and tourists have the opportunity to relax and taste natural products (Shcherbakov, 2021; Blynova, 2020; Antonova, 2020; Aletdinova, 2019; Akimbekova, 2019). The development of agricultural tourism will provide agricultural enterprises, in particular entrepreneurs, with additional income to supplement their core activities. It is possible to resume work by holding various competitions to identify the best agricultural workers according to the results of the year for their moral and material encouragement (Blynova, 2020). The solution to these tasks will raise the prestige of living and working in rural areas. There is an acute shortage of qualified personnel in rural areas. One of the main factors in the sharp decline in agricultural development has been the fall in the level of wages (Khodakivska et al., 2022). At the current stage, the difference between wage levels in agriculture and urban areas is about 60%. Improving working conditions, combined with motivational measures, would create a base that would increase the attractiveness of working in rural areas for highly qualified personnel. Solving the problem of supplying the village with qualified human resources, by identifying the factors that have an intensive influence on the decrease in people's motivation to live and work in rural areas, and finding ways to form a qualified personnel reserve is of the greatest interest to research (Gagiyev et al., 2020). The requirements for young professionals are constantly increasing and are reduced not only to the presence of a high level of professional erudition but also to the ability to creatively organise agricultural production, the ability to motivate agricultural workers, to prevent and resolve managerial conflicts. To develop and strengthen a highly qualified human resource potential, one of the main ways is to attract investment, the feasibility of which is as follows:

- increasing the competitiveness of agricultural enterprises;
- expansion of production and the expansion of agricultural enterprises to a higher level, including the global level;
- improving the financial condition of enterprises through higher profits, lower production costs, and higher labour productivity (Shahini et al., 2023).

Young people mostly leave for the cities and do not want to engage in agriculture (Gainanov and Migranova, 2020; Zabelina, 2021). Table 1 demonstrates the number of urban and rural populations in Eurasian Economic Union countries in recent years (2017-2020) according to Statistics of the Eurasian Economic Union (Statistics of the Eurasian Economic Union, 2021). Due to the process of urbanisation all over the world, including in the countries of the Eurasian Economic Union, the number of the urban population compared to the rural population is increasing every year, which can be seen in Table 1.

Due to the data in Table 1, the urban population has increased in recent years in almost all EAEU countries except Armenia. The increase in the urban population indicates that there is an urbanisation process, i.e., an outflow of the rural population to cities, which creates the problem of a lack of human resources in rural areas. The urban population of EAEU countries in 2020 was 131928.3 thousand people, compared to 13065.8 thousand people in 2017, i.e., an increase of 13025 thousand people, compared to 2018 an increase of 7905 thousand people. In Kazakhstan, there is also an increase in the urban population in 2020 compared to 2017 by 607.2 thousand people (Liasnykov and Romanova, 2019). From the analysis in Table 1, it can be concluded that, overall, the urban population dominates, characterised by an urbanisation process in which urban settlements increase in relation to rural settlements. The main reasons for the rural population's exodus to cities are as follows: more employment opportunities; more favourable living conditions than in rural areas; higher wage levels; career prospects for young people (Lakomý and Alvarez-Galvez, 2022).

## Analysis of data on employment in areas of economic activity

The working-age population of countries is employed in different areas of economic activity, and in order to determine the ratio of the employed population in different areas of economic activity, an analysis of the population and its dynamics in recent years has been carried out (Herasimov et al., 2020). Table 2 shows the number of people employed by type of economic activity in recent years from 2016 to 2020.

According to data in Table 2, the number of the employed population in Russia has increased in recent years from 1011, thousand people in 2017 to 1077.4 thousand people, including a decrease in the agriculture, forestry and fishing industries from 317.1 thousand people in 2017 to 235.9 thousand people in 2020. The decrease in the number of people employed in the agricultural industrial sector is mainly due to the fact that in recent years there has been an outflow of the rural population to urban areas, which directly affects the human resources potential of agriculture. The industry sector has seen an increase in the number of people employed in recent years, from 132900 in 2017 to 149000 in 2020. In Kazakhstan, the total employed population by economic activity increased from 8583.4 thousand people in 2016 to 8832.0 thousand people in 2020, including a decrease in the employed population in agriculture

| | 2017 | 2018 | 2019 | 2020 | Deviations of 2020 from | | |
|---|---|---|---|---|---|---|---|
| | | | | | 2017 | 2018 | 2019 |
| **Urban population** | | | | | | | |
| EAEU | 130625.8 | 131137.8 | 131512 | 131928.3 | 13025 | 7905 | 4163 |
| Armenia | 1901.5 | 1895.8 | 1894.9 | 1892.1 | 9.4 | 3.7 | 2.8 |
| Belarus | 7286.5 | 7284.3 | 7291.7 | 7303.9 | 17.4 | 19.6 | 12.2 |
| Kazakhstan | 10331.5 | 10509.8 | 10698.2 | 10938.7 | 607.2 | 428.9 | 240.5 |
| Kyrgyzstan | 2073.9 | 2121 | 2173.7 | 2231.1 | 157.2 | 110.1 | 57.4 |
| Russia | 109032.4 | 109326.9 | 109453.5 | 109562.5 | 530.1 | 235.6 | 109 |
| **Rural population** | | | | | | | |
| EAEU | 52962.9 | 52577.6 | 52448.3 | 52345.6 | 617.3 | 232 | 102.7 |
| Armenia | 1084.7 | 1076.9 | 1070.4 | 1067.6 | 17.1 | 9.3 | 2.8 |
| Belarus | 2183.2 | 2164 | 2137.5 | 2106.4 | 76.8 | 57.6 | 31.1 |
| Kazakhstan | 7586.7 | 7647.5 | 7697.4 | 7697.4 | 110.7 | 49.9 | |
| Kyrgyzstan | 4066.3 | 4135.7 | 4215.8 | 4292.4 | 226.1 | 156.7 | 76.6 |
| Russia | 37772 | 37553.5 | 37327.2 | 37186.1 | 585.5 | 367.4 | 141.1 |

Source: Statistics of the Eurasian Economic Union (2021)

Table 1: Urban and rural population (at the beginning of the year, thousand people).

| | 2016 | 2017 | 2018 | 2019 | 2020 | Deviations of 2020 from | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2016 | 2017 | 2018 | 2019 |
| **Armenia** | | | | | | | | | |
| Employed population | 1006.2 | 1011.7 | 1048.5 | 1077.4 | 1025.4 | 19.2 | 13.7 | 23.1 | 52 |
| Agribusiness | 338.1 | 317.1 | 272.0 | 235.9 | 229.6 | 108.5 | 87.5 | 42.4 | 6.3 |
| **Belarus** | | | | | | | | | |
| Employed population | 4 405.7 | 4 353.6 | 4 337.9 | 4 334.2 | 4 319.6 | 86.1 | 34 | 18.3 | 14.6 |
| Agribusiness | 425.1 | 416.6 | 404.9 | 377.0 | 375.9 | 49.2 | 40.7 | 29 | 1.1 |
| **Kazakhstan** | | | | | | | | | |
| Employed population | 8 553.4 | 8585.2 | 8695.0 | 8780.8 | 8732.0 | 178.6 | 146.8 | 37.0 | 48.6 |
| Agribusiness | 1 385.5 | 1319.0 | 1228.2 | 1184.7 | 1175.1 | 210.4 | 143.9 | 53.1 | 9.6 |
| **Kyrgyzstan** | | | | | | | | | |
| Employed population | 2 363.7 | 2 351.2 | 2 382.5 | 2 442.7 | 2 445.2 | 81.5 | 94 | 62.7 | 2.5 |
| Agribusiness | 633.3 | 541.4 | 482.7 | 443.2 | 446.0 | 187.3 | 95.4 | 36.7 | 2.6 |
| **Russia** | | | | | | | | | |
| Employed population | 72 392.6 | 72 315.9 | 72 531.6 | 71 933.1 | 70 601.4 | 1714.5 | 1930.2 | 1930.2 | 1 331.7 |
| Agribusiness | 4 863.2 | 4 268.0 | 4 266.8 | 4 196.1 | 4 236.7 | 626.5 | 31.3 | 30.1 | 40.6 |

Source: Statistics of the Eurasian Economic Union (2021)

Table 2: Number of employed populations by type of economic activity (according to NACE ed. 2; annual average; thousand people).

from 1385.3 thousand people in 2016 to 1157.1 thousand people. In 2020, the decrease is 210.4 thousand people. The decrease in the employed population in agriculture is associated with the development of urbanization, i.e., the outflow of the rural population to cities. Young people do not want to work in rural areas, as agricultural occupations are currently considered to be non-prestigious and low-paid. Currently, there are several reasons why school graduates do not want to enter agrarian specialities (Shcherbakov, 2021). To make agrarian specialities prestigious it is necessary to carry out extensive work at the state level to attract school graduates to agrarian education, first of all, it is necessary that agrarian specialities are in demand, promising and highly paid in the labour market. Table 3 shows the distribution of the employed population by main economic activity in the EAEU countries and in Russia and Kazakhstan in 2020 relative to 2019.

Table 3 demonstrates, that in the EAEU countries, the share of the employed in different economic activities has fluctuated insignificantly over the last five years. Thus, in the EAEU countries over the period from 2016 to 2020, the highest share of the employed population is in the service sector, which fluctuates between 65.1-66.7%. In industry, the share of the employed population in recent years has varied between 18.9% and 19.1%. The lowest share of the employed population is in agriculture, which accounted for 7.3-8.6% of the total employed population from 2016 to 2020. This figure is very low compared to the service sector and indicates that the countries' populations are not interested in working in the agricultural sectors. In Russia, for example, over the last five years, the service sector has also had the highest share of the employed population, ranging from 66.3 to 67.5%. The agricultural sector employs between 5.8-6.7% of the population, which is also very low. In Kazakhstan from 2016 to 2020, the share of the employed population in 2020 has increased by 3.6% compared to 2016 to 66.8%. The share of the employed population in agriculture in Kazakhstan is higher compared to the EAEU and Russia, but nevertheless, there has been a 2.7% decrease in the share in recent years from 16.2% in 2016 to 13.5% in 2020. The decrease in the share of the employed population in agriculture is mainly due to a decrease in the share of agricultural enterprises. The decrease in the number of working-age people in agriculture is a major blow to the development of rural areas, in particular, the shortage of agricultural personnel is increasing, which affects the investment attractiveness of the village (Trusova et al., 2021). One of the main indicators determining the level and quality of life of the population is the amount of workers' wages by type of economic activity (Blynova, 2020). Table 4 shows the ratio of average monthly nominal wages of employees by the main types of economic activities in 2020 as a percentage of 2019.

| | Agriculture, forestry, and fisheries | Industry | Construction | Service sector |
|---|---|---|---|---|
| | **EAEU** | | | |
| 2016 | 8.6 | 18.9 | 7.4 | 65.1 |
| 2017 | 7.7 | 18.9 | 7.3 | 66.1 |
| 2018 | 7.5 | 19.0 | 7.2 | 66.3 |
| 2019 | 7.3 | 19.1 | 7.1 | 66.5 |
| 2020 | 7.4 | 19.1 | 6.8 | 66.7 |
| | **Russia** | | | |
| 2016 | 6.7 | 19.8 | 7.2 | 66.3 |
| 2017 | 5.9 | 19.7 | 7.3 | 67.1 |
| 2018 | 5.9 | 19.7 | 7.1 | 67.3 |
| 2019 | 5.8 | 19.9 | 6.9 | 67.4 |
| 2020 | 6.0 | 19.9 | 6.6 | 67.5 |
| | **Kazakhstan** | | | |
| 2016 | 16.2 | 12.7 | 7.9 | 63.2 |
| 2017 | 15.4 | 12.7 | 7.1 | 64.8 |
| 2018 | 14.1 | 12.6 | 7.2 | 66.1 |
| 2019 | 13.5 | 12.5 | 7.2 | 66.8 |
| 2020 | 13.5 | 12.5 | 7.2 | 66.8 |

Source: Statistics of the Eurasian Economic Union (2021)

Table 3: Distribution of the employed population by field of activity (as a percentage of total employment).

| | Armenia | Belarus | Kazakhstan | Kyrgyzstan | Russia |
|---|---|---|---|---|---|
| National average | 103.2 | 114.2 | 114.6 | 107.7 | 106.0 |
| agriculture, forestry, and fisheries | 98.6 | 116.1 | 114.4 | 102.3 | 107.0 |
| mining industry | 95.6 | 111.6 | 110.3 | 109.5 | 106.5 |
| manufacturing industry | 99.0 | 110.6 | 112.0 | 106.0 | |
| electricity supply, gas supply | 98.9 | 110.4 | 109.9 | 104.4 | |
| water supply | 109.4 | 109.3 | 106.9 | 115.4 | 104.1 |
| construction | 108.7 | 112.8 | 104.8 | 100.9 | 101.6 |
| wholesale and retail trade | 103.9 | 110.6 | 105.4 | 101.8 | 103.2 |
| transport and storage | 100.6 | 105.1 | 109.4 | 91.6 | 102.8 |
| accommodation and food services | 92.1 | 102.4 | 113.7 | 112.4 | 94.1 |
| information and communication | 111.6 | 124.8 | 109.6 | 116.1 | 109.6 |
| real estate | 104.2 | 111.5 | 107.8 | 96.0 | 102.8 |
| education | 106.0 | 113.3 | 130.3 | 118.7 | 106.2 |
| health | 108.6 | 129.5 | 130.9 | 101.2 | 114.5 |
| provision of other services | 99.6 | 110.9 | 135.0 | 88.3 | 111.6 |

Source: Statistics of the Eurasian Economic Union (2021)

Table 4: Average monthly nominal wages and salaries by major economic activity in 2020 (as a percentage of wagesd and salaries by 2019).

Due to Table 4, nominal wages in all EAEU countries increased in 2020 compared to 2019, in Armenia by 3.2%, Belarus by 14.2%, Kazakhstan by 14.6%, Kyrgyzstan by 7.7%, and Russia by 6.0%. The largest increase in nominal wages is observed in Kazakhstan, while the smallest increase is observed in Armenia. Thus, the average monthly nominal wage in Armenia increased by 3.2% in 2020 compared to 2019. The average monthly wage in Armenia increased in such economic activities as wholesale and retail trade – by 3.9%, water supply – by 9.4%, construction – by 9.4%, information and communication – by 11.6%. The average monthly wage in agriculture decreased by 1.4% in 2020 compared to 2019. In Kazakhstan, average nominal wages in 2020 compared to 2019

increased in almost all economic activities, with a nationwide increase of 14.6%, in agriculture by 14.4%, In Russia, nominal wages in 2020 increased in almost all economic activities compared to 2019, except in accommodation and catering services, where the decrease amounted to 5.9%.

Agriculture is one of the main branches of the national economy and provides the population with food, and raw materials for industries, including food and light industry (Atamanyuk et al., 2016; Antonova, 2020). The provision of high quality and affordable food has a huge impact on the level of food security of the countries. In this regard, an important role in the production, procurement, and processing of agricultural products belongs to agricultural personnel. The labour market is currently experiencing an acute shortage of highly qualified agricultural specialists whose role is very important in production and technological processes (Shcherbakov, 2021).

To determine the reasons for reluctance to work in rural areas, a survey was conducted among students. The survey was conducted among students studying agricultural specialities and according to its results, the main reasons for students' reluctance to live and work in rural areas were identified, as shown in Table 5. The respondents were selected 250 students of agricultural specialities of I-V courses of Zhetysu University named after I. Zhansugurov. Zhansugurov. Of them 170 women (68%) and 80 men (32%). The age range of the students was from 17 to 23 years old.

| No. | Reasons | Percentage, % |
|---|---|---|
| 1 | Low wages | 2.1 |
| 2 | Poor organisation of work – no normal working conditions | 12.3 |
| 3 | Inadequate social infrastructure | 7.2 |
| 4 | Lack of desire to work in the village | 22.0 |
| 5 | Agricultural occupations are unattractive | 12.5 |
| 6 | Lack of prospects for further professional development | 15.2 |

Source: Statistics of the Eurasian Economic Union (2021)

Table 5: Main reason for lack of desire to work in rural areas.

Nevertheless, according to the results of the surveys, some students expressed a desire to live and work in rural areas under the following conditions:

1. High wages – 45.0%.
2. Normal housing and living conditions, i.e., the provision of comfortable accommodation – 25%.
3. A well-established infrastructure – 30%.
4. Creation of normal working conditions, opportunities for further career development – 25%.

However, some students do not want to live and work in rural areas, even if all the conditions are in place (Aletdinova, 2019; Akimbekova, 2019; Tsyhankova, 2019; Petrova, 2021; Altykhov, 2019; Gainanov and Migranova, 2020; Zakuskin, 2021). Time has shown that the development and improvement of the agricultural sector require agricultural specialities. Based on the research, taking into consideration supply and demand in the labour market, the list of the most demanded specialities in the Eurasian labour market in the agricultural sector for the coming years has been determined. Table 6 shows the list of the most demanded professions in the Eurasian labour market in the field of the agricultural industrial complex from 2021 to 2022.

At present, the most in-demand professions in the agricultural sector are those in both crop production and animal husbandry. There is a shortage of agronomists – specialists who are engaged in the effective management of crop production, studying the issues of planting, care of plants, and harvesting. It is the work of the agronomists that determines the high yield of plants at minimum cost (Petrikov, 2020; Lischuk and Kapeluk, 2021; Dudin, 2021; Polukhina, 2020). Plant protection specialists, who deal with plant protection against various pests and insects, also play a major role in the efficiency of crop production. There is a shortage of seed agronomists, who deal with the breeding of new zoned plant varieties. In animal husbandry, the most sought-after specialists are veterinarians, who deal with the prevention and treatment of farm animals. In recent years, there is no recruitment for such a speciality as "Zootechnics" and after a certain period, there is a shortage of this profession, which is engaged in breeding and caring for animals. There is also a shortage of veterinary laboratory technicians, as their number has decreased in recent years (Tsyhankova, 2019). Time has also shown that in recent years enrolment in such specialities as "Reclamation Engineer" and "Hydrotechnician" has decreased due to which there is a shortage of these specialities. The main function of these specialities is to work on improving the quality of land, which directly affects the yield of crops. Table 6 reflects the most demanded agrarian professions in the Eurasian labour market, but it is not a complete list, which was supplemented

| No. | Name of the agricultural occupations in demand | | | | |
|---|---|---|---|---|---|
| | Armenia | Belarus | Kazakhstan | Kyrgyzstan | Russia |
| 1 | Agronomist | Agronomist | Agronomist | Agronomist | Agronomist (various specialisations) |
| 2 | Specialist (crop protection agronomist) | Plant protection agronomist | Plant protection agronomist | Plant protection agronomist | |
| 3 | Seed agronomist | Seed agronomist | Seed agronomist | Seed agronomist | |
| 4 | Veterinary surgeon | Veterinary surgeon | Veterinary surgeon | Veterinary surgeon | Veterinary surgeon |
| 5 | Geneticist | | Geneticist | | Breeder zootechnician |
| 6 | Hydrotechnician | | Hydrotechnician | | Hydrotechnician |
| 7 | Zootechnician | Zootechnician | Zootechnician | Zootechnician | Zootechnician |
| 8 | Keclamation engineer | | | Keclamation engineer | Keclamation engineer |
| 9 | Veterinary laboratory technician | Veterinary laboratory technician | Veterinary laboratory technician | Veterinary laboratory technician | Veterinary laboratory technician |

Source: Statistics of the Eurasian Economic Union (2021)

Table 6: List of the most demanded professions in the Eurasian labour market in the agricultural sector (ACS) from 2021 to 2022.

with professions according to the requirements of the modern labour market. Since in modern conditions of management preference is given to more advanced specialities and given the widespread application of digitalisation in the near future, the following specialities may be the most in-demand:

1. The agronomist-geneticist. This profession will be in demand in the future, and the agronomist, in addition to solving problems in cultivation and plant care, may also be involved in the development of new plant varieties and their adaptation to each climatic zone (Mero et al., 2023).
2. Agricultural engineer. Given the fact that more modern agricultural machinery is being produced every year, where knowledge of programming, microelectronics is required, there is a shortage of specialists in agricultural machinery in the labour market. In this regard, the agricultural engineering profession will be the most in-demand in recent years.
3. Drone operator. Drones are now widely used in agriculture, which has created a need for drone operators.
4. 4. Agricultural ecologist. The profession of ecologist has existed for a long time, but few ecologists deal directly with the ecological climate in agriculture. Therefore, this speciality will be in demand in the coming years.
5. Agrocybernetics. The speciality of agrocybernetics is necessary due to the use of automation and digitalisation of all production and technological processes. This specialist is engaged in the development of new automation programmes, and digitalisation methods (Erochkina and Potapova, 2020; Ryabchikova, 2021).

## Conclusion

To enhance the competitiveness of agricultural specialists, there is a pressing need to elevate the standards and quality of agricultural personnel training. This entails active engagement of employers in the educational process to instill practical skills and the potential for practical training leading to graduate employability. Furthermore, the integration of educational institutions and agricultural enterprises within the agricultural industrial complex is imperative. Establishing favorable working, social, and living conditions, along with providing competitive wages, will heighten the prestige associated with agricultural occupations. Moreover, a systematic approach is required to continuously elevate the qualifications of agricultural personnel, involving ongoing training, retraining, and the establishment of a talent pool.

To address the agricultural sector's need for a skilled workforce, key measures include reviving state-sponsored training programs, ensuring graduates have access to employment opportunities, providing social and economic support during their transition into the workforce, and implementing incentive systems. Revitalizing targeted training programs helps align education with industry demands. Creating employment pathways for graduates

through partnerships with agricultural enterprises, rural administrations, and educational institutions is crucial. Supporting graduates with measures like installation grants and financial assistance fosters a smooth transition. Finally, introducing incentives, such as scholarships, training programs, and professional competitions, not only motivates talent but also contributes to the sector's growth and long-term sustainability. These strategies collectively promote a qualified talent pool and enhance the agricultural sector's resilience and prosperity.

In addition to the measures mentioned earlier for boosting rural employment, a pivotal and crucial approach involves fostering growth within the real sector of the economy, particularly in agriculture. It is imperative to focus on sustaining and augmenting employment opportunities through dynamic and innovative advancements in diverse businesses. This entails initiatives such as fostering local industry, establishing agricultural product processing enterprises, constructing storage facilities, broadening the scope of services, and more.

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# The Impact of the Price Factor on Farmers' Incomes in Turbulent Conditions

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## Abstract

Farmers face various types of risks that affect their behavioural strategies and well-being. In 2022, the main problem was the rapid and uncontrolled acceleration of inflation in the markets of raw materials, energy and food products. Farmers have faced price volatility in food, raw materials and energy. The purpose of the article was to analyse the impact of the price factor on farmers' incomes, including the total impact of prices on manufactured products and energy carriers. The regression-based analysis showed the negative nature of such an impact, which requires increased state support for farm income during the crisis period. As a result of the study, we proposed to reorient government support from simple subsidies to incentives for farmers to produce bioenergy from waste. This measure will increase farmers' energy independence, reduce income dependence on rising energy prices, and increase the efficiency of public spending.

## Keywords

Bioenergy, energy independence, energy prices, farm income, governmental support, inflation, price shocks, price volatility, the price of agricultural products.

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## Introduction

The problem of regulation and support of farm income is one of the main issues in European politics. Especially it became more complicated in the conditions of unprecedented acceleration of inflation in the markets of raw materials, energy carriers and foodstuffs practically in all countries. Large-scale Russian aggression in Ukraine has affected global food markets, value chains, agricultural supply chains, inflation and the financial environment for doing business. The disruptions exacerbated existing tensions in commodity markets following the recovery from the COVID-19 pandemic. As a result, commodity price volatility has risen sharply, and food prices reached their highest level since 2007-2008. Under such circumstances, the question arises of how farm incomes will behave. Will it increase because of rising prices or decrease as a result of rising prices for fertilizers and energy carriers? The political importance of this issue stems from the fact, that in the context of accelerating inflation in world commodity markets and tightening monetary policy against the backdrop of increased budget spending in EU countries to ensure national security, updated the task of increasing the efficiency of spending public funds to support the agricultural sector (Yurik et al., 2020).

The purpose of the article is to analyse the price factors that affect farmers' incomes in conditions of turbulence and to identify their cumulative impact.

In today's challenging environment, farmers face a variety of risks that affect their behaviour and well-being. First, in 2022, farmers faced volatile food prices, which are closely related to the crisis in the global food market. Price risk is the most economically sensitive and is associated with fluctuations in prices for finished products and resources. Therefore, farmers develop various strategies to cope with the consequences of exposure to risks, use the tools offered by the market, or diversify their sources of income.

The problem of the influence of prices on farm incomes is studied by many scientists. Assouto et al. (2020) argue that in agriculture, prices are subject

to sudden large fluctuations that make it impossible to build expectations and that quickly affect farm incomes. The significance of this price risk is mainly due to the delay between the production decision and the timing of the harvest, due to the elasticity of demand at a low price (Assouto et al. 2020; Mukaila, 2022).

Serra (2015) points to important volatility links between consumer and producer prices, who argue that price volatility for basic foodstuffs is one of the most complex factors influencing food security.

Increased price volatility means greater uncertainty about future prices for agricultural products, which can affect the welfare of producers, especially in the absence of a risk insurance mechanism (Rezitis and Stavropoulos, 2008).

Food price volatility affects smallholder farmers, who derive a significant portion of their income from food sales. Price fluctuations can distort the distribution of inputs, discourage investment in agriculture and reduce agricultural productivity growth, especially in the absence of effective risk-sharing mechanisms, with long-term consequences for poor consumers and farmers (Ceballos et al., 2017).

Jouf and Lawson (2022) concluded that rising agricultural prices have a statistically significant positive impact on agricultural production because in response to expected price changes, the crop mix is being adjusted qualitatively and quantitatively to achieve higher incomes.

Volatility in food prices has important economic and political implications. And in the context of additional volatility in energy prices, the total cost effect for farms is extremely difficult to determine, which increases their risks and can lead to a difficult situation in agricultural production. The multidirectional impact on farmers' incomes of food prices is upward, and that of energy prices is downward, which creates a situation of uncertainty and leads to insufficiently substantiated decisions in the field of agricultural policy. Policies to increase the responsiveness of supply and demand to changes in price, as well as to mitigate price risk and increase competition in agricultural markets, may be necessary to protect farmers' incomes. Therefore, it is important to investigate and determine the impact of the price factor on farm incomes, which will help stabilize farm incomes under turbulent conditions.

## Materials and methods

Our goal was to assess the impact of the price factor associated with the dynamics of food and energy prices on farmers' incomes. For this, we used the data FAO, Eurostat Database, World Bank Data.

Using the data processing method and the graphical method of data series analysis, graphs were constructed illustrating the dynamics of changes in prices and incomes of farmers over time. This helped to track trends and identify dependencies between the studied indicators.

A factorial regression analysis of farm incomes was carried out and the hypothesis of mutually compensating influence of prices for energy resources and agricultural products on farm incomes was tested. The World Bank consumer energy price index is constructed explicitly, using surveys of the cost of a defined basket of consumer goods and services. The Laspeyres formula is generally used. Data are period averages. World Bank Energy price index is represented by weights coal (4.7 %), crude oil (84.6 %), and natural gas (10.8 %). To improve the results of the analysis of the profitability of farms and the profitability of labour, real indicators were used, clear of the price effect.

The conducted correlation-regression analysis made it possible to trace the relationship between farm income and a set of factors. One of the most common methods for estimating the parameters of multiple linear regression is the least squares method, the essence of which is to minimize the sum of squared deviations of the observed values of the dependent variable Y from the values, obtained on the basis of the constructed regression equation. The use of correlation-regression analysis made it possible to quantify the dependence of the volume of farm income on specific factors and to determine the most important indicators that affect the variable.

The general appearance of a multiple regression model can be seen in the formula:

$$y = a + b_1 X_1 + b_2 X_2 + \ \ldots + b_n X_n + \varepsilon$$

Where:

$y$ – the dependent variable;

$a$ – the y-intercept;

$b$ – beta coefficient;

$X_n$ – factors (the independent variables);

$\varepsilon$ – the error term.

To measure the strength of linear relationships of different pairs of variables, a correlation matrix was calculated. In particular, it is taken into account that for each individual pair of variables, the linkage is influenced by links with other variables.

The coefficients of multiple correlations of the connection of the regression analysis indicate a fairly close relationship between the dependent variable and the factor values (multiple R is 0.8704). The calculated value of the coefficient of determination R Square = 0.7576 indicates a close relationship between the signs (the difference from unity is 0.2424). The value of R Square shows that the variation in farm income is 75.76 % determined by the factors selected above, and only 24.24 % is accounted for by other unaccounted quantities or factors. The conclusion about the adequacy of the model can be made on the basis of the calculated value of the Fisher significance F. The calculated value of Fisher's F-test – 0.1013 indicates that the model parameters are statistically significant.

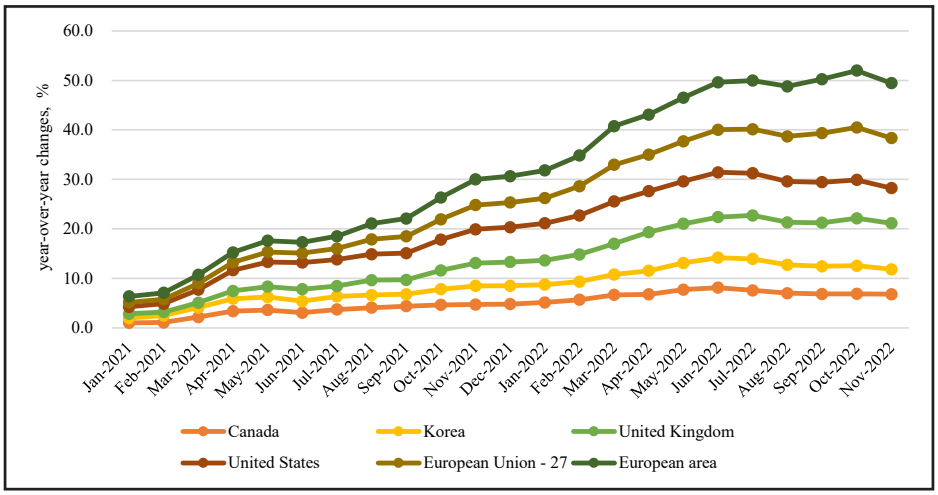
## Results and discussion

The state of global food markets is extremely important for the inflationary dynamics in the EU and the income of their farms. The stagflation shock of 2022 is of a global nature associated with the consequences of Covid-19 and the fall in grain exports from Ukraine and Russia. The main feature of the war in Ukraine and the early spikes in food prices is the rise in food prices due to the impact of energy and fertilizer price volatility. In most countries, since February 2022, a significant surge in prices has been recorded against the background of a decrease in economic activity.

In particular, in the EU-27, consumer price growth in 2022 increased from 5.1% in January to 10.1% in November, in the US – from 7.5% to 7.1%, in the UK – from 4 .9% to 9.3%, Canada – from 5.1% to 6.8%, Korea – from 3.6% to 5.0%. Global inflation in 2022 is projected at 6.2%, up 2.25% from the original forecast (Figure 1).

The growth of world inflation is largely determined by the following factors:

- disruption of product supply chains as a result of hostilities in Ukraine and sanctions imposed against Russia;
- renewed supply disruptions as a result of new quarantine restrictions imposed in China;
- rising prices due to commodity shocks in many regional markets caused by a reduction in the supply of gas, oil, wheat, fertilizers and other materials as a result of the war in Ukraine. Prices for goods whose supply is limited are rising both directly (the increase in world food prices is caused by a drop in the supply of wheat, barley, corn, rapeseed and oil from Ukraine) and through inter-industry relations (for example, oil is an intermediate product that affects the cost of a large quantity of goods and services at the expense of raw materials and transportation costs);
- a gradual increase in demand for certain groups of goods as a result of the recovery of economic activity in the countries




Source: Authors´ own processing based on OECD Database

Figure 1: Growth rate of the consumer price index, % compared to the corresponding month last year.

of the world after the lifting of anti-COVID restrictions;

- decline in grain production in developing countries due to lack of fertilizers, the main suppliers of which were Ukraine and Russia;
- termination of gas supplies by Russia to some EU countries (Poland, Bulgaria, Denmark, etc.);
- rising oil prices due to bans on Russian oil imports imposed by countries of the sanction's coalition (USA, EU, UK). The price of Brent crude rose 20% to $139 per barrel (the highest level since 2008);
- tightening labour markets in many countries (USA, UK, Canada and Australia) due to labour shortages caused by the pandemic. This threatens to create a wage-price spiral where, with limited labour supply, businesses must pay higher wages to get the skilled workers they need, further pushing up prices.

These trends have led to significant increases in government spending to keep food supply chains functioning, help producers overcome disruptions, and provide additional food assistance to poor consumers. Figure 2 shows that in 2020 and 2021, governments spent an additional USD 55 billion and USD 70 billion, respectively, representing 10% and 13% of all budget support in those years. And these data represent only the lower bound of the actual additional costs during the pandemic. And extra budget expenditures serve as an additional factor in increasing inflation.

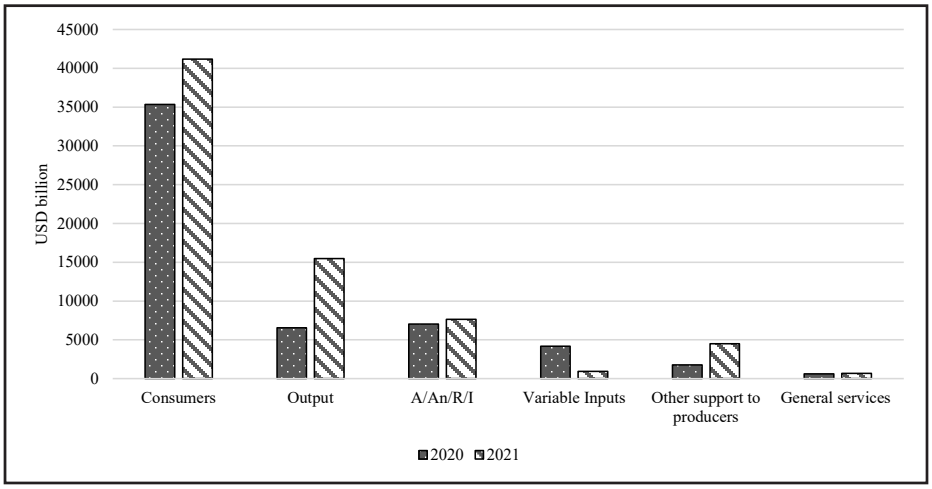
Volatility in energy prices drives up food costs and lowers farm incomes, which the current increase in food prices may not be enough to offset. As a result, the EU countries will enter a new level of food market conditions, with higher prices, but with an unchanged level of food supply and falling real incomes of farmers. This is an unfavourable prospect.

## Analysis of farmers' income factors

We analysed the dependence of the farmer's income on the main factors (prices, labour productivity, production volumes, costs), the nature of which has changed in the conditions of turbulence of recent years. The farmer's income is also influenced by the technological factor and financial assets, but in this case their influence did not make a significant impact on the results of our research.

In 2022, a significant reduction in grain and fuel supplies to the world markets was observed, resulting in an increase in prices for these groups of goods. The food market deficit and rising prices theoretically imply an increase in demand for farmers' products, which should create favourable conditions for increasing their incomes in nominal terms. However, such an increase may occur to a much lesser extent than expected. The cause of this is the divergent influence of price dynamics on energy carriers and food on farmers' incomes, the rise in fuel and fertilizer prices in the short- and medium-term perspective:

- on the one hand, it will exert upward pressure on agricultural prices that will be offset




Source: Authors´ own processing based on OECD Database

Figure 2: Distribution of estimated agricultural support in response to COVID-19, 2020-2021 year, USD billion.

by a decline in real incomes,

- on the other hand, it will lead to a partial loss of the income gain achieved by farmers due to the increase in the cost of agricultural production and transport costs.

This assumption is confirmed by the correlation coefficients of the real incomes of peasant households with production factors and prices. Thus, the real income factor of peasant households per unit of annual labour is negatively correlated with the index of prices for energy carriers (correlation coefficients is 0.37) and the index of prices for agricultural products (correlation coefficients is 0.25), while the net entrepreneurial income of peasant households is weakly positively correlated with the index prices of energy carriers and agricultural products (correlation coefficients were 0.023 and 0.116 respectively).

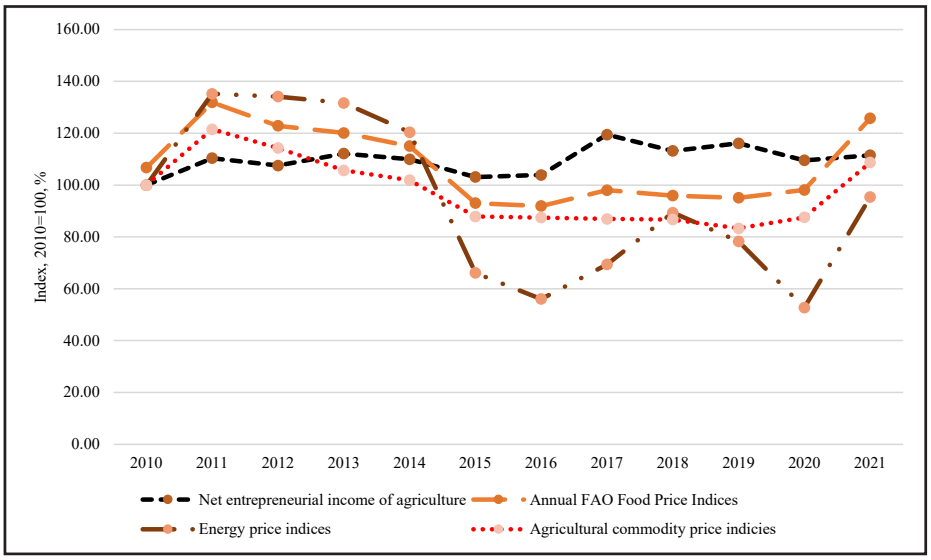
At the same time, the influence of energy prices on the incomes of farms is more significant and negative than on their cost, which to some extent explains the traditional orientation of CAP measures to support incomes.

The dynamics of net entrepreneurial income of agriculture and prices of agricultural products and energy carriers according to the FAO and the World Bank for the past years are shown in Figure 3.

Figure 3 shows that the food price index declined in 2015-2016 and 2018-2020, resulting in a positive gap between the price index and the net income in agriculture. However, the surge in prices due to COVID-19 in 2020-2021 has increased the rate of growth of net income in the agro-industrial complex to 125.08 versus 111.5%. Overall, since 2012, the growth rate of net income in agriculture has been showing a leading trend compared to food prices. At the same time, labour productivity was growing faster than the net income of farmers (Figure 4). This may be the result of improvement of the farm equipment and at the same time create the preconditions for the decrease in motivation for further increase in labour productivity due to its underestimation. The extensive factor of income is the volume of production, as evidenced by Figure 4.

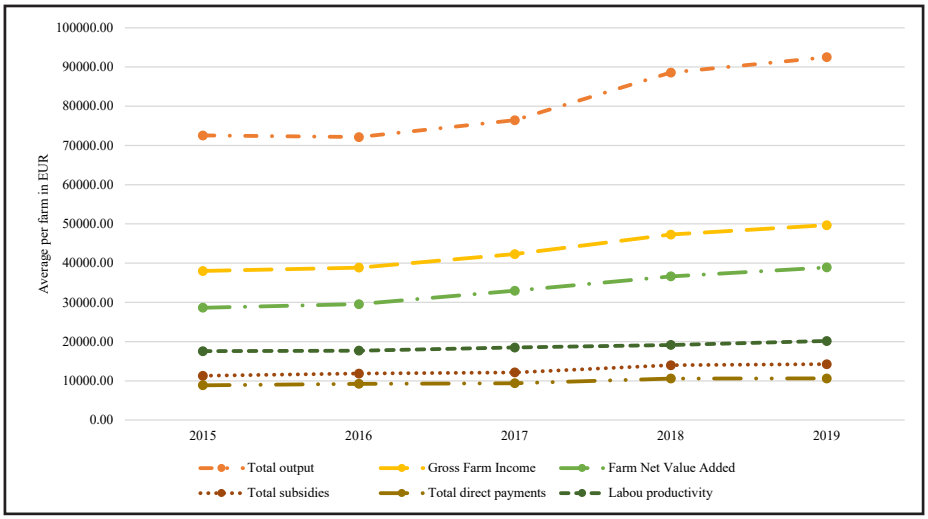
High yields increase the supply on the food markets and exert a downward pressure on prices. This somewhat neutralizes their positive impact on farmers' incomes and reduces the motivation to increase production volumes. It should be noted that in the absence of significant changes in labour productivity in recent years, the growth of agricultural production has been positively correlated with income. The reason for this is government subsidies, which weakened the dependence of farmers' incomes on the market situation in the EU.

The level of income of farms depends on production costs, including labour costs. From 2000 to 2017, the share of intermediate consumption and wages in the EU was 58% and 10% (on average) of the value of agricultural production respectively. The impact of the growth of agricultural expenses on the incomes of farmers is to a lesser extent




Source: Authors´ own processing based on Eurostat Database, FAO and World Data Bank

Figure 3: Indices of income in agriculture and food and energy prices.




Source: Authors´ own processing based on Eurostat Database

Figure 4: Dynamics of the main indicators of economic results in agriculture.

compensated by CAP. At the present stage, due to the rise in food and fuel prices, the growth of fuel and delivery costs, as well as the need to increase the wages of farmers and hired workers, there will be a negative impact of costs on farm incomes.

Thus, the volatility and instability of incomes in the agrarian sector are becoming a circumstance that provokes the outflow of labour resources and requires an appropriate response from the state. Structural changes in agriculture affect the outflow of labour from the agricultural sector in the EU (Figure 5).

The low labour force in agriculture means that agricultural income is shared among fewer people, which in turn increases income per person, although not symmetrically across sectors as their income differs.

Significant annual income volatility in rural areas, as well as their significant undervaluation compared to the average income level in the economic system (overall 40.0%), creates the need for government funding to address such structural inequalities in income.

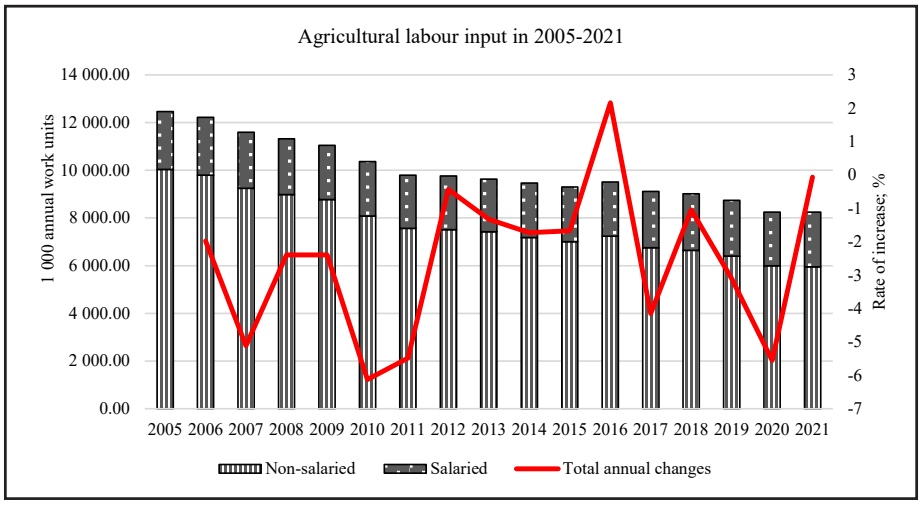
For a more specific factorial analysis of farm income, we built linear regression models with logarithmic transformations, regression coefficient was 75.76% and statistically significant (Table 1).

Analysis of the results of the regression showed that the most significant factor influencing income was output – with its increase by 1%, income increased by 2.02 per cent. Budget payments also had a positive effect on income – according to our calculations, an increase in payments by 1% gives an increase in income by 0.58%. An increase in interest payments and rent payments by 1% increases income by 0.98 and 0.35%, respectively. The price factor has a negative effect – a 1% increase in food and energy prices reduces income by 0.32 and 0.28%, respectively. The growth of labour productivity also does not have a positive impact, given its downward trend and spasmodic nature. The rather large explanatory coefficient illustrates a general downward trend in farm incomes, signalling that drastic measures must be taken immediately.

Thus, our assumption was confirmed: the rise in prices of food and fuels has a negative impact on farmers' incomes, but the degree of the negative influence of fuel prices increase turned out to be lower than we expected. It is possible that the effect of transferring the cost of fuels to the price of products and the presence of time lags are manifested here. In general, we observe the fact of absence of an increase, and on the contrary – a decrease in farmers' incomes in the situation when prices of food and fuel rise simultaneously.

In general, the absence of the traditional positive impact on income from the price factor and labour productivity may indicate a violation of the market mechanisms for the functioning of the agricultural spheres. The deformation of market mechanisms is compensated by state payments.

Figure 6 illustrates the importance of government payments for farmers' incomes: farmers' incomes



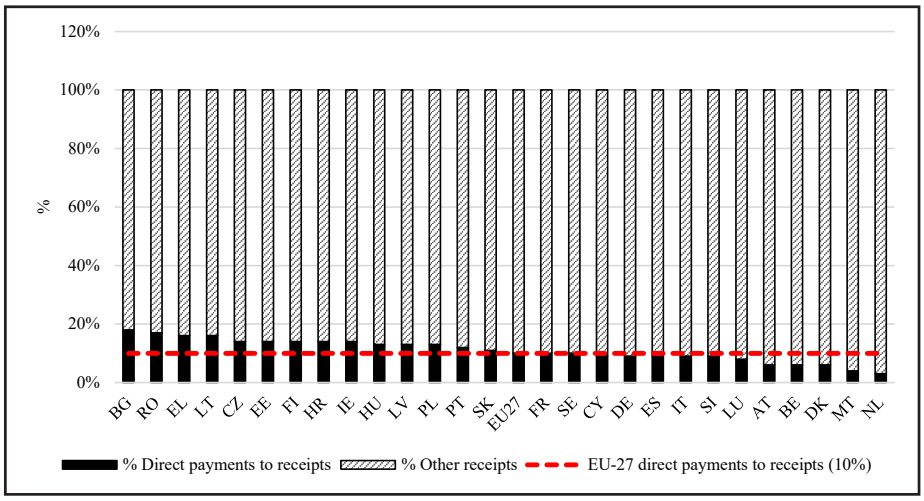

Source: Authors´ own processing based on Eurostat Database

Figure 5: Agricultural labour input in 2005-2021.

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | -7.359270 | 5.063214 | -1.453480 | 0.189406 | -19.3319 | 4.613332 | -19.3319 | 4.613332 |
| Agricultural output | 2.021217 | 1.477478 | 1.368019 | 0.2136 | -1.47246 | 5.514897 | -1.47246 | 5.514897 |
| Total Inputs | 0.294893 | 1.656784 | 0.177991 | 0.863771 | -3.62278 | 4.212563 | -3.62278 | 4.212563 |
| Total direct payments | 0.586502 | 0.695067 | 0.843806 | 0.42667 | -1.05707 | 2.230075 | -1.05707 | 2.230075 |
| FAO Food Price Index | -0.326190 | 0.69875 | -0.466810 | 0.654813 | -1.97847 | 1.326094 | -1.97847 | 1.326094 |
| Labour productivity in agriculture | -0.186250 | 0.532329 | -0.349870 | 0.736725 | -1.44501 | 1.072512 | -1.44501 | 1.072512 |
| Interest paid | 0.098951 | 0.510555 | 0.193811 | 0.851828 | -1.10832 | 1.306221 | -1.10832 | 1.306221 |
| Rent paid | 0.347512 | 0.9134 | 0.380459 | 0.714886 | -1.81234 | 2.507359 | -1.81234 | 2.507359 |
| World Bank Energy price index | -0.282590 | 0.344869 | -0.819400 | 0.439559 | -1.09807 | 0.532898 | -1.09807 | 0.532898 |

Source: Own processing based on FADN Database, FAO and Worl Bank Data

Table 1: Results of regression analysis of farm income.




Source: Authors´ own processing based on Agridata Database

Figure 6: Dynamics of subsidies to farmers in relation to total receipts by Member State in 2020.

could fall more than 17% if CAP payments were abolished, which would have the greatest impact on sectors where farmers' incomes are heavily dependent on subsidies.

Thus, farm products are not adequately valued in the market, so direct government payments have been introduced to support farmers' incomes. The focus on improving state payments on the needs of farmers is indicated by the results of studies of the impact of such support on various areas of agriculture. Studies by M`barek et al. (2017) have confirmed the conclusions that the main impact of the CAP is not on the level of production, but on a smoother model of structural adjustment in agriculture, a balanced regional distribution of production and a reduction in the burden on the environment. Thus, the state support of the farm holdings within the CAP mainly played the role of a compensator and shock absorber of the disparities in income between the types of economic activities, not having a significant impact on overcoming the factors of low incomes of the farmers. This means some cushioning in softening the effect of today's crisis on farmers' incomes, but will not protect them from the general decrease in incomes in the future.

Radically changing the influence of the price factor on farmers' incomes can be achieved by changing the structure of the cost of farm products in the direction of reducing the proportion of purchased energy carriers due to the reduction of the energy dependence of farms. We are talking about switching to green energy sources and processing waste into bioenergy. It is in this direction that state support and policy should work. In this connection, the task of changing the forms of financial assistance to farms from direct subsidies to financing the development of innovative agrotechnology, and green technologies for using waste to produce biofuel is relevant. These types of activities are able to help diversify farm income, increase the resilience of the latter to crisis shocks and correspond to the concept of "green economy" development in Europe.

## Conclusion

It was determined, that in recent years in the agricultural sector of the EU there has been a situation, despite the important role of the agricultural sector in the economic system, when farmers' incomes were below the average wage in the EU, which required government action to support them. In 2022 combination of increased price and production risks increase pressure on farm incomes. The specificity of the influence of the price factor on the formation of farm income in modern conditions, when the negative effect of rising energy prices outweighs the positive rise in prices for manufactured products, is revealed. Given the chronicity of the problem of slow productivity growth and low incomes of farmers, compared with the average for the economy, direct budget expenditures can support farmers' incomes only in the short term, without creating a basis for further sustainable income growth based on the balanced development of the agricultural sector. Therefore, at the present stage, the priority of the actions of the EU governments in the agricultural sector should be to stimulate farmers to increase energy independence and diversify incomes through the transition to more technologically advanced and profitable production. In other words, the current crisis should be used as an opportunity for reform and prioritize the non-short-term goals of maintaining farmer incomes (while maintaining the minimum required level) in favour of the strategic goals of technological re-equipment and more active adoption of biotechnologies as more productive and profitable.

The main measures in this context should be the following:

- Refocus fiscal support to stimulate the transition of farmers towards renewable energy sources but maintain targeted income support to farms that need it most.
- Implement an efficient pricing and financing system for those farms that develop bioenergy production.
- Develop a set of measures to achieve significant recycling of agricultural waste.
- Review the system for purchasing products from those farms that use bioenergy.

Much attention should be directed to the processing of waste from crop production, animal husbandry, processing enterprises, biomass and the production of biogas from it. Biogas can be used to replace imported natural gas, fuel and electricity generation. Thus, the environmental problem of processing agricultural waste and the energy problem of meeting the country's needs for energy resources will be solved. An additional positive effect will be a reduction in inflationary pressure from energy

prices and an additional source of income for farms.

The use of public funds for the technological re-equipment of agriculture and the introduction of biotechnologies will reduce the negative dependence of farmers' income on prices and will have a triple environmental, social and economic effect, and therefore will be the most effective direction of budget spending.

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# Detection of Creative Accounting in Agricultural Enterprises

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## Abstract

The paper deals with the detection of creative accounting of enterprises in the agricultural sector to verify whether creative accounting is used to an increased extent by those farming enterprises that have been granted a bank loan; and then whether there is an effort to manipulate financial statements mainly in micro-small or medium and large enterprises. Four mathematical-financial models were applied to 150 accounting units with primarily agricultural activity to verify the hypotheses. Beneish M-score, Jones model, Altman Z-score and IN05 model were used. An increased risk of using creative accounting methods was identified in 28% of the investigated companies on average during the monitored period. Still, the assumption that the size of the accounting unit has a significant effect on the use of creative accounting methods was not proven. However, a higher motivation to manipulate financial statements can be expected in smaller accounting units due to their less stable financial position confirmed Altman Z-score and IN05 models. At the same time, a higher probability of using and a tendency to use creative accounting techniques were found among units that were granted a bank loan, which stems from the need to secure and maintain sufficient financing for business activities.

## Keywords

Agriculture, creative accounting, detection models, reporting.

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## Introduction

Creative accounting is one of the most sophisticated evergreens in the Czech and European and it can be said that even modern world crime. To inform shareholders and other stakeholders, often presented using the profit and several other indicators from accounting, it is necessary to deliver these results and indicators using real numbers. However, by applying creative accounting principles, this picture can be changed and demonstrate a different economic reality.

When reading the impacted articles on creative accounting, it is evident that the number of procedures and methods for detecting innovative accounting practices is growing over time. An increase in the sophistication of detection methods can also be observed over time. On the other hand, it can be said that the published knowledge of detection methods is a valuable source of information for further "creativity" for companies that practice creative accounting – agricultural enterprises without exception.

Due to the absence of a study that would deal with the detection of creative accounting in Czech enterprises in the agricultural sector and compare the results with foreign studies, this article was created. The article is divided into five chapters, with an introduction followed by a description of the supporting arguments through a review of recent studies from scientific databases. Methods and data sources are also described. The fourth chapter contains the results, and the concluding chapter summarizes the authors' findings.

Zborková and Hinke (2011) point to financial statements users approach to creative accounting. In many companies, the management comes up with the requirement for creative approaches in accounting. Remenaric and Kenfelja (2018) characterize creative accounting as follows: “The practice of creative accounting usually includes overstating assets, high stocks, decreasing expenses, changes of depreciation methods, or presenting provisions as an asset. Creative accounting techniques follow the changes of accounting standards, which are modified

in order to reduce financial information manipulation." Durana et al. (2022) describe the manipulation of enterprises' financial statements using creative accounting methods. The ethical and moral level of creative accounting is also emphasized by Popescu et al. (2009). Popescu et al. (2009) illustrate creative accounting as one of the components shaping a moral and financial crisis. Dias et al. (2016) published research demonstrating the disagreement of some academics on creative accounting. In contrast, some academics emphasize the ethical level, some present creative accounting as an acceptable tool for fiscal optimization.

Creative accounting techniques are used across all sectors of the economy. In addition to the already mentioned manufacturing industry, many examples can also be found in agriculture. For instance, Blažek et al. (2020) describe the prevalence of techniques among agricultural corporations in Slovakia. These authors limited the research to creative accounting techniques for adjusting economic results to increase competitiveness and further optimize the tax base of Slovak agricultural enterprises. Their results were the inspiration for the creation of this article, as it emerged from them that a large number of companies in this sector tend to use creative accounting, which is harmful not only to entrepreneurs and their business partners but also to the state administration, as the real financial positions are not transparent companies.

Brandt et al. (2012) published a comprehensive set of firm-level total factor productivity (TFP) estimates for China's manufacturing sector that spans China's entry into the WTO. In contrast to earlier studies looking at total non-agriculture, including services, they found that TFP growth dominates input accumulation as a source of output growth.

An interesting detection method is Beneish M-Score Models. It was practically applied by Adamiková and Corejova (2021). Another relevant tool is the Jones model. Here is an inspiring article by Kliestik et al. (2022).

Mare et al. (2017) describe Z-Score as a technique for measuring bank insolvency risk. Lepetit and Strobel (2015) re-examine the probabilistic foundation of the link between Z-score measures and banks' probability of insolvency, offering an improved measure of that probability without imposing further distributional assumptions. The key output from their research is the finding "The log of the Z-score is shown to be negatively proportional to the log odds of insolvency."

Akpanuko and Umoren (2018) state that creative accounting practices are motivated by greed and intend to deceive the public, potential investors, and shareholders.

Sanhueza and Parada (2017) investigated the impact on creative accounting of IFRS. IFRS allows several possibilities, especially those related to the regulation of asset items and those in which manipulative techniques mainly focus on the applicability options of standards over subjectivity.

The relationship between fiscal and municipal policies to creative accounting is analyzed in detail by Hirota and Yunoue (2021). Their interesting finding is that "…municipalities engage in stockflow adjustments by increasing their expenditures and revenues through intergovernmental transfers, which represents creative accounting because it allows municipalities to delay improving their fiscal conditions."

There is a higher demand for capital investments, and thanks to this, an agricultural entrepreneur can be expected to be more interested in financing business activities with a bank loan (Gancarczyk et al., 2022; Marjánski and Sulkowski, 2021; Stawasz-Grabowska, 2020; Blanco and Raurich, 2022; Toušek et al., 2021). The above facts led the authors to define the following hypotheses, which will be verified in this article:

H1: creative accounting is used to an increased extent by those agricultural enterprises that have been granted a bank loan,

H2: the effort to manipulate financial statements exists mainly in medium and large enterprises.

The stated hypotheses will be verified by applying mathematical-financial models to the financial statements of a statistically significant sample of Czech agricultural enterprises.

## Materials and methods

First, it was necessary to define a statistically significant sample set of subjects, including the method of obtaining it, based on the analysis. To apply the detection models, the following requirements were imposed on the companies in the sample: the subject is a legal entity; the issue is an agricultural enterprise; the entity has been in existence for at least six years between the calendar years 2010-2019; the entity reports

the financial statements in complete form; the entity's financial statements are available in readable form on the website of the commercial register (Czech Statistical Office, 2021).

The first step to obtaining a suitable database was securing a complete list of economic entities in the Czech Republic. The source was the open database of the Czech Statistical Office (2021). Business corporations with a predominant agricultural NACE and an existence of at least six consecutive calendar years were randomly selected from the data set. If any selected accounting entity did not report the financial statement in the commercial register in full length, did not report it in a legible form, in the scope of six consecutive years, or did not send it to the register at all, the selection step was repeated for the remaining companies until it was reached of the desired data set of 150 enterprises. If the entity's financial statements were available for more than six years, the youngest data section was included in the file.

Enterprises were further divided according to the size of assets and turnover into two groups, namely micro-small and medium-large.

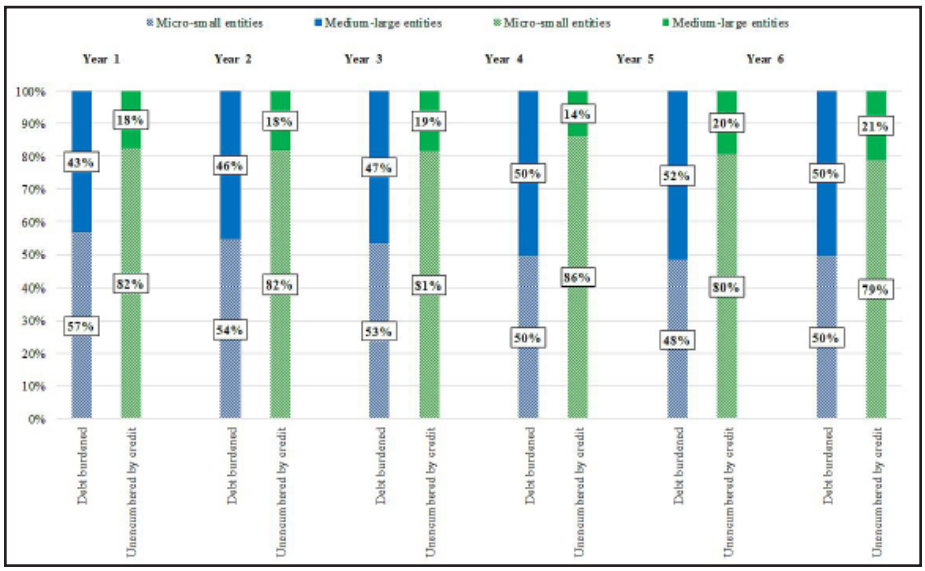
Another aspect of the classification of entities is their capital structure from the point of view of the amount of indebtedness, which is shown in Table 1.

| Number of entities | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Average |
|---|---|---|---|---|---|---|---|
| With a bank loan | 99 | 101 | 107 | 107 | 104 | 103 | 104 |
| Without a bank loan | 51 | 49 | 43 | 43 | 46 | 47 | 47 |
| With the share of foreign capital in total assets above 50% | 56 | 57 | 59 | 54 | 58 | 54 | 56 |
| With the predominant financing by foreign capital | 44 | 49 | 52 | 46 | 46 | 43 | 47 |
| With EBIT / interest expense > 0 | 105 | 102 | 110 | 96 | 94 | 85 | 99 |
| With EBIT / interest expense > 3 | 89 | 78 | 78 | 70 | 66 | 59 | 73 |

Note 1: foreign capital consists of foreign liabilities and accruals on the liabilities side.
Note 2: on average 104 entities out of 150, i.e., 69% of all entities, use a bank loan as a form of asset coverage, on average 56 entities out of 150, i.e., 38% of all entities, cover their assets with foreign capital and in 47 entities out of 150, i.e., 31 % of all entities, foreign capital exceeds the value of own capital. On average, over the monitored period, 73 companies out of 150, i.e., 49% of all companies, show a three-fold excess of interest costs by EBIT, these companies can generate very good profits for the payment of interest from the use of external sources for financing.

Source: own processing (2022)

Table 1: Number of entities by level of indebtedness.




Note: The structure of enterprises burdened with credit is relatively balanced, so both types of enterprises are equally represented. In contrast, the group of subjects without bank credit is dominated by micro-small enterprises whose operations and assets are covered by other sources.
Source: own processing (2022)

Figure 1: Structure of entities according to indebtedness status.

The following Figure 1 shows the structure of entities according to debt status:

The analysis of the financial statements of the companies within the sample is carried out using the following mathematical and financial models:

1. Beneish's M-score, which identifies the manipulation of the company's profit by using a combination of financial indicators in a linear regression model consisting of 8 variables, 8 parameters, and one constant. It compares the resulting value with the critical value of -1.78. Moreover, if the calculated value of the M-score is lower than the critical value, the company did not use earnings management techniques in the monitored period.

   The formula is as follows (Beneish and Vorst, 2020):

$$MSCORE = -4.840 + 0.920 * DSRI_t + + 0.528 * GMI_t + 0.404 * AQI_t + + 0.892 * SGI_t + 0.115 * DEPI_t - - 0.172 * SGAI_t + 4.679 * TATA_t - - 0.327 * LGVI_t \quad (1)$$

   The Beneish M-score was successively applied to 5 accounting periods. To calculate the GMI indicator, the cost of sales was considered power consumption. In the SGAI indicator, the cost of sales, management, and overhead represents the sum of power consumption and personnel costs. The amount of accruals in the TATA indicator represents the difference in the values of working capital, total CF, income tax payable, and long-term liabilities of the current period compared to the previous period, less the depreciation of fixed assets of the current period. DSRI is the day's sales receivables index, AQI is presented with the asset quality index, DEPI is the depreciation index, and LGVI is the leverage index.

   For calculation purposes, extreme values for each indicator were discarded, and indicators with an error value were excluded. The erroneous or extreme value occurred when the business did not report sales, accrued assets, non-current assets, or liabilities.

2. Jones' non-discretionary accrual model evaluates whether businesses use guesswork and accruals to manipulate the financial statement. The general formula calculates the difference between two accounting periods, but observing the development over a more extended period provides better results.

$$X = total\ assets_{t-1} + (turnover_t - turnover_{t-1})/ total\ assets_t + tangible\ fixed\ assets_t/total\ assets_{t-1} \quad (2)$$

   where *t* represents the current accounting period and *t*-+ the previous accounting period, if non-discretionary additions compared to the value of total assets in one period are lower than in others. The model shows discretionary expenditures in future periods to be higher, which assumes possible data manipulation.

3. Altman's Z-score evaluates the financial health of the company based on the expected values of economic indicators as regressors - Altman's Z-score, similarly to Beneish's model, works with indicators of financial analysis and, based on their deviations from expected normal values, considers the company's financial situation and, consequently, the presence of elements of creative accounting in financial statements. Net working capital was calculated as the value of current assets less current liabilities. The formula for the calculation is as follows :

$$Z = 0.717 * x_1 + 0.847 * x_2 + 3.107 * x_3 + + 0.420 * x_4 + 0.998 * x_5 \quad (3)$$

   Where: $x_1$ = net working capital/total assets; $x_2$ = retained earnings/total assets; $x_3$ = earnings before interest and taxes/total assets; $x_4$ = book value of equity / current a non-current liabilities; $x_5$ = sales/total assets. If the calculated value of the Z-score is higher than the constant 2.7, the model assumes a good financial position of the company. If the calculated value is between 1.2 and 2.7, the model assumes an uncertain financial position of the company. A calculated value lower than 1.2 means that the company is in a situation with the risk of bankruptcy in the foreseeable future.

4. Bankruptcy model IN05 – evaluates the financial situation of the company, according to the formula:

$$IN05 = 0.13 * x_1 + 0.04 * x_2 + 3.97 * x_3 + + 0.21 * x_4 + 0.09 * x_5 \quad (4)$$

Where: $x_1$= total assets / current a non-current liabilities; $x_2$= EBIT/interest expense; $x_3$ = EBIT/total assets; $x_4$ = sales/total assets; $x_5$ = current assets/current liabilities. Moreover, if the value of the index is lower than the constant 0.9, the company will go bankrupt with a high probability and will no longer create value. If the index is in the range of 0.9 to 1.6, a crash cannot be reliably determined, but it will likely continue to build value. Usually with a value higher than 1.6, the company is probably healthy or creating value.

The models are applied at the level of individual enterprises for five consecutive years between 2010 and 2019. This period is chosen to obtain the most up-to-date data and thus ensure better usability of the analysis results. The year 2020, which was significantly affected by the COVID-19 pandemic and therefore considered less compared to previous years, is excluded from the database.

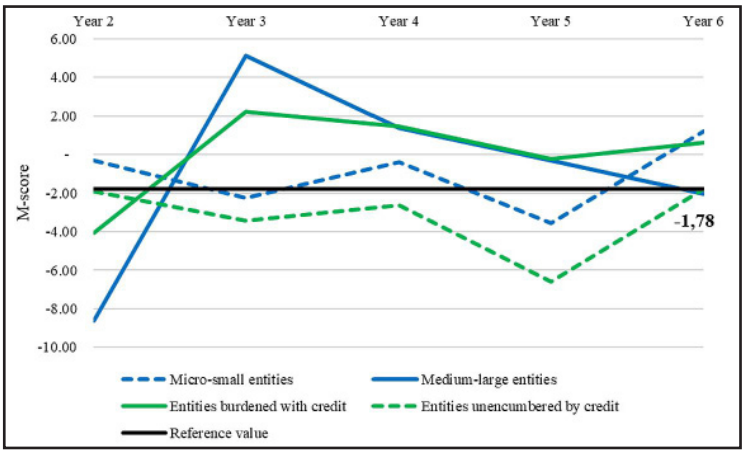
## Results and discussion

### Beneish M-score results

First, all eight values for calculating the M-score were determined separately for micro-small enterprises, medium-large enterprises, enterprises burdened with credit, and enterprises without bank credit. Detailed results are available upon request. The following Figure 2 shows the comparison and, at the same time, the development of the average M-score for all types of monitored enterprises.

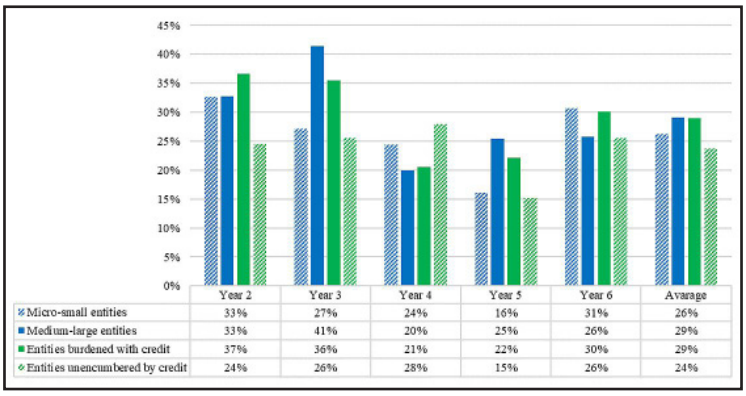
It is evident from the graph that only the average value calculated for enterprises without credit burden is in the zone below the reference value of -1.78 for the entire monitored period. Therefore, the probability of accounting manipulation is not assumed for them.

Figure 3 shows that medium-sized enterprises and enterprises burdened with credit use creative accounting techniques with the highest risk.




Source: own processing (2022)

Figure 2: Evolution of the calculated M-score compared to the reference value.




| | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Avarage |
|---|---|---|---|---|---|---|
| Micro-small entities | 33% | 27% | 24% | 16% | 31% | 26% |
| Medium-large entities | 33% | 41% | 20% | 25% | 26% | 29% |
| Entities burdened with credit | 37% | 36% | 21% | 22% | 30% | 29% |
| Entities unencumbered by credit | 24% | 26% | 28% | 15% | 26% | 24% |

Note: the percentage shows the share of the total number of monitored enterprises of the given category in the given year.
Source: own processing (2022)

Figure 3: Companies with a calculated M-score above the reference value.

Nevertheless, the resulting values showing an average annual proportion of manipulators between 24-29% for each type of subject are relatively balanced.

### Results of the Jones non-discretionary accrual model

Table 2 shows the year-on-year development of model values on average for individual types of enterprises. The most significant fluctuation between the measured values appears in micro-small enterprises and enterprises unencumbered by bank credit.

The model anticipates a stable development of the measured values, and if the values fluctuate, there is an assumption that these subjects are using creative accounting methods. To evaluate this indicator at the level of individual enterprises, a value that differed more than two times from the previous period was designated as a fluctuating value, i.e., the year-on-year movement was higher than +/-100%.

Figure 4 shows the result of positive detection of fluctuating accruals for the examined types of business, which on average reaches 11-21% of the total number of subjects of the given type during the monitored period. A higher incidence of inconsistent use of accruals occurs in micro-small enterprises and enterprises not burdened with loan. Micro-small enterprises are often not subject to the obligation to verify the financial statements by an auditor, so there is no validation of the correctness of the use of accounting methods by an independent third party, which could be an explanation for the increased positive detection in these enterprises. The reason for lower average value for enterprises burdened with loan may be greater caution in applying creative accounting methods for fear of losing the bank's trust.

### Altman Z-score results

The Figure 5 shows the average Z-score values and their movement in individual bands for each observed period.

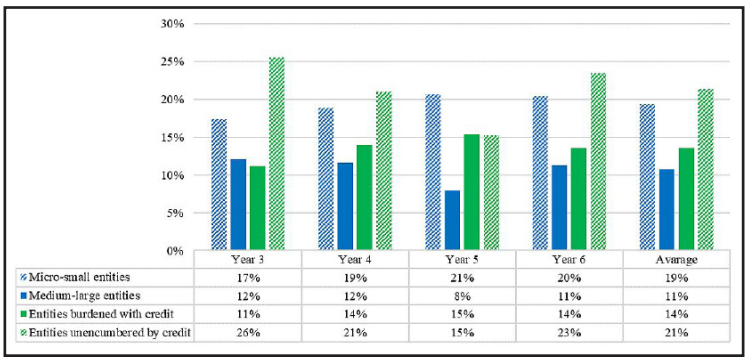
Above the value of 2.7, the upper reference value, appear micro-small and unencumbered enterprises, which on average qualified for the group of enterprises with a good financial position. Between the value of 2.7 and the lower reference value of 1.2, there are, on average, companies burdened with bank loans whose financial stability cannot be determined with certainty. Medium-sized enterprises move between the zone of good and uncertain economic situation. The average value of the Z-score of none of the groups of enterprises fell below the threshold value of 1.2, indicating impending financial problems.

Partial results (available on request) showed the authors the representation of the type of subjects in particular intervals of the Z value,

| Jones model | Year 2 | % movement | Year 3 | % movement | Year 4 | % movement | Year 5 | % movement | Year 6 |
|---|---|---|---|---|---|---|---|---|---|
| **Micro-small entities** | 0.69 | *-17%* | 0.58 | *-22%* | 0.45 | *-172%* | - 0.32 | *-34%* | - 0.21 |
| **Medium-large entities** | 0.88 | *-16%* | 0.74 | *-17%* | 0.61 | *53%* | 0.93 | *-28%* | 0.68 |
| **Loan encumbered entities** | 0.82 | *-23%* | 0.64 | *-10%* | 0.57 | *41%* | 0.81 | *-39%* | 0.49 |
| **Loan unencumbered entities** | 0.63 | *3%* | 0.65 | *-44%* | 0.36 | *-417%* | - 1.16 | *-50%* | - 0.58 |

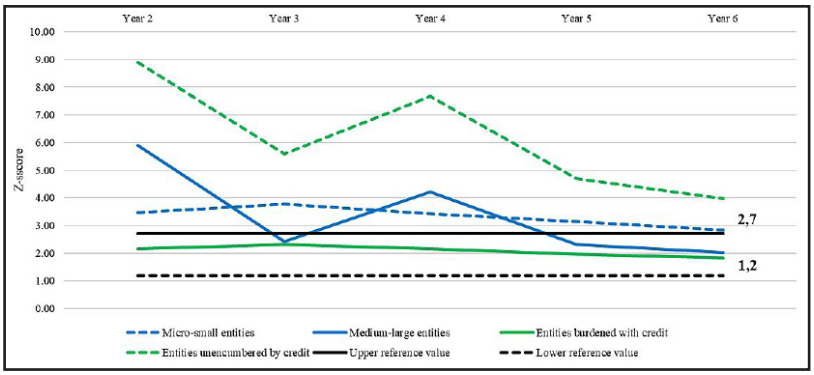
Source: own processing, 2022

Table 2: Average values of the Jones model and their interannual movement.



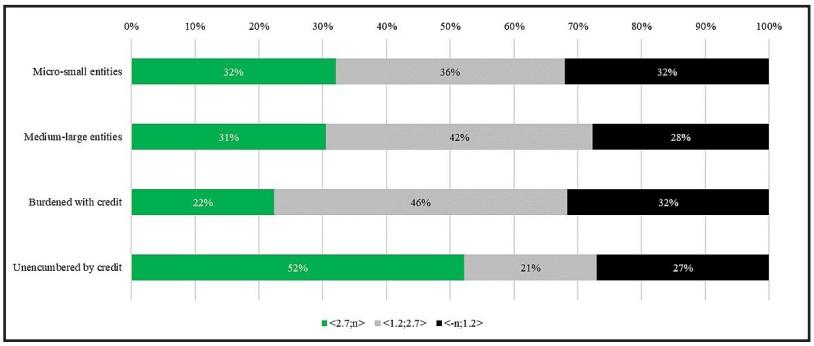

Source: own processing (2022)

Figure 4: Entities with accrual volatility detected by the Jones model.




Source: own processing (2022)

Figure 5: Average Z-score values in the monitored period.




Source: own processing (2022)

Figure 6: Composition of enterprises by type and achieved Z-score in an average of 5 years.

measured at the enterprise level. What is interesting about these results is the fact that, although the number of companies in a good financial situation for individual years is almost unchanged, in the last two monitored years, which are in most cases 2018 and 2019, there was an increase in companies in the black zone, indicating the risk of bankruptcy, and regardless of the business category.

Figure 6 (showing the average representation of the type of enterprise in the detection intervals for 2-6 years) shows that 27-32% of enterprises from each category are in the black zone, indicating financial instability. Deviating results for individual companies only occur in the green zone, which indicates a good financial situation, and the grey zone, when looking at the loan burden, where companies that have not received a bank loan appear to be the most stable.

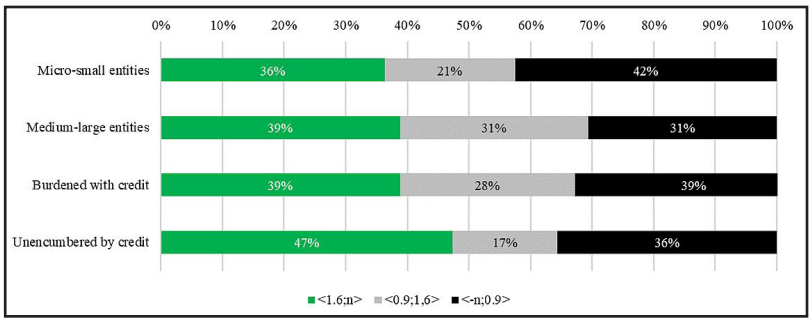
## Results of Bankruptcy model IN05

Figure 7 presents the achieved IN05 values for individual entities, confirming the good financial position of companies unencumbered by loan. While according to the M-score, on average, 32% of micro-small and 28% of medium-sized enterprises were in the risky black zone, according to the IN05 model, it is 42% and 31%. This was done by moving some of the micro-small subjects from the indeterminate grey area to black. In the case of medium-sized enterprises, the trend is the opposite; a more significant part of the grey zone has moved into the green.

Although both models work with the ratio of sales and EBIT to total assets, each uses different variables to calculate liquidity and indebtedness. Another factor is the width of the grey zone interval, which for the Z-score is the extreme values of 1.2 to 1.7, while for the IN05 model, this interval is more than half as narrow. It is also necessary to consider the conditions in which the model was created - IN05 is directly applicable to Czech economic and accounting requirements. Therefore, the result of this model should have more weight than Altman's Z-score, which is a foreign product.

## Detection of the presence of creative accounting according to the size of the company

From the Table 3, it is clear that the detection of a higher risk of applying creative accounting techniques prevails in micro-small businesses.




Source: own processing (2022)

Figure 7: Composition of enterprises by type and achieved IN05 value in an average of 5 years.

The reason may be their poorer financial stability, proven by the Z-score and IN05 models. At the same time, these may be units without mandatory financial, so they are not subject to increased control.

| Model | Subject type | | | Difference |
|---|---|---|---|---|
| | Micro-small | | Medium-large | |
| M-score | 26 | < | 29 | -3 |
| Jones model | 19 | > | 11 | 9 |
| Z-score | 33 | > | 29 | 4 |
| IN05 | 42 | > | 31 | 12 |

Source: own processing (2022)

Table 3: Evaluation of the propensity to use creative accounting techniques in enterprises by size (in %).

Based on the predominant outputs from the models, the hypothesis that there is an increased effort to manipulate financial statements in medium and large agricultural accounting units is rejected.

### Detection of the presence of creative accounting according to the company's credit load

As Table 4 shows, except the Jones model, all other methods show a higher risk of using creative accounting methods for credit-burdened enterprises. In particular, the IN05 and Z-score models work with indicators of liquidity, indebtedness, and profitability. Indebted companies with a high proportion of fixed assets do not appear to be liquid, and the low profitability of assets caused by insufficiently quickly generating profit, which would otherwise be used for financing, in turn, worsens the company's performance.

Based on the predominant outputs from the models, the hypothesis is confirmed, according to which the manipulation of financial statements occurs mainly in agricultural enterprises that have been granted a bank loan. At the same time, these businesses are more motivated to use creative accounting.

| Model | Subject type | | | Difference |
|---|---|---|---|---|
| | Debt burdened | | Unencumbered by credit | |
| M-score | 29 | > | 24 | 5 |
| Jones model | 14 | < | 21 | -8 |
| Z-score | 33 | > | 28 | 5 |
| IN05 | 39 | > | 36 | 3 |

Source: own processing (2022)

Table 4: Evaluation of the propensity to use creative accounting techniques according to credit load (in %).

## Conclusion

In the research, it was possible to verify both formulated hypotheses. The H2 hypothesis was rejected, according to which there is an increased effort to manipulate financial statements in medium and large agricultural accounting units. On the contrary, hypothesis H1 predicting that creative activities in accounting appear mainly in agricultural enterprises granted a bank loan, was confirmed. Furthermore, the applicability of individual detection tools to Czech agricultural economic entities was assessed. IN05 model was tested in the environment of Czech legislation and economy and should therefore be well used for analysing domestic companies.

In contrast, The Jones, M-score, and Z-score models are foreign products, so they were tested on foreign economic entities operating under different legislation and under different economic conditions. This must be kept in mind when applying them because the models will not show an explanatory power comparable to the Czech detection tools. Nevertheless, as mentioned above, the deviation between these models and the IN05 model was not evaluated as significant.

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# UX and Machine Learning – Preprocessing of Audiovisual Data Using Computer Vision to Recognize UI Elements

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## Abstract

This study explores the convergence of user experience (UX) and machine learning, particularly employing computer vision techniques to preprocess audiovisual data to detect user interface (UI) elements. With an emphasis on usability testing, the study introduces a novel approach for recognizing changes in UI screens within video recordings. The methodology involves a sequence of steps, including form prototype creation, laboratory experiments, data analysis, and computer vision tasks. The future aim is to automate the evaluation of user behavior during UX testing. This innovative approach is relevant to the agricultural domain, where specialized applications for precision agriculture, subsidy requests, and production reporting demand streamlined usability. The research introduces a frame extraction algorithm that identifies screen changes by analyzing pixel differences between consecutive frames. Additionally, the study employs YOLOv7, an efficient object detection model, to identify UI elements within the video frames. Results showcase successful screen change detection with minimal false negatives and acceptable false positives, showcasing the potential for enhanced automation in UX testing. The study's implications lie in simplifying analysis processes, enhancing insights for design decisions, and fostering user-centric advancements in diverse sectors, including precision agriculture.

## Keywords

Usability, UX, audiovisual data, computer vision, frame extraction, object detection, YOLOv7, precision agriculture.

Čejka, M., Masner, J., Jarolímek, J., Benda, P., Prokop, M., Šimek, P. and Šimek, P. (2023) "UX and Machine Learning – Preprocessing of Audiovisual Data Using Computer Vision to Recognize UI Elements", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 3, pp. 35-44. ISSN 1804-1930. DOI 10.7160/aol.2023.150304.

## Introduction

The agricultural industry exhibits a unique set of characteristics that sets it apart from other sectors. In particular, the availability of funding for research and development is limited compared to other industries. Consequently, implementing user experience (UX) testing practices in the agricultural sector must rely heavily on automated approaches in the future. The limited financial resources within the industry necessitate such automation to obtain necessary insights and data to enhance agricultural practices.

During UX testing, it is now possible through recording technologies to store audiovisual data of the participant's movement within the user interface (UI) and the participant's eye movement (using eye tracking technology) or other data, including biometric data. Obtaining these types of data (i.e., audiovisual data) using dedicated UX laboratories is the first step in developing machine learning technologies that could allow UX experts to process and evaluate the data automatically and efficiently. The reasoning is that the information about users' behavior is stored within these data. The new technology should automatically detect this behavior (or deviations from the expected behavior), thus making the data evaluation process faster and more efficient.

Although there are many studies on UX evaluation, few works have addressed the optimization and automation of this process (Aviz et al., 2019).

Since it is not yet possible to analyze this data algorithmically, it is necessary to process it manually (usually by UX experts), which, however, leads to extreme time and thus financial complexity of the analysis, especially in the case of many tested users (Harms, 2019). Experts often find this repetitive work tedious. Using human labor to explain and measure UX is inefficient (Koonsanit and Nishiuchi, 2021). A method based on Computer Vision could be a promising way to tackle the automatic evaluation of UX testing data. Computer vision techniques involve analyzing and understanding digital images and videos with the help of algorithms and mathematical models. (Batch et al., 2023) propose UXSense – a method for extracting multi-modal features of human behavior from video and audio footage using machine learning (ML) to support UX and usability professionals in their analysis of user session data using interactive visualization. Furthermore, computer vision in video analysis has gained tremendous attention in recent years. Video analysis involves extracting meaningful information from a sequence of frames. In contemporary times, computer vision plays a significant role in enhancing the field of precision agriculture, commonly referred to as agro-vision. Its applications encompass various tasks, including the monitoring and characterization of crops, weed management, assistance in harvesting, guiding agricultural vehicles, and creating yield maps. (Patrício and Rieder, 2018; Mavridou et al., 2019; Wang, Zhang and Wei, 2019; Bulanon et al., 2020)

To successfully develop a computer vision-based method, it is, therefore, necessary first to create a frame extraction algorithm that would consider only distinct frames of the record. (Harrison, Beverly L. and Baecker and Ronald, 1992) pointed out years ago that user pressure on the quality of applications in terms of usability and UX is constantly increasing. Therefore, the potential results of the present research may also be demanded at the commercial level. The development of this type of automation should optimize the analysis process, where only relevant data relevant to the research is presented in the output from the entire testing record without wasting time and risking overlooking essential facts. Moreover, as concluded by (Novák et al., 2023), the evaluation automation of UX and usability is a current research trend, even though not much addressed by the researchers yet.

This study was conducted within a project aimed at developing and optimizing methods that would, in the future, enable automatic evaluation of audiovisual data from usability and UX testing using AI-based methods. These methods can be used to develop applications specifically for the agricultural sector. In this study, we focus on a possible prediction of user actions associated with common form elements (text fields, select boxes, dropdown lists).

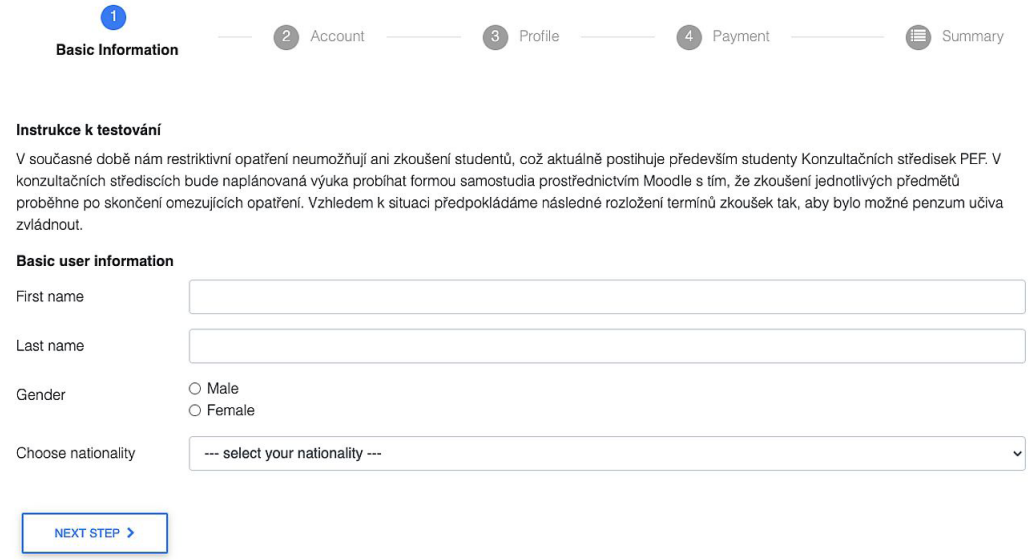
The main objective of this paper is to explore the use of computer vision methods for detecting UI objects within a video stream during usability tests conducted in a laboratory setting. The primary focus of this study is to assess the significance of changes between consecutive frames in the video recording. The aim is to identify pertinent images for the computer vision task. Subsequently, the findings from this task can be integrated with eye-tracking data to pinpoint the UI elements users target at specific moments.

## Materials and methods

In the introductory section, the significance of the frame extraction algorithm within the realm of automated video processing was highlighted. This entails the partitioning of a digital image or video into distinct segments or regions guided by their inherent attributes. The research methodology comprises a sequence of steps, commencing with creating an experimental prototype form (step 1). Subsequently, controlled experiments were conducted in a laboratory setting to collect audiovisual data (step 2). In step 3, the data is subjected to computational analysis to extract unique frames (step in the form). Lastly, we investigated the possibility of using computer vision methods to identify the UI elements (step 4).

### Experimental prototype

Considering technology solutions to the specific needs and challenges of the agrarian sector, a basic web form was created. By creating an application that mirrors the digital tools commonly employed in the agrarian sector - such as precision agriculture applications, applications for subsidies, and supply chain management interfaces—we can thoroughly follow the common environment within this specialized technological landscape. The application was designed to mimic a stepwise process, as depicted in Figure 1. The design was developed using the Bootstrap 4 CSS framework, which provides a cohesive and consistent appearance across numerous form designs utilized on the web. The web page layout incorporated several form elements, which are enumerated in Table 1.




Source: own procesing

Figure 1: Example of the web page prototype application form.

| Input name | HTML Element | Label alignment | Prototype step |
|---|---|---|---|
| Simple text input | <input type="text"> | inline | 1 |
| Number | <input type="number"> | inline | 1 |
| Radio buttons 2 choices | <input type="radio"> | inline | 1 |
| Radio buttons | <input type="radio"> | separately | 2,3 |
| Checkboxes | <input type="checkbox"> | separately | 2,3 |
| Single checkboxes | <input type="checkbox"> | inline | 4 |
| Select box | <select> | inline | 1,3 |
| File upload | <input type="file"> | inline, separately | 1,3 |
| Textarea | <textarea> | separately | 2,3 |

Source: own procesing

Table 1: Description of the elements of the created form for the experiment.

## Experimental protocol

The experiments were held in the Laboratory of usability (under the Human Behavior Research Unit; HUBRU) at the Czech University of Life Sciences Prague. The laboratory is composed of two separate rooms. The test room is a soundproof space containing chairs, computers, and an eye-tracking device as shown in Figure 2. The control room, which to the primary room and is used for the supervision of the research activities. The moderators have the option of either monitoring the participants from the control room or being physically present in the primary room to communicate with them. There are three cameras and ambient microphones installed in the primary room, and communication between the two rooms is feasible in either direction if required. The technologies used for data collection are described in Table 2.

Source: own procesing

Figure 2: Laboratory of usability (HUBRU) used to conduct the experiments.

| Device | Description |
|---|---|
| PC | Windows 10 Professional edition |
| Screen | Full HD (1920x1024) |
| 24-inch display | |
| Peripherals | Standard mouse and Keyboard |
| Web browser | Google Chrome |
| Eye tracker | Tobii Pro X2-60 (60hz; see Figure 3) |

Source: own procesing

Table 2: Technologies used for data collection.

The eye tracker was tuned with the default parameters for the whole experiment. At the beginning of each testing session, participants were introduced to the scope and purpose of the experiment. After that, they were instructed to find a comfortable seating position. Participants received instructions about the testing method from the moderator. Then, a nine-point calibration of the eye tracker was carried out. Each participant had to participate in a preliminary task to acquire familiarity with the equipment.

In the following step, the participants followed the prototype application according to instructions. The task was finished by form submission. The instructions were the following:

- Switch to the web browser window.
- Read the introductory paragraph.
- Fill out the following form. Consider it as a registration to a web service.
- Fill in all the following steps and click next until the summary section.
- Click the submit button to finish.

During the experiment, the audiovisual data were acquired by the Tobii Pro Studio software, which operates the eye tracker. The collected data was then filtered and analyzed by a UX expert to select appropriate samples for subsequent data processing using computer vision techniques.

### Frame extraction method

This task aimed to automate identifying screen changes in eye-tracking videos using computer vision algorithms. A screen change can be naturally understood as a major change in pixel values. In our case, we aim to identify moments when a user moves to the next page while filling out the presented form. Video records were loaded and cut into frame images and were converted to grayscale to reduce potential error sources. The structural similarity index (SSIM) in Formula 1, as well as the mean squared error (MSE) in Formula 2, were computed on every two consecutive frames of the example video. MSE expresses error signals as the difference between the original and distorted signals. When comparing images, the MSE – while simple to implement – is not highly indicative of perceived similarity. SSIM aims to address this shortcoming by taking texture into account (Wang et al., 2004; Wang and Bovik, 2009)

$$S(x,y) = l(x,y) \cdot c(x,y) \cdot s(x,y) = \\ = \left(\frac{2\mu_x\mu_y + C_1}{\mu_x^2 + \mu_y^2 + C_1}\right) \cdot \left(\frac{2\sigma_x\sigma_y + C_2}{\sigma_x^2 + \sigma_y^2 + C_2}\right) \cdot \left(\frac{\sigma_{xy} + C_3}{\sigma_x\sigma_y + C_3}\right) \quad (1)$$

Formula 1 - SSIM, where $\mu_x$ and $\mu_y$ are (respectively) the local sample means of $x$ and $y$, $\sigma_x$ and $\sigma_y$ are (respectively) the local sample standard deviations of $x$ and $y$, and $\sigma_{xy}$ is the sample cross-correlation of $x$ and $y$ after removing their means. The items $C_1$, $C_2$, and $C_3$ are small positive constants that stabilize each term, so that near-zero sample means, variances, or correlations do not lead to numerical instability.

$$MSE(x,y) = \frac{1}{N}\sum_{i=1}^{N}(x_i - y_i)^2 \quad (2)$$

Formula 2 - Mean Squere Error (MSE), where $x$ and $y$ represents pixel values of the two executive frames and $N$ is number of pixels.

We implemented a floating threshold dependent on SSIM results calculated as the mean SSIM score values in addition to constant $c$, as shown in Formula 3. Frames with SSIM scores lower than the threshold are considered dissimilar to the next consecutive image. They, therefore, are extracted together with their timestamp - calculated as a multiplication of image order index and frame rate, as shown in Formula 4. Extracted frames with timestamps are suspected of representing major screen changes. Coming from (Shultz et al., 2011) we then evaluated our algorithm using confusion matrix and its related metrics as shown in Table 3.

$$\theta = \frac{\sum_{i=0}^{n} s_i}{n} + c \quad (3)$$

Formula 3 – Floating threshold calculation dependent on mean value of SSIM scores $s_i$ and constanc $c$ that is manually set to -0.03.

$$t_d = k_i \cdot v \quad (4)$$

Formula 4 - Frame to timestamp conversion, $k_i$ is frame order number and $v$ is frame rate being ~0.067.

| | |
|---|---|
| Sensitivity / Recall | $TPR=\frac{TP}{TP+FN}$ |
| Precision | $PPV=\frac{TP}{TP+FP}$ |
| Accuracy | $ACC=\frac{TP+TN}{TP+FP+TN+FN}$ |
| F1 score | $F1=\frac{2TP}{2TP+FP+FN}$ |

Source: own procesing

Table 3: Evaluation metricss of our computer vision experiments are sensitivity, precision, accuracy and F1 score. Confusion matrix contains true positives (TP), true negatives (TN), false positives (FP), false negatives (FN).

### Identification of UI elements

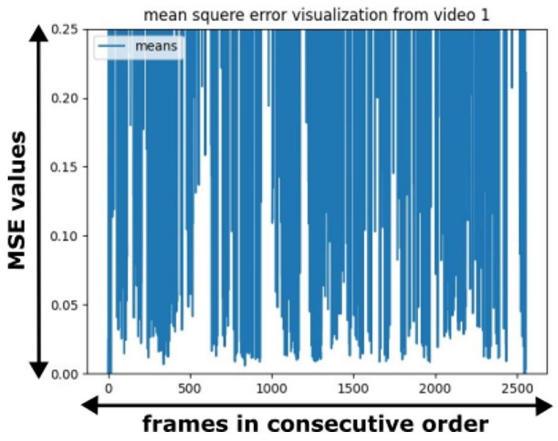
The objective of this step is to detect elements of the user interface, such as buttons, checkboxes, date pickers, file dialog, payment menu, radio button, select box, textbox. Identification (getting screen coordinates) of those items using object detection would empower video processing automation and bring new opportunities for video analysis.

The utilization of YOLOv7 for object detection is well-justified due to its exceptional performance and efficiency in real-time image analysis. YOLOv7's ability to balance accuracy and speed makes it an ideal choice for applications requiring swift and reliable object detection.

We collected and annotated various images of screenshots containing UI elements for object detection training. We divided dataset into a training set, validation set and training set. We applied augmentation steps – flip and 90° rotation to extend training set. Images were stretched into maxiumum allowed shape for YOLOv7. All images were converted to grayscale. We used mplementation of paper YOLOv7: Trainable bag-of-freebies sets new state-of-the-art for real-time object detectors. (Wang, et al., 2022) on a pretrained COCO dataset model YOLOv7 (Lin et al., 2014). We then evaluated using confusion matrix and related metrics.

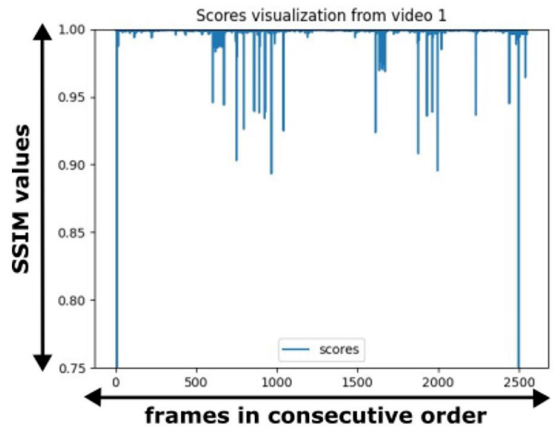
## Results and discussion

In Figures 3 and 4, we show an example of both MSE and SSIM applied on our eye tracking video records and visualized in time. The example shows that SSIM can identify screen changes while MSE is not capable of detecting them correctly. Choosing SSIM we processed thirty videos according to technical details of the run introduced in Table 4. The results of evaluating the detection of the unique form step are shown in a confusion matrix in Table 5. To further evaluate the results, we calculated various metrics, as shown in Table 6. All screen changes have been detected. We achieved zero false negatives and, therefore, high sensitivity and accuracy values. We obtained high true negatives number 111 630. This result can be attributed to the prevailing inactivity within the video content, with screen changes occurring in only approximately 0.7% of the total video duration. We reached 630 false positives, bringing precision down to 0.16 and F1 score to 0.364. But exploring false positives showed that the algorithm generates only four types them. In fact, it worked correctly as the screen did change in all cases, although not from one form to another, which was the intended output. In Figures 5, 6, 7, and 8, we may see detections of the opening select box, file browser dialog, change of content in file browser dialog, and switching of the eye tracking at the end of the session. The last-named error can be eliminated by either excluding all black screens or ignoring the last screen change of the video if the timestamp is just before the end of the record. From the nature of the other three types of errors, we stated that they all represent a screen change (although the user didn't move to the next screen) and cannot be worked around by a simple algorithm. Considering this, we did detect all screen changes with 100%. accuracy (False Negative is 0, and False Positive would be 0 if the above-described detected events are considered screen changes, which, in pixel comparison, they are).




Source: own procesing

Figure 3: Mean Square Error (MSE) visualization of an example video where each two consecutive frames are compared.




Source: own procesing

Figure 4: Structural Similarity Index (SSIM) visualization of an example video where each two consecutive frames are compared.

| | |
|---|---|
| Environment | CULS AI-LAB (Nvidia P40) |
| Number of processed videos | 30 |
| Average video size | 1.5 GB |
| Average video length | 4,5 min |
| Total computation time | 19h 47m |
| Number of compared frame pairs | 112 440 |
| Detected screen changes candidates | 790 (26.3 per video in average) |
| Threshold constant c | -0.03 |

Source: own procesing

Table 4: Technical details of the run points out on time inefficiency of the proposed solution.

| Predicted class<br>Ground truth class | Positive (1) | Negative (0) |
|---|---|---|
| Positive (1) | TP<br>180 | TN 111<br>630 |
| Negative (0) | FP<br>630 / * 0 | FN<br>0 |

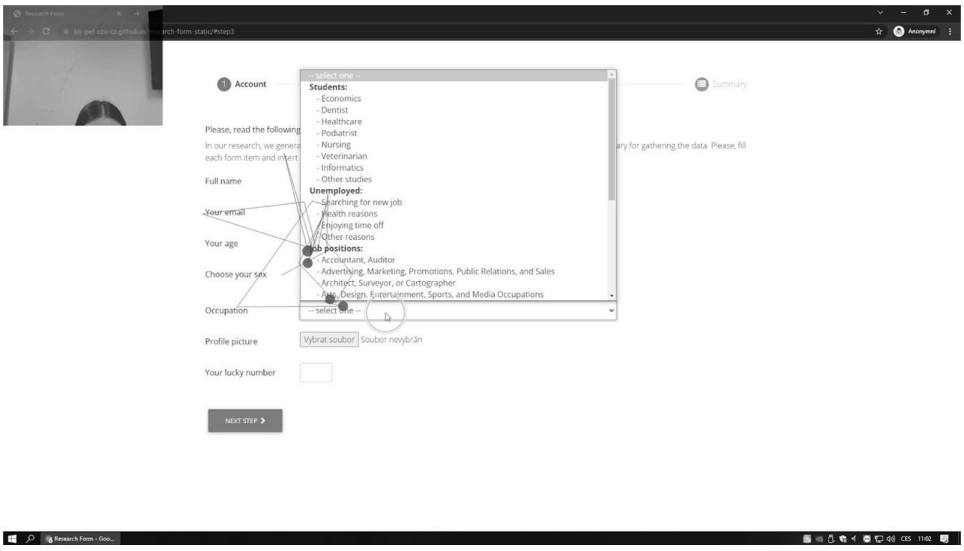
Source: own procesing

Table 5: Confusion matrix of the screen change detection using SSIM. Shows unbalanced distribution of data between tru positives and true negatives. * All 630 false positives might be concluded not to be a failure of the algorithm if error types in Figures 5,6,7,8 are considered not errors.

| | |
|---|---|
| Sensitivity | 1.0 |
| Precision | 0.22 / * 1 |
| Accuracy | 0.998 / * 1 |
| F1 score | 0.364 / * 1 |

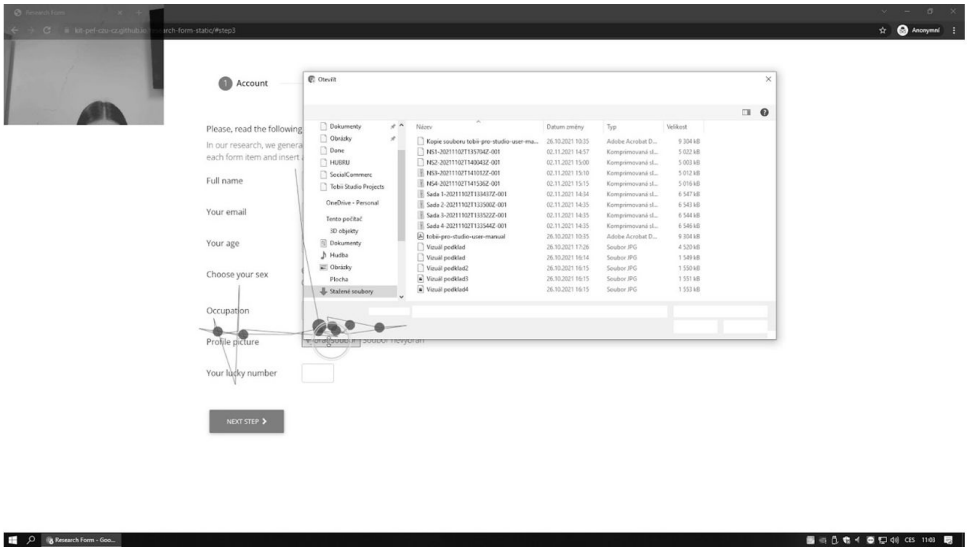
Source: own procesing

Table 6: Related metrics of the screen change detection using SSIM. * All metrics might be concluded equal to 1 if error types in Figures 5,6,7,8 are considered not errors.



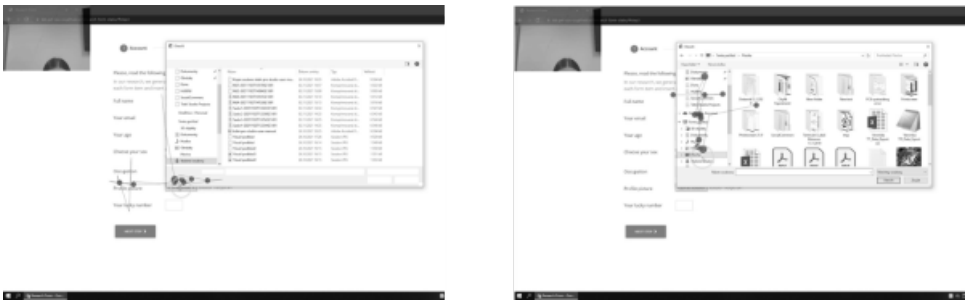

Source: own procesing

Figure 5: Error of type 1 - user opens a selectbox component which triggers higher SSIM value and is considered a screen change.




Source: own procesing

Figure 6: Error of type 2 – user opens a file browser dialog component which triggers higher SSIM value and is considered a screen change.



Source: own procesing

Figure 7: Error of type 3 – user changes content inside the selectbox and algorithm chooses a pair to be a screen change.

Source: own procesing

Figure 8: Error of type 4 - As the recording session ends, it detects a screen change at the end of the video.

The situation with known errors that cannot be worked around, and the very high computation cost clearly calls for a machine learning based object detection algorithm to do the rest of the work. As object detection would also empower both process automation and new opportunities for video analysis. YOLOv7 was trained using attributes in Table 7 and evaluated manually resulting in confusion matrix in Table 8 and related metrics in Table 9. Considering the findings presented, we discern that there exists significant promise for enhancements in several key facets of our approach. These potential areas of improvement include the fine-tuning process, the expansion of our dataset, the split of frames into smaller frames rather than applying stretching techniques,

and the optimization of dataset distribution to ensure an sufficient representation of each class.

| | |
|---|---|
| Environment | Google Colab (Tesla T4) |
| Training set examples | 435 (70%) |
| Validation set examples | 43 (20%) |
| Test set examples | 21 (10%) |
| Epochs | 55 |
| Batch size | 16 |
| Duration (minutes) | 30 |
| Image shape | 608 x 608 |
| Pretrained model | COCO |

Source: own procesing

Table 7: Technical details of YOLOv7 train run – dataset split details and training parameters.

| Confusion matrix | | |
|---|---|---|
| Predicted class<br>Ground truth class | Positive (1) | Negative (0) |
| Positive (1) | TP<br>107 | TN<br>does not apply |
| Negative (0) | FP<br>37 | FN<br>9 |

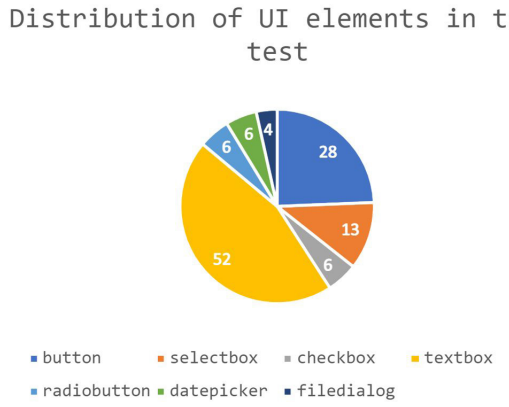
Source: own procesing

Table 8: Confusion matrix of results from our YOLOv7 implementation shows potential of object detection task as well as the need of improving both dataset and training parameters.

| | |
|---|---|
| Sensitivity | 0.922 |
| Precision | 0.743 |

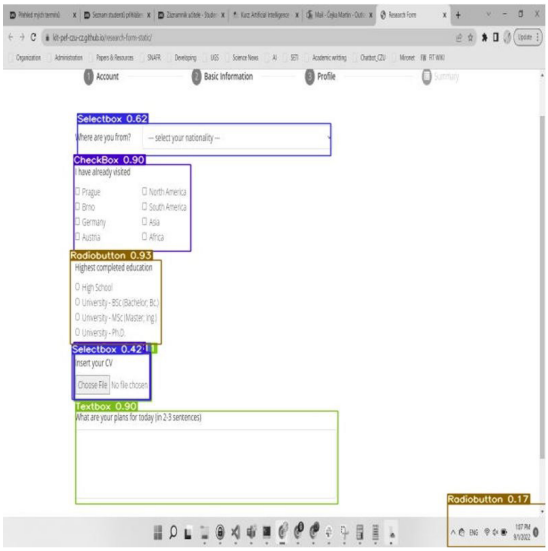
Source: own procesing

Table 9: While YOLOv7 resulting sensitiity is quiet high, precision metric shows space for improvement.




Source: own procesing

Figure 9: Graph shows unbalanced distribution of UI elements in test set.




Source: own procesing

Figure 10: Example from test set shows both great potential and great challenges in UI elements object detection.

The landscape of object detection remains dynamic, with diverse models continually emerging (such as a fresh YOLOv8). This study is a proof-of-concept solution and demonstrates feasibility while acknowledging the evolving nature of the field. Future strides are expected to introduce models with improved performance and adaptability. The presented solution is a foundational step, but the ongoing evolution of technology and research will likely yield better performances and models trained on broader data sets. This proof-of-concept highlights the vast potential for innovation in automation of UX testing evaluation.

## Conclusion

In conclusion, computer vision techniques, specifically object detection, play a key role in the development of technologies for the automatic evaluation of audiovisual data from UX testing. The ability to automatically identify objects and regions in video data is the first step towards developing technology that can provide valuable insights into user behavior and enable researchers to make more informed design decisions. Recent advances in single-stage detectors push the boundaries of performance up and opens new opportunities for UX researchers to quickly and efficiently understand user behavior.

The resulting solution could significantly contribute to the automation of UX testing within the agricultural sector, encompassing various

applications in precision agriculture. These applications include the configuration and control of machinery and IoT devices, processes related to subsidy applications, and production reporting for subsidy claims. Given the generally lower ICT literacy in the agricultural sector, these applications often tend to be complex and challenging to navigate. The proposed approach could thus represent a substantial advancement in simplifying and automating UX testing in these applications, ultimately enhancing their user-friendliness and overall effectiveness.

Our future research is directed towards developing the aforementioned technology. Leveraging the video image segmentation algorithm as a foundational step, as expounded upon in this study. Following this, our investigation will utilize object detection, integrating with eye-tracking data to facilitate a comprehensive analysis aimed at delineating the precise points (i.e., UI elements) of user focus. This multi-faceted approach holds promise for advancing our understanding of user interactions within the studied context.

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# An Empirical Evaluation of Information Sharing's Impact on Profitability; Evidence from the Solar Sector

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## Abstract

The role of online marketing is significant. Businesses strive to maximize their profit, and there are low-budget but efficient digital solutions for this aim. Social media sites are not just a connection point but also a great surface to collect information regarding products and/or companies. Even though these free opportunities are often used, websites are the „classical" standalone digital surfaces used for marketing purposes. SEO (Search Engine Optimization) provides various techniques to improve the companies' websites' SERP (Search Engine Result Page). In addition, it could provide even statistically proven financial benefits. The current study analyzes the SEO's influence on the financial performance of SMEs in the solar sector. The nationwide study based on the Kruskal-Wallis test revealed the importance of connecting social media sites to the company's website. The proper Social SEO results in significantly higher after-tax profit. Regarding the first contentful paints (first feedback to the browser about the website loading), the Pearson correlation coefficients showed up moderately strong, positive, significant relationships with many financial indicators.

## Keywords

SEO, financial impact, SME, renewable energy.

Csordás, A. and Füzesi, I. (2023) "An Empirical Evaluation of Information Sharing's Impact on Profitability; Evidence from the Solar Sector", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 3, pp. 45-56. ISSN 1804-1930. DOI 10.7160/aol.2023.150305.

## Introduction

The internet has been playing a crucial role in many aspects of life. The various social media sites offer plentiful opportunities for private people, communities, companies, and even governments. If businesses do not want to lose competitiveness, they must be widely and properly presented online. Free and easy-to-use social media sites are often used as a browser. Therefore, businesses should strive to have a complete and interesting profile on each site. However, these platforms do not provide free customization and direct selling for companies. In addition, the curious but not registered enquirers cannot access (totally) these contact points. The pandemic and the lockdowns increased internet traffic. Not only do the home office-related platforms and streaming providers enhance their positions, but the online stores could also multiply their sales and profit. Many factors could considerably influence the customers' purchasing decisions. The search engines, based on their secret algorithms, look for the demanded information on the web. Since the users trust them – they think the higher ranked website, the better result – they regularly choose the first few sites (they even do not look for the next pages). Because of this phenomenon, many online tools and experts deal with Search Engine Optimization (SEO). The companies' ranking could be increased by presenting preferred content for the search engines. Considering the higher ranking, the higher click, the better-optimized companies' websites could receive more orders and, through these, generate higher revenues. The limited resources, uncertain circumstances, and the pressure of sustainable development lead more and more people to use renewable energy. Recently, electricity prices in Hungary have increased significantly due to the growing military threat and inflation. Many households found implementing solar panels a favorable solution to reduce utility fees, dependency, and carbon footprint. This study aims to analyze the SEO's impact on firms' business performance in the solar energy sector.

Digital marketing is a technology-based process established by interacting with businesses, partners, and consumers to create, share, and maintain value for all stakeholders (Kannan, 2017). Various forms could be found within the applied techniques to satisfy consumer needs (Gao and Zhang,

2020). Nowadays, not just mobile marketing and social media marketing are involved, but also continuously developing tools, like data mining (Langan et al., 2019). The studied SEO is one of the most cost-effective tools dedicated to improving a website's popularity and traffic (Malaga, 2007). Even though it could be used as a "standalone" solution, it belongs to a wider phenomenon, the so-called Search Engine Marketing (SEM). SEM involves the paid (Search Engine Advertising, SEA) approach and organic ("free") aspect, which is represented by SEO (Chopra and Tandon, 2022). SEO could be interpreted as a web writing skill that engages customers (Sheffield, 2020). The quality content could be stolen and used (duplication), which was earlier just like keyword stuffing, link spamming, or the application of light affiliate forms of grey or black-hat SEO practices (Zhang and Cabage, 2017). Various works (Evans, 2007; Malaga, 2008; O'Neill and Curran, 2011) identified content, link building, and social sharing as crucial parts of SEO strategies, although diverse SEO guides name more main aspects (Google, 2013; SEO MOZ, 2016). According to (Google, 2013), the SEO basics start with accurate page titles and the application of "description" meta tags. The improved site structure should be implemented through the proper structure of URLs and more straightforward navigation. The optimization of the content is also advisable by quality content, anchor text, appropriate heading text, and the proper application of images. The crawlers (these read and analyze the websites) should be treated well through the effective usage of robots.txt and the proper application of nofollow links. Important the persistently application of the (right) SEO, because it can help increasing the online brand positioning too (Ahmad et al., 2022). Even if the business page appears in an adequate position (first page) on the Search Engine Results Page (SERP) – it contains the most relevant results for a given query – there is no guarantee for business. Since purchasing is a series of choices (Indumathi, 2018), before the decision is made, information must be collected, and the alternatives must be identified. These options need to be weighted according to different sets of criteria and then evaluated. If these steps are done, the last one is selecting the best alternative (Rezaei, 2015). The needed information could be collected through the search's results. Therefore the content could be the king, but it is not necessarily (Desai et al., 2013). Many factors can influence online shopping. Within the demographical variables, gender (Clemes et al., 2014), level of internet usage (Saprikis, 2013), purchase experience (El-Ansary and Roushdy, 2013) and age (Lian and Yen, 2014) are the most often studied factors (Akar and Nasir, 2015) that have an impact on online purchasing. From the general variables, the same could be said about; trust (Al-Nasser et al., 2014), perceived risk (Adnan, 2014), and attitude (Mazaheri et al., 2012). While related to the product characteristics; the product type (Chen et al., 2022) and its price (Lestari et al., 2022) are the most often studied and some of the relevant factors. However, the latest studies (Ansari et al., 2019; Athapaththu and Kulathunga, 2018; Dabbous and Barakat, 2020) reveal a positive and significant relationship between the (website's or social media site's) content and online purchase intention.

## Material and methods

To get a proper dataset for the analyses of SEO, the countrywide database of the Hungarian Solar Panel, Solar Collector Association was used. They aim to promote the application of solar energy and spread it widely. There are various types of memberships available. However, at least two recommendations of (previous) members and the acceptance of the presidency are needed for successful admission. The organization is open to Hungarian investors, manufacturers, traders, constructors, designers, and users. However, some international companies also could be found on the list of members. All in all, three hundred-sixty-two companies, sixty-two members, and two honorary members were registered on 30.10.2022. on the website. The number of contractors among the members was relatively low, only one hundred nineteen provided this service. This amount of companies created the base of the analyses. However, during the in-depth review, some self-employed and businesses without websites were identified and excluded from the next stages. In fifty cases, the websites did not work or could not be scanned by the SEO analyzer. So seventy-five contractors were called in the last section. Since the Hungarian regulation provides free access to the registered businesses' financial reports, this information was also involved. But this extra data resulted in six more companies being excluded because their reports were unavailable. Despite this information must be updated after six months of the latest financial year. This regulation reduces the data quality because the reports are from 2021. However, SMEs do not regularly modify their websites (even the aware businesses change

it approximately every two to three years, but proper study related to this question has not been published). So the final number of the analysed contractors was sixty-nine. The potential customers can search on the associations' website by region. Previously the companies' results were shown like business cards, where the primary purpose (electricity, hot water, heating) and the activity (design, construction, repair) of the solar panels' installations were indicated. Their business websites were analyzed using the six main SEO factors in Table 1.

| | |
|---|---|
| TOTAL | It makes the website more relevant and popular within the user search queries. It helps to rank the webpage higher in search engines. |
| ON PAGE | It helps search engines understand the website's content and rank it based on the keywords. |
| LINKS | Search engines treat links as „citations". Each citation represents the content more valuable and credible. |
| USABILITY | It maximizes the available audience and minimizes their bounce rates. |
| PERFORMANCE | It provides a good user experience and decreases bounce rates. |
| SOCIAL | It is crucial for customer communication and brand awareness. It can be considered as a marketing channel that brings visitors to the website. |

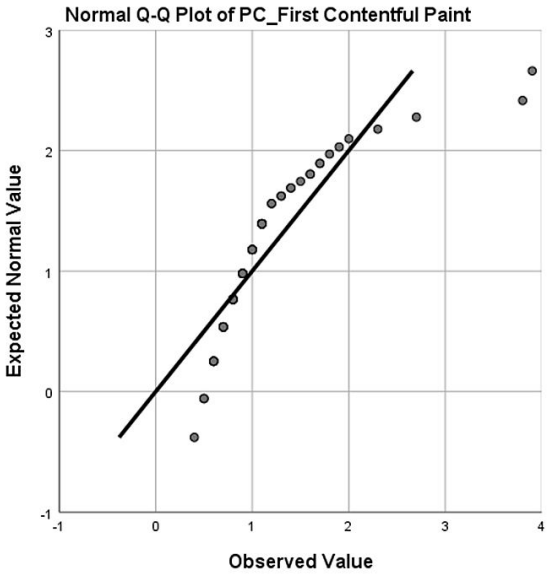
Source: based on (SEOptimer, 2022), own elaboration

Table 1: The main SEO dimensions of the current analyses.

Considering the available dataset and the type of variables Kruskal-Wallis test was applied. This nonparametric method is the extended version of the Mann-Whitney U test (Bugała et al., 2017). This statistic could identify whether the data comes from the same distribution. The Kruskal-Wallis test is used to study more than two groups. Since it requires independent random samples, a one-way ANOVA test was used (Xia, 2020). It is a well-known tool that determines whether there are any statistically significant differences between the groups' means (Kim, 2017). If two groups were tested, an independent samples t-test would be ideal. If three or more groups need to be analyzed, one-way ANOVA has to be used. This method requires regarding the variables; the independency of observations, normality of the populations, and homogeneity of the variances (Mishra et al., 2019). The nonparametric Kolmogorov-Smirnov test is ideal for testing distributions with a reference probability distribution or comparing two samples (Aslam, 2019). The Shapiro–Wilk test has the same function. It analyses whether the random sample comes from a normal distribution (Aslam, 2021). In the current study, the Pearson correlation was also applied. It is a bivariate correlation that analyses the linear correlation between two data sets. The relationship between the studied variables can be positive, neutral, or negative, and its strength is between -1 and 1 (Ly et al., 2018).

## Results and discussion

The companies with various focuses (electricity, hot water, heating) activities (design, construction, repair) and the number of regions (where they provide their services) were studied with ANOVA to highlight the differences within the groups. Since the test's assumptions were filled out, it was ideal for this approach. However, no similarities or differences regarding any of the SEO indicators could be identified at a reliable significance level. The correlation analysis of scale variables showed up a lot of relationships between many financial indicators and some technical-related SEO variables. Outliers and pairless variables were not within the dataset. In addition, the normality of the scale variables and the linear relationships between them were proved (Figure 1).




Source: own elaboration

Figure 1: Normal distribution of PC First Contentful Paint.

Therefore, the Pearson correlation coefficient could be used to identify their hidden relations. A robust (0.918) correlation was highlighted at a 0.05 significance level between the first contentful paint on mobile and the first on PC. This variable represents the first feedback the user receives when the opened webpage is

loading. It could be interpreted as a fast answer from the business website, and the strong connection means both interfaces have the same importance for the studied companies. If a quick "response" is provided for mobile users, the same will be valid for desktop users. Because these variables moved together, similar correlation coefficients were expected, demonstrated by the Figure 2.

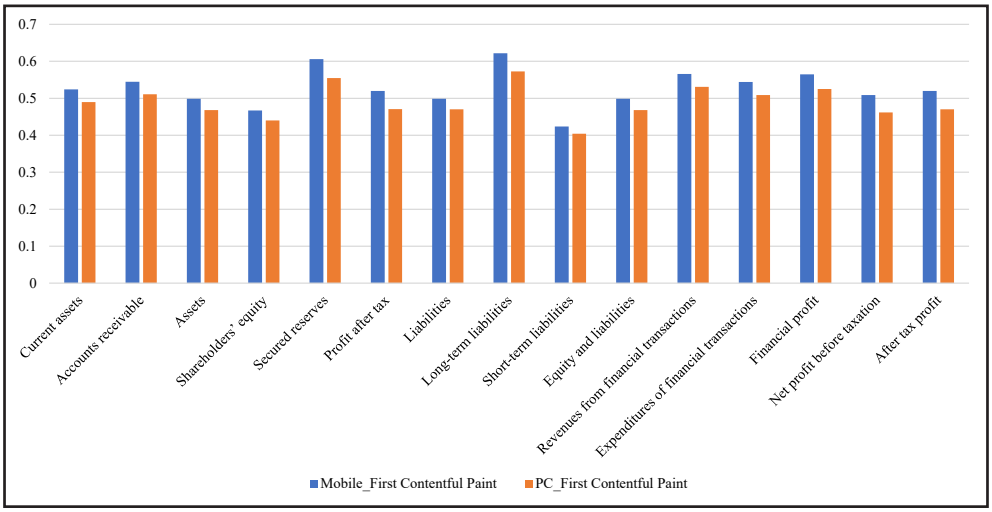
The correlation coefficients showed moderately strong (from 0.4 to 0.62) relationships with various financial indicators at a high (0.05) significance level. However, the Mobile first contentful paint always revealed higher values. Naturally, the financial indicators are connected, so the results could be slightly distorted. Despite all that, these findings suggest the higher effect of mobile devices, which could also be measured in the financial results.

The ideal statistical tests were sought to analyze the relations between the diverse SEOs and financial indicators. For the ordinal (social SEO) and the scale (after-tax profit) variable, the Kruskal-Wallis test seemed to be ideal. To test the parameters' suitability to the assumptions, the independency of the observations was studied. For this purpose, an independent sample t-test should be used, but with it, only two groups could be compared. Therefore, the one-way ANOVA was used, which rejected the similarity of the studied groups. After that, the distributions and the variances were studied. The Kolmogorov-Smirnov and even the Shapiro-Wilk tests identified the normal distribution of the studied variables (Table 2).

From the descriptives of these tests, the ideal variances were highlighted. The last requirement regarding the Kruskal-Wallis test was the random sampling of the observations, which was already fulfilled during the data collection. After all the assumptions were checked, the dissimilarities within the groups could be analyzed. Applying the Kruskal-Wallis test revealed a significant difference in the distribution of after-tax profit regarding social SEO. The statistic value was 8,524 at a 0.036 significance level. The pairwise comparisons highlighted the distinct levels of after-tax profit in the case of 1-3 and 2-3 social SEO groups (Table 3).

The measured difference meant those companies whose websites' had an "average" (3) social SEO realized significantly higher after-tax profit than those that had "poor" (1) or "slight" (2) social SEO.

The studied enterprises' customers (individuals or companies) can not be identified based




Source: own elaboration

Figure 2: Pearson correlation coefficients of financial indicators.

| | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SOCIAL SEO | 0.437 | 68 | 0.001 | 0.590 | 68 | 0.001 |
| After-tax profit | 0.358 | 68 | 0.001 | 0.336 | 68 | 0.001 |

Source: own elaboration

Table 2: Test of normal distribution.

| Sample 1-Sample 2 | Test Statistic | Std. Error | Std. Test Statistic | Sig. | Adj. Sig.a |
|---|---|---|---|---|---|
| 1-2 | -1.260 | 6.850 | -0.184 | 0.854 | 1.000 |
| 1-4 | -20.760 | 14.259 | -1.456 | 0.145 | 0.872 |
| 1-3 | -22.260 | 8.543 | -2.606 | 0.009 | 0.055 |
| 2-4 | -19.500 | 15.317 | -1.273 | 0.203 | 0.000 |
| 2-3 | -21.000 | 10.211 | -2.057 | 0.040 | 0.238 |
| 4-3 | 1.500 | 16.145 | 0.093 | 0.926 | 1.000 |

Note: The adjusted significance levels were not significant in any of the cases.
Source: own elaboration

Table 3: The pairwise comparisons of the Kruskal-Wallis test.

on the information provided on the websites. Furthermore, the sites studied do not emphasize the contribution of solar energy to the Sustainable Development Goals (SDGs) and its enormous potential to support rural development. But these issues are of particular importance today. Energy independence is also a frequently discussed topic, where the role of solar panels is often mentioned (Abhyankar et al., 2023; Sattich et al., 2022). Solar energy is clean, renewable, and abundant, and it also reduces the reliance on fossil fuels and all the disadvantages of their application (Al-Shahri et al., 2021; Kuşkaya et al., 2023). Some settlements are difficult to reach (typically with a low population) and/or too expensive to connect to the grid. Therefore, they are not connected to the electricity network. The so-called off-grid solutions can provide power in these cases. By applying solar panels, batteries, and inverters, their needs can be satisfied sustainably (Baurzhan and Jenkins, 2016; Brunet et al., 2022; Pal and Mukherjee, 2021). The tremendous economic opportunities provided by solar panels have to be stressed too. It can reduce the energy cost, create new jobs and through higher employment, economic growth and tax revenues could be increased (Guo and Xiang, 2022; Madsen and Hansen, 2019; Tănasie et al., 2022; Yasmeen et al., 2022). These advantages could powerfully support the development of rural regions (Ibrik, 2019; Palit, 2013). The operation of agriculture‘s efficiency can be enhanced through cost-saving, automatization, and remote monitoring opportunities supported by solar energy. In addition, the widespread of various greenhouses could also enhance the quality of life in these areas (Hu, 2023; Pascaris et al., 2021; Sharma et al., 2019). The benefits of this form of renewable energy are probably not known to everyone. Due this reason, a form of advertising should be pursued by the companies studied, which should present not only the benefits of their given product but also the benefits of the sustainable operation itself in an educational way. So they could address more potential customers and increase their profit further.

SEO has been playing an essential role in business life, and the pandemic showed how important the SERP for companies could be. Digital marketing is strongly correlated with online presence, and the proper management of digital surfaces could further increase the efficiency of digital marketing even without ads. Mostly the influence of SEO on SERP has been studied (Iqbal et al., 2022; Sellamuthu et al., 2022; Wahba and Barhoom, 2019), but there are a few studies related to SEO’s financial impact too. The work of (Poturak et al., 2022) studied a private university, where SEO influence on business performance was analysed. The implementation of SEO tactics resulted in a better position on the SERP, and through this development, the number of visitors, the spent time on the website, and the user engagement increased. These also affect the student enrollment, which causes higher annual sales revenue. The study of (Tomasi and Li, 2015) analyzed three SMEs regarding the SEO impact on their performances. The applied SEO techniques resulted in the same effects; increased SERPs ranking, a higher number of visitors, longer average time on site, better user engagement, and increased annual sales revenue. The research of (Zhang and Cabage, 2017) implemented three different aspects of SEO tactics (content-based, content-based and proactive link building, content-based and, social media campaigns) for various websites. The authors found link-building results in better ROI in long term, while social media builds traffic fast. However, both of them increase website traffic and revenue. Like the previous studies, the current work highlights SEO's positive impact on financial indicators. However, this work reveals the importance of Social SEO on the higher after-tax profit in the solar sector. Even though the social media campaign’s influence was studied, the recent findings show that the connected and on the website

presented social media links'/appereances' a significant role. This could be explained by the extended content of the website. May these platforms be crawled by search engines. However, it would bring back the question of "Is content king?". The technical side of the work stressed the relevance of the first contentful paints (both on PC and mobile) and their moderately strong correlations with many financial indicators. The fast answer provided to the user could be crucial since everybody looks for fast interactions nowadays. The consumers' attitudes towards fast replies have not been studied. The SERP-related works reveal the preference for organic (search) results (Lewandowski et al., 2018; Lewandowski and Schultheiß, 2022), and higher rank (Alanazi et al., 2020; Wu et al., 2014), but the other preferences are just seldom analyzed (Agichtein et al., 2006).

## Conclusion

The current work studied the information-sharing's impact on the profitability of SMEs in the solar sector. Since, nowadays next to the support of sustainable development, the growing military threat and inflation also highly increased the demand for solar panel-based solutions. The potential consumers' information-collecting habits changed too through the strengthening of social media platforms. The Hungarian solar sector was studied to see how the proper online presence and linkage of various sites could affect the financial performance. In line with previous works, the current study found a significant and positive relationship between the application of SEO and profit. The higher rank of Social SEO was connected with a higher profit after-tax too. The research's technical aspect showed the importance of first contentful paints. In both cases of PCs and mobiles, they showed moderately strong correlations with various financial indicators. The correlation between the PC's and mobile's first contentful paints was nearly linear. So, the studied businesses found both or none of these aspects important. Based on the current findings, the more content obligatory involves the connection of social media platforms to the website, and the fast reply of the website could positively influence the financial performance of the business too. Specializing the content/ad could further increase the visibility and profit of the contractors. Informative material focusing on the features of solar panels (e.g., upfront cost, payback period, relevance of weather) could increase the knowledge of potential customers while improving the SMEs' brand and reputation.

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# Appendix

| | | | |
|---|---|---|---|
| ON PAGE | Title Tag | USABILITY | Use of Mobile Viewports |
| | Meta Description Tag | | Google's PageSpeed Insights - Mobile |
| | Language | | Mobile_First Contentful Paint |
| | H1 Header Tag Usage | | Mobile_Speed Index |
| | Keyword Consistency | | Mobile_Largest Contentful Paint |
| | Amount of Content | | Mobile_Time to Interactive |
| | Image Alt Attributes | | Mobile_Total Blocking Time |
| | Canonical Tag | | Mobile_Cumulative Layout Shift |
| | Noindex Tag Test | | Google's PageSpeed Insights - Desktop |
| | Noindex Header Test | | PC_First Contentful Paint |
| | SSL Enabled | | PC_Speed Index |
| | HTTPS Redirect | | PC_Largest Contentful Paint |
| | Robots.txt | | PC_Time to Interactive |
| | Blocked by Robots.txt | | PC_Total Blocking Time |
| | XML Sitemaps | | PC_Cumulative Layout Shift |
| | Analytics | | Flash Used |
| | Schema.org Structured Data | | iFrames Used |
| LINKS | Total Traffic From Search | | Favicon |
| | Friendly Links | | Email Privacy |
| PERFORMANCE | JavaScript Errors | SOCIAL | Facebook Connected |
| | HTTP2 Usage | | Twitter Connected |
| | Optimize Images | | Instagram Connected |
| | Minification | | YouTube Connected |
| | Deprecated HTML | | LinkedIn Connected |
| | Inline Styles | | Used_Tech |

Source: own elaboration

Table A1: The used variables of SEO analyses.

| |
|---|
| Invested assets |
| Intangible assets |
| Tangible assets |
| Investments and funds |
| Current assets |
| Inventory |
| Accounts receivable |
| Securities |
| Liquid assets |
| Accrued and deferred assets |
| Assets |
| Shareholders' equity |
| Issued capital |
| Issued, unpaid capital |
| Capital reserve |
| Accumulated profit reserve |
| Secured reserves |
| Valuation reserves |
| Profit after tax |
| Provisions |
| Liabilities |
| Subordinated liabilities |
| Long-term liabilities |
| Short-term liabilities |
| Accrued expenses and deferred income |
| Equity and liabilities |

| |
|---|
| Net sales revenues |
| Capitalised value of own performance |
| Other revenues |
| Material type expenditure |
| Payments to personnel |
| Depreciation charge |
| Other expenses |
| Trading profit |
| Revenues from financial transactions |
| Expenditures of financial transactions |
| Financial profit |
| Net profit before taxation |
| Tax liability |
| After tax profit |

Source: own elaboration

Table A2: Balance sheet, profit and loss.

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# Climate Change Perception and Innovative Mitigation Practices Adopted by Hungarian Farms

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## Abstract

Climate change is becoming a growing concern for the agricultural sector. Variable weather events, such as droughts and floods, are expected to have a significant negative impact on agricultural losses, earnings and consumption. The agriculture industry in Europe is not immune to these difficulties. This study focuses on Hungary, a country with a strong agricultural focus that, as a result, is particularly susceptible to climate change. An exploratory factor analysis (EFA) was performed to synthesis data about the perspectives of Hungarian farmers on the dangers of climate change. Then, latent variables were employed as explanatory variables in the Logit model to investigate the link between the perceptions of climate change risks by Hungarian farmers and their inclination to adopt innovative ways to mitigate its repercussions. Changes in temperature and precipitation, economic damage, water damage, and insect damage are seen as the most serious repercussions of climate change by Hungarian farmers. These beliefs raise the possibility of adopting new strategies to offset harmful consequences, including (i) the adoption of new varieties, (ii) ice and frost protection, and (iii) the use of agro-meteorological data. The results show that the chance of adopting new varieties is substantially influenced by farmers' assessments of harm caused by pests, pathogens, and illnesses (2.91***). In contrast, water damage concerns seem to have a significant impact on the adoption of novel approaches to reduce cold and frost damage (2.18***). This study's findings support the efforts of stakeholders and policymakers to encourage the dissemination of technology to protect crops from climate change in Hungary and imply that governments should provide financial incentives to farmers to boost innovation uptake.

## Keywords

Climate change, agriculture, farmers, practices, innovation, perception.

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## Introduction

Over the last few centuries, human-caused activities such as fossil fuel combustion and widespread deforestation have resulted in an increase in atmospheric greenhouse gas (GHG) concentrations, resulting in major climate change over the globe (Di Vita et al., 2017; Gudmundsson et al., 2021). The Intergovernmental Panel on Climate Change (IPCC) reveals that the year 2019 experienced the highest $CO_2$ levels in two million years and reported in its fifth assessment report that the global average temperature has been growing since 1880 and is anticipated to continue to do so (IPCC, 2021). Additionally, from 2011 to 2020, the average global surface temperature increased by 1.09 degrees Celsius over pre-industrial levels (IPCC, 2021). Consequently, climate change (CC) has become one of the world's most perplexing and difficult topics today (Zhu et al., 2021). Indeed, it has long been recognized as a major worldwide issue (Yokomatsu

et al., 2020) that poses significant threats to social, ecological, and economic well-being (O'Neill et al., 2020).

This emergency has been recognized as such by several international organizations and Intergovernmental agencies. The United Nations framework convention on climate change defined it as "a change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods of time" (Sands, 1992).

Within all human production activities, agriculture is considered one of the sectors most vulnerable to the effects of climate change due to its reliance on natural resources and climate (Spina et al., 2021). It is constantly impacted by climate change through extreme weather events, unanticipated temperature and rainfall variations, all of which pose considerable threats to the agro-economy (Nicita et al., 2020).

This results in decreasing agricultural yields (Raimondo et al., 2021), disrupted food supply networks, higher food prices and lower food quality (Edenhofer et al., 2011).

By 2050, adverse effects on agricultural yields and farmer livelihoods are anticipated to result in a 20% rise in the worldwide population of hungry people (Hossain et al. 2019). Although climate change affects the whole world (Lobell et al., 2017), declining yields exacerbate the food insecurity of smallholders in developing countries (Huong et al., 2017), whose livelihoods are entirely dependent on climate (Wang et al., 2017).

The European agriculture sector is not exempt from this concern, being one of the world's major food producers; climate change's impact on agriculture varies by place, depending on the direct effects of changing climatic conditions on agricultural productivity as well as the indirect repercussions of increasing pest and disease pressure (Olesen et al., 2011).

Given the importance of such topic and considering little deepening of climate change effect on the agricultural economies of EU eastern countries, this study focused on Hungary, whose economy mainly reliant on agriculture.

Suffice it to say that Hungary's agriculture, forestry, and fisheries sector is worth $5221 million, up from $3591 million in 2000 (FAO, 2020). It is currently considered a moderately vulnerable country to the impacts of climate change. But long-term analyses show a considerable increase in climate risk, particularly an increased hazard of drought during summer and seasonal flooding, water stagnation and erosion as the result of augmented frequency of extreme events (Ladanyi et al., 2009).

Among other ways for addressing these issues, efforts are being undertaken to enhance climate resilient agriculture using integrated pest management and precision agriculture (Ahmed et al., 2018), as well as by adjusting cropping schedules and selecting new crop varieties (Amare and Simane, 2017).

That the effects of climate change have a negative impact on agricultural activities and farm profitability (Jamil et al., 2021) is a well-known issue, yet the perception of climate change in Eastern European Union countries has been little investigated by researchers. Given that perception of change is the most important factor in climate change adaptation, this study aims to investigate the effect that perception of climate change has on the likelihood of Hungarian farmers adopting innovative techniques to mitigate its impacts.

To fill this gap in the literature, it estimated the willingness of Hungarian farmers to introduce innovative tools and techniques on their farms.

Furthermore, according to several scholars, the more you believe in the idea of climate change, the more likely you are to adjust your actions to the projected outcomes (Syropoulos and Markowitz, 2022).

In light of these premises, this paper intends to address the following research questions:

RQ1: What, in the opinion of Hungarian farmers, are the most significant effects of climate change on the agricultural productivity?

RQ2: Are agrometeorological data considered useful tools to reduce the negative impact of climate change on Hungarian farms?

RQ3: How likely is it that these effects will prompt Hungarian farmers to use climate change adaptation tools like new warm and floods resistant crop varieties?

RQ4: How likely is it that these effects will prompt Hungarian farmers to use climate change adaptation tools like ice and frost protection in cold seasons?

RQ5: Do the socio-economic characteristics (education level) of Hungarian farmers affect

the possibility that they will adopt climate change adaptation tools?

## Literature review

### Farmers' perception of climate change

Several studies have examined farmers' perceptions of climate change (Brown et al., 2018) and their impact on the development of appropriate farm management measures (Singh, 2020).

Most of the extant research on farmers' perceptions and reactions to climate change either investigates their future possibility of adopting a practice or they are already adopted (Niles et al., 2015).

Current research indicates that farmers are generally aware of climate change, especially in terms of severe weather events and their influence on agriculture at the local level (Timpanaro et al., 2013), even if, one of the primary issues with climate change, however, is that threats are often seen as physically and temporally remote (Spence et al., 2011). In this direction, some scholars (Arbuckle et al., 2015) argue that farmers make sense of climate and weather changes and develop adaption methods based on their own observations and experiences on their own properties. For instance, Spence et al. (2011) and Schattman et al. (2016) found that prior exposure to floods, air pollution, or other severe weather events enhanced farmers' anxiety about climate change.

The scientific literature, however, reveal a discrepancy between farmers' beliefs and adaptive actions (Nguyen et al., 2019). This discrepancy could be caused by the uncertainty in understanding and forecasting future weather and climate change (Ricart et al., 2018), and/or by the likelihood of adaptation, which varies according to a variety of factors, including socioeconomic characteristics (Stringer et al., 2020). Nevertheless, some authors (Huong et al., 2017) assert that many farmers may be unaware of climate change issues due to a variety of factors, among others, the level of education, age, farm size, and income.

### Innovative adaptation strategies

Several adaptation methods that are both accessible and effective in strengthening farm-level resilience have been found, and they are now being disseminated to the agricultural community (Di Vita et al., 2015a). These include the use of new technologies to adapt to climate change, such as the deployment of more robust crop varieties; plant disease protection; agro-meteorological forecasting; and crop protection against cold and frost (Di Vita et al., 2015b).

Adaptation techniques are often long-term reactions to climate change's consequences and include making adaptations to the increased internal risks imposed by the phenomenon (Helling et al., 2015).

The IPCC (2014) defined adaptation as "the process of adapting to actual or projected climate and its effects; in human systems, adaptation seeks to moderate damage or exploit beneficial opportunities; in natural systems, human intervention can facilitate adaptation to projected climate and its effects".

Farmers have evolved a range of coping methods to deal with weather unpredictability, which are short-term tactics designed to mitigate exposure to shocks (Lolig et al., 2019).

Since the capacity to make credible predictions in advance is a critical component of any agricultural system, the availability of a sufficient agro-meteorological database is a prerequisite for studying and managing agricultural production processes. Agrometeorological parameters are crucial for making day-to-day and seasonal farm management decisions as well as mitigating climate change risks in agriculture, as they guide the actions mandatory to transform and further reorient agricultural systems to effectively support development and ensure regional food security in a changing climate (Singh et al., 2009). For instance, in precision agriculture, it is key to be able to forecast future situations and estimate changes in biophysical crop responses because of these environmental oscillations. Forecasting is particularly critical for risk minimization in agricultural systems, which depend on empirical data and process-based models to simulate the uncertainty associated with unknown data (Allen, 1994). Additionally, wireless sensor networks have developed as a potent technology for data collecting and processing in the agricultural sector in recent years (Borgia, 2014), enabling agrometeorological information systems to function with a range of affordable, high-performance, and dependable sensors (Mirhosseini et al., 2017).

Nowadays, modern agriculture has recognized the fundamental need of having and using agro-meteorological data for effective agricultural operations. For example, air temperature is often regarded as the primary climatic variable that controls the pace of vegetative and reproductive growth (Sawan, 2018). Thus, having access to this variable enables the application of appropriate therapies in real time, allowing for profitable agricultural production regulation and catastrophe risk reduction operations (Reznik et al., 2017).

Frost is another weather hazard that perennial crop farmers must contend with. As a result, future estimates of frost risk have been highlighted as beneficial for long-term planning efforts (Parker et al., 2019). Frost exposure also places a geographical limitation on plants' bioclimatic niches and may be a limiting factor for agricultural output in temperate areas worldwide (Maracchi et al., 2005).

Perennial crops progressively harden and become more vulnerable to cold temperatures when temperatures increase in early spring, increasing their sensitivity to frost damage. Abnormally mild weather in late winter or early spring may also accelerate phenology, resulting in a false spring in which crops emerge from dormancy and begin their yearly growth earlier than usual, increasing the risk of frost damage.

Any divergence from ideal growth circumstances, such as excessive or insufficient rainfall, excessive or insufficient warmth, increased cloudiness or abrupt wind, or hailstorms, may influence yields in both rain-fed and irrigated crops (Gobin, 2018). For example, Del Toro et al. (2015) discovered that dryness during the growth season and excessive rainfall during the harvest season are the two climate-related variables that historically have had the largest detrimental influence on production.

The development of protection strategies, such as hail and frost nets, aerators, and heating equipment, to combat ice and frost damage can be considered an important factor for Hungary, which has a continental climate with harsh winters.

Climate change may result in severe weather events, which may influence agricultural productivity, as well as pests and illnesses (Adamo et al., 2012). These severe phenomena include protracted droughts, prolonged periods of torrential rain and very high temperatures (Rosenzweig et al., 2001).

Moreover, global warming has a significant impact on insect life in a variety of ways: changes in population growth rates; increases in the number of generations of insects; geographic range expansion (Kiritani, 2013); introduction of species to alternative host plants; increased risk of invasion by migrating insects; overwintering insects (Bale et al., 2002); movement of pests from lower to higher latitudes (Barzman et al., 2015).

Ectothermic insects are the least vulnerable to climate change and global warming because they can swiftly adapt to changing environmental circumstances. This provides them with an edge in terms of aggressive reproduction, hence increasing their danger to agricultural productivity (Ferrer et al., 2014). Additionally, climate change is extremely likely to modify insect pests and the connection between the host and the bug (Bale et al., 2002), reducing agricultural yield. Certain crops that are known to be insect pest resistant may become sensitive to pest damage and react positively to pest damage because of climate change and global warming (Reddy, 2013).

High temperatures may impact an insect's growth and development at various phases of its life cycle (Zhang et al., 2015), as well as its fecundity and mortality (Khaliq et al., 2014). For instance, when impacted by warmer circumstances, insects that have acclimated to high temperatures may be able to increase the number of generations each year (Van Dyck et al., 2015). Furthermore, as temperatures rise, infections might travel to new locations with vulnerable hosts, influencing disease development (Etterson and Shaw, 2001). Hence, developing more climate-resilient agricultural production systems is the right way to deal with climate change.

Improvements in crop varieties have been discovered to assist growers to respond to increased drought frequency and changing insect populations. Indeed, developing new varieties that are more resistant to drought and heat stress while maintaining the same production potential should help mitigate some of the predicted climate change consequences (Cairns et al., 2013).

In this context, the introduction of novel cultivars in Hungary, which suffers from summer dryness, is an important adaptation strategy for Hungarian agricultural output.

Crop variety changes have been shown to enable farmers to address climate change, including higher drought frequency (Yu and Babcock, 2010), changed insect populations, extended growing seasons and other variables (Harvey et al., 2014).

To alleviate the effect of climate change on agricultural systems, one strategy is to produce superior varieties that are genetically tolerant or resistant to a new spectrum of abiotic and biotic stresses. Crop improvement needs access to novel gene variations (Kilian et al., 2021).

Adaptation in the form of improved varieties, trading patterns, and crop mixtures has been shown to be beneficial in mitigating the effects of climate change (Aisabokhae et al., 2011). Adopting drought-tolerant maize cultivars would

provide adaptive advantages by preventing major output redistribution (Malcolm et al., 2012).

Numerous modifications, such as advancing planting dates or spreading new crop kinds, may be implemented reasonably rapidly by individual farmers in reaction to observable consequences.

While emerging technologies like as genome editing may aid in the focused development of superior cultivars, public perception and legislative concerns continue to limit their successful usage (Vindigni et al., 2022).

In light of this context, the current study aims at investigating which perceived effect of climate change affect the adoption of some important innovative adaptation techniques by Hungarian farmers.

## Materials and methods

### Data collection

A semi-structured questionnaire was developed to determine how perceptions of the negative effects of climate change influence the likelihood that Hungarian farmers will implement innovative techniques.

Survey was carried out in three different steps. Firstly, a survey was designed by analyzing main contribution of literature about climate change effects on the agriculture, thus also examining the specificity of Eu eastern European countries. This exploration was also associated with the analysis of existing tools and innovative agricultural practices to face and reduce negative effects of climate change. Secondly a questionnaire was designed to collect data and information and explore the farmers intention to face climatic change and introduce adaptive innovations in their agricultural practices.

Subsequently an interview survey, based on farmers statements, was carried out between 2017 december and 2018 february. Data collection was administered by staff members of the Hungarian FADN through face-to-face setup. Responses were recorded online using Google Form platform.

The 300 farms that made up this study's sample was a sub-sample of the 2171 sample holdings that were chosen for data collection as part of the 2017 Farm Accountancy Data Network (FADN) framework. The FADN sample is representative of the agricultural holdings larger than 4-thousand-euro Standard Output. In 2017 this population was made up of 108 thousand individual and 7664 corporate holdings (Keszthelyi and Kis Csatári, 2019). This study took a sub-sample from the FADN sample using convenience sampling method; therefore, the sample of 300 farms used for this study's statistical analysis cannot be considered representative of the whole population. The questions were meant to evaluate the key climate change adaptation strategies that farmers believed may prevent unfavorable climatic factors.

Specifically, **the first section** was designed to analyze farmers' views of climate change because of climatic variability in terms of average temperature rise and effect on production cycles. In this regard, they were asked whether "*the weather in my agricultural area has become significantly more variable over the past year*" or "*average temperatures have clearly increased during crucial production cycle periods*" or "*annual rainfall has clearly decreased during crucial production cycle periods*".

The **second section** was designed to evaluate farmers' perspectives on climate change and its probable effects on crop productivity and farm profitability. In this respect, respondents were questioned, "Due to the change in climatic conditions, the profitability of my farm has decreased" or "*Due to the change in climate conditions, the quality of my crops has decreased*" or "*Which of the consequences of a changing climate have been felt on the farm?*". Each item was ranked on a 5-point Likert scale ranging from 1 ("*I do not agree/not at all*") to 5 ("*I agree completely/very lot*").

**The third section** aimed at collecting main socio-demographic data of farmers, such as age (24-72 years), education, and gender (Table 1), and structural characteristics of farms (Table 2), such as farm type, ownership type and geographical position of farms.

| | Freq. | % |
|---|---|---|
| Gender | | |
| Male | 257 | 85.67 |
| Female | 43 | 14.33 |
| Tot. | **300** | **100.00** |
| **Manager's education** | | |
| None | 15 | 5.00 |
| Vocational tranining | 78 | 26.00 |
| Skilled worker | 114 | 38.00 |
| Plant engineer | 75 | 25.00 |
| Agriculture engineer | 18 | 6.00 |
| Tot. | **300** | **100.00** |

Source: authors'eleboration

Table 1: Farmer's socio-demographic data.

| Type of farms | Freq. | % |
|---|---|---|
| Fruits | 116 | 38.67 |
| Horticultural | 123 | 41.00 |
| Vineyard | 61 | 20.33 |
| Tot. | **300** | **100.00** |
| **Ownership type** | | |
| Sole proprietorship | 282 | 94.00 |
| Limited liability company (LLC) | 18 | 6.00 |
| Tot. | **300** | **100.00** |
| **Geographical position of farms** | | |
| Great Plain | 29 | 9.67 |
| Transdanube | 105 | 35.00 |
| Northern Hills | 166 | 55.33 |
| Tot. | **300** | **100.00** |

Source: authors'eleboration

Table 2: Farms structural characteristic.

## Data analysis

To synthesize the information about Hungarian farmers' perception on climate change damages an exploratory factor analysis (EFA), with an orthogonal rotation (varimax) of 0.6 was used (Hamam et al., 2022a; Raimondo et al., 2022). The descriptive statistics of each variable are shown in Table 3.

Then, latent factors will be employed as explanatory variables in the Logit model to examine the effect that perception of risks due to climate change has on the propensity of Hungarian farmer to adopt innovative techniques to mitigate climate change damages.

Table 4 shows the descriptive statistics of the innovative techniques considered in this study, such as: i) use of new warm and floods crop varieties, ii) ice and frost protection and iii) use of agrometeorological data.

The coefficients derived from the EFA were included into the logit model, and they were employed as covariates to examine the likelihood of Hungarian farmers to adopt novel strategies to offset the consequences of climate change.

Three linear equations were established for the three explored novel techniques: the adoption of new varieties, ice and frost protection, and the use of agrometeorological data.

Since the dependent variable in our regression equations is a dummy variable assuming the value 0 or 1, the Logit estimator was used in this investigation.

$$INNOV_i = \alpha + \beta\ perceived\_cc\_eff_i + \nu\ manag\_edu_i + \\ + \varepsilon_i \qquad i = 1, 2 \ldots 300 \qquad (1)$$

where for each of the three equations, INNOV is the dependent variable that corresponds to one of the three innovative techniques investigated (i.e. use of new varieties, ice and frost protection and use of agrometeorological data), while $\alpha$ is

| Variables | Description | Item | Mean | Std. Dev. |
|---|---|---|---|---|
| K1 | 1 - 5 Likert scale | The weather became volatile | 3.35 | 1.31 |
| K2 | 1 - 5 Likert scale | The average temperature has risen | 3.37 | 1.27 |
| K5 | 1 - 5 Likert scale | The quality of my produce has deteriorated | 2.68 | 0.85 |
| K6 | 1 - 5 Likert scale | Yields have fallen | 2.86 | 0.93 |
| K9b | 1 - 5 Likert scale | Soil degradation by water | 2.02 | 1.14 |
| K9d | 1 - 5 Likert scale | Waterlogging | 2.61 | 1.21 |
| K9e | 1 - 5 Likert scale | Flood | 1.40 | 0.82 |
| K9h | 1 - 5 Likert scale | Emergence of new pests | 2.94 | 0.98 |
| K9i | 1 - 5 Likert scale | Emergence of new pathogens and diseases | 2.91 | 0.97 |

Note: 1 - strongly disagree; 5 - strongly agree.
Source: authors'eleboration

Table 3: Perception variables.

| Variables | Type | Item | Mean | Std. Dev |
|---|---|---|---|---|
| INNOV_1 | Dummy (0-1) | Use of new warm and floods crop varieties | 0.82 | 0.38 |
| INNOV_2 | Dummy (0-1) | Ice and frost protection | 0.25 | 0.43 |
| INNOV_3 | Dummy (0-1) | Use of agrometeorogical data | 0.81 | 0.39 |

Note: 0 - I don't want to apply; 1- I've already adapted or I intend to apply in the next 5-10 years.
Source: authors'eleboration

Table 4: Adaptation practices variables.

the intercept of the equations and $\beta$ is a vector of perceived climate change effects.

The degree of agricultural education of the manager was also included as an explanatory variable (*manag edu*) in the model. The categories for the categorical variable "management education level" are as follows: 1) none; 2) vocational training; 3) skilled worker; 4) plant engineer; and 5) agriculture engineer. Finally, εi is the model's error term.

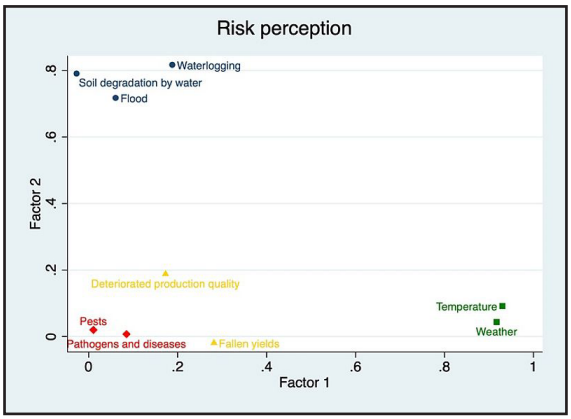
In addition, the odds ratio was calculated to offer a precise measure of the constant impact risk perception has on the likelihood of adopting or not adopting an innovative strategy to reduce climate change consequences.

## Results and discussion

The study was conducted in two different steps: the first one consisted of a factorial analysts aimed at identifying the main impacts, resulting from climate change, on agricultural productivity. Subsequently a logit model was impended to assess the probability of farmers adopting strategies to mitigate climate change damage.

According to main findings derived from the Explanatory factor analysis (EFA) it emerges the existence of four latent variables that assume different and antithetic features. These variables, according to the farmers opinions, represents the main group of potential risks deriving from the climate changes,

As shown in Table 5, variables were synthesized and named as follows: i) meteorological changing, ii) economic damage, iii) water damage and iv) insect's damage, revealing the mainly climate change effects perceived by Hungarian farmers (Figure 1).




Source: authors'eleboration

Figure 1: EFA plot on farmers' risk perception.

The first factor, defined as meteorological changes construct, concerns the perception of increasing temperature and decreasing rain while water damage means perception of floods caused by meteorological events.

The insects damage and economic damage indicate the pests and diseases damages affecting crops, and a decrease in crop quality and yield due to climate change respectively. The factor loading of each item is shown in Table 5 ranging from 0.72 to 0.93.

As reported in Table 6, the findings reveal that all climate change effects (meteorological changing, economic damage, water damage and insect's damage) influence positively the probability of Hungarian agricultural farms to use agro-meteorological data to improve their agronomic and economic performances.

Meteorological events caused by temperature (2.13***) and the presence of pests, pathogens, and diseases (2.01***) are particularly strongly and positively correlated with the likelihood that

| Variables | Item | Meteorological changing | Water damage | Insects damage | Economic damage |
|---|---|---|---|---|---|
| k1 | The weather became volatile | 0.92 | | | |
| k2 | The average temperature has risen | 0.93 | | | |
| k5 | The quality of my produce has deteriorated | | | | 0.82 |
| k6 | Yields have fallen | | | | 0.81 |
| k9b | Soil degradation water | | 0.79 | | |
| k9d | Waterlogging | | 0.82 | | |
| k9e | Flood | | 0.72 | | |
| k9h | Emergence of new pests | | | 0.93 | |
| k9i | Emergence of new pathogens and diseases | | | 0.92 | |

Note: * varimax blank 0.6.
Source: authors'eleboration

Table 5: Exploratory factor analysis (EFA) results.

agricultural operators will use agro-meteorological data as an innovation tool to forecast events and thus attempt to avoid damage caused by climate change.

The perception of water damage (1.83**) is also positively correlated with the likelihood of utilizing forecasting data, whereas the perception of a decline in production quality and yield (-0.66*) as an economic risk appears to be negatively correlated with the likelihood of utilizing agro-meteorological data. Additionally, the manager's education is strongly connected (1.78**) with the possibility of using agrometeorological data.

| | *Coeff.* | *Odds ratio* |
|---|---|---|
| Economic damage | -0.415 | -0.66** |
| Meteorological changing | 0.757 | 2.13*** |
| Water damage | 0.607 | 1.83** |
| Insects damage | 0.696 | 2.01*** |
| Manager's education | 0.578 | 1.78** |

Note: ***, ** Indicate significance at 0.01 and 0.05 levels, respectively.
Source: authors'eleboration

Table 6: Logit results on agrometeorological data.

Results in Table 7 showed the that the probability of a farm to adopt new warm and floods resistant crop varieties is positively associated to the perception of meteorological change (1.66**), water damage (1.63*), and insects damage (2.91***). Conversely, the probability to cultivate new crop varieties seems not affected by the perception of economic loss due to climate change. Additionally, the manager's education positively affects (1.81**) the possibility of using new varieties.

| | *Coeff.* | *Odds ratio* |
|---|---|---|
| Economic damage | 0.096 | 1.10 |
| Meteorological changing | 0.505 | 1.66** |
| Water damage | 0.489 | 1.63* |
| Insects damage | 1.070 | 2.91*** |
| Manager's education | 0.595 | 1.81** |

Note: ***, **, * Indicate significance at 0.01, 0.05, and 0.10 levels, respectively.
Source: authors'eleboration

Table 7: Logit results on the use of new warm and floods resistant crop varieties.

As for the adoption of ice and frost protection improvements as innovative strategy to reduce negative effects of climate change, Table 8 indicate that the perception of economic damage (1.62***), water damage (2.18***), as well as insects damage (1.62***) increase the probability of Hungarian farmers to use novel techniques for minimizing cold and frost damages. Moreover, none statistically significant effect has the perception of changing of temperature and precipitation as well as the manager's education level in adopting innovative technologies for ice and frost protection.

| | *Coeff.* | *Odds ratio* |
|---|---|---|
| Economic damage | 0.483 | 1.62** |
| Meteorological changing | -0.042 | 0.96 |
| Water damage | 0.779 | 2.18*** |
| Insects damage | 0.484 | 1.62** |
| Manager's education | 0.169 | 1.18 |

Note: ***, ** Indicate significance at 0.01 and 0.05 levels, respectively.
Source: authors'eleboration

Table 8: Logit results on ice and frost protection improvements.

## Discussion

The study revealed interesting results can assist clarify how perceptions of climate change-related dangers impact Hungarian farmers' adoption of mitigation techniques.

Previous studies have already discussed how experiences related to natural disasters have had indirect impacts on economic and technological strategies through the application of innovations by farmers (Li et al., 2021).

This section provides a briefs discussion by responding to five research questions.

**RQ1**. Concerning the first research question, the findings of the factor analysis indicate that the main factors perceived by Hungarian farmers as compromising the agricultural productivity are damages related to temperature volatility (Ricart et al., 2022), and in particular the increase in average temperature. In addition, farmers believe that important damages are also related to flooding resulting in soil erosion (Oh et al., 2023; Angra et al., 2022); as well as to the damages resulting from new pathogens and diseases; that cause economic damages related to a reduction of the quality and yield of crops (Datta et al., 2022).

**RQ2.** Related to the second research question, the key finding is that the perception of temperature and precipitation changing, water and insect damage increase the probability that farmers use agrometeorological data (Guo et al., 2023). A possible explanation of this outcome is that the perception of a damage due to insects, or caused by a flood, prompts the farmer to use agrometeorological data to carry out effective insect treatments, or to prevent flooding or drought

conditions by implementing ad hoc interventions. This result is confirmed by scientific studies where the use of agrometeorological data is helpful to assist irrigation management (Culman et al., 2019) as well as the control of pests and diseases (Orlandini et al., 2020). Conversely, our findings revealed that the use of agrometeorological data decreases as the economic damage increases and consequently the probability to adopt this kind of innovation is lower. It also makes sense since several scientific papers pointed out that the access to sets of weather data could be quite expensive (Chirico and Bonavolontà, 2020).

**RQ3.** As regards the third research question, our results confirm that utilizing new warm and floods resistant crop varieties is a fresh challenge for adopting new production techniques in response to changing climatic conditions. Consequently, the possibility of adopting new varieties is favorably impacted by the farmer's impression of changing temperature and precipitation, as well as the farmer's assessment of water and insect damage (Raza and Bebber, 2022). These results are coherent with previous literature whereby the farmer's perception of increasing temperature as well as the risk of waterlogging and the consequent dissemination of pests and diseases could push farmer to adopt crop varieties more resistant to drought, waterlogging or to such insects and diseases (Juroszek et al., 2022). In this direction, a recent study of Harsányi et al. (2021) underlines the introduction of new varieties of sunflower resilient to drought as an important strategy to overcome the yield loss in Hungary. Moreover, the outcomes of our research are in line with Aristya et al. (2021), who have highlighted how the introduction of new crop varieties resistant to pests and diseases helps to increase crop yield.

**RQ4.** Pertaining to the fourth study question, the study findings revealed the positive effect of perceived economic damage, perceived water damage and the perceived insects damage on the farmer's probability to adopt innovative techniques for ice and frost protection. This result is quite in line with a previous study (Wisniewski et al., 2008) that has previously emphasized the significance of frost protection by inhibiting the ice propagation from outside to inside plants. Consequently, the widespread perception is that the economic damage, water damage and damage caused by insects could prompt farmers to protect their crops from ice and frost, maybe because freezing reduces the vigour of plants thus exposing them to pests and diseases attacks (Chahal et al., 2022; Hamam et al., 2022b). Accordingly, protecting plants from ice and frost could be seen an effective tool for reducing yield loss and economic damage.

**RQ5.** Regarding the fifth study question, our findings show that the education level of farmers seems to impact the probability of adopting agro-meteorological data. The positive effect of manager education variable on the probability to adopt weather forecasts data agrees with scientific literature (Nkuba et al., 2023), thus confirming that the innovation adoption in agriculture is positively related to a high level of education and know-how of farmer. In agreement with what has been said, we also found the positive effect of farmer's level of manager education on the probability to adopt new varieties for mitigating the consequences of climate change on agricultural crops.

## Conclusion

Climate change is becoming the main issue for all over the world. Hungary, which is located in the central Europe, is not exempt from this problem, suffering of animal devastation, yield loss and risk of hunger caused by climate change consequences, particularly droughts and floods. However, little is known about the farmer's perception on climate change consequences on agricultural crops and on their propensity to adopt technical innovations for overcoming negative effects of climatic events.

Given the paucity of studies conducted on the perception of climate change in middle Europe, the novelty of this study is to fill this gap in the literature by analyzing the most prominently perceived negative effects of climate change in EU eastern country and how these may affect the propensity of Hungarian farmers to adopt technological innovations such as agro-meteorological data, new varieties, and ice and frost protection.

The main results showed that the adoption of the technical innovations included in this study depends on the farmer's perception of climate change consequences on agricultural crops. Moreover, the managerial capability of farmer also affects the probability to adopt agrometeorological data and new varieties.

The results of the research will be of considerable interest to stakeholders and policymakers in their efforts to increase the use of technologies to safeguard Hungarian crops against climate change. A helpful outcome of the research is enhancing farmers' understanding of the effects

of climate change, for instance by holding seminars with farmers to discuss the danger of adverse effects of climate change on agriculture. Facilitating the transmission of adaptation-related knowledge and expanding farmers' social networks should inspire farmers to advocate for more effective climate change mitigation strategies. On the other side, our findings show that policymakers could provide farmers with economic incentives to encourage the adoption of innovations, such as the utilization of agrometeorological data. Increasing the farmer's administrative capacity to implement technological innovation is also required. In this regard the EU, in the 2021-2027 multiannual financial framework, is investing significant amounts of its budget in climate-related expenditures. All climate adaptation actions are to be integrated into all major EU spending programs, and to this end a monitoring system has been established to ensure that these goals are met. It is assumed, therefore, that these investments will support the appropriate instruments to mitigate climate change.

Nevertheless, this research is not exempt from some limitations. The main of them can be attributed to the use of a convenience sample of farmers, besides being referred to a particular EU eastern country. Another constraint of this paper relies on the limited number of innovative climate change adaptation tools. Consequently, this study gives way to incremental research based on a representative and cross-national sample. However, comparable research might be undertaken in the next future in other European nations to observe different perspectives of farmers of neighboring countries about climate change. Additionally, it would be useful to investigate other variables or obstacles that impact the chance of utilizing additional technical innovations to reduce the output losses due to climate changes.

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# Estimating Household Price and Income Elasticities for Animal-Sourced Food: The Case of Bengkulu Province, Indonesia

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## Abstract

Bengkulu is one of the provinces in Indonesia where household protein consumption is still below the national protein recommended allowance. This paper examines the effect of price, income and socio-demographic factors on household demand using the Quadratic Almost Ideal Demand System (QUAIDS) model and data from the Indonesian National Socio-Economic Survey (Susenas) in March 2021, which includes 5,079 households. The QUADS parameters were estimated using the Iterated Nonlinear Seemingly Unrelated Regression technique with theoretical restrictions imposed. The estimated parameters from the model were utilized to derive price and income elasticities for animal-derived foods. Empirically, it was found that fish is the most elastic animal-sourced food with a demand elasticity of 4.44%, followed by beef (2.78%), milk (1.94%), poultry (1.54%), and eggs (0.82%). Fish substitutes for beef, chicken, and eggs when prices increase but is complementary to milk. Four animal-sourced food groups, namely fish, beef, milk, and poultry, are luxury items, with income elasticities of 2.57%, 2.39%, 2.22%, and 1.36%, respectively. In contrast, eggs were found to be a normal good with an income elasticity of 0.53%. Fish and beef are very elastic; thus, the government can use pricing strategies and implement policy to increase poultry and eggs production so that daily protein requirements of 57 grams per capita per day are reached in Bengkulu province.

## Keywords

Animal sourced food, Bengkulu Province, elasticity, QUAIDS.

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## Introduction

The pattern of household consumption of animal-derived protein foods can be seen as one indicator that can be used to measure the level of household welfare (Tiberti and Tiberti (2018); Giwa and Choga (2020)). According to Jackson and Marks (1999) and Donkoh et al. (2014), households with high-income levels tend to have smaller food expenditures than those with lower levels. This generally confirms Engle's (1857) law, which notes an inversed relationship between income and the amount of expenditure on food. In addition, Khoiriyah et al. (2020) assert that households with higher income levels tend to have higher economic welfare, which leads to higher levels of non-food consumption, assuming that the nutrition and dietary requirements of the household are met. Prior to the COVID-19 pandemic, Indonesia was experiencing rapid economic growth; however, recent statistics reveal that GDP in the first quarter of 2020 slowed to around 3% (Paramashanti, 2020). According to the Asian Development Bank (2019), around 22 million Indonesians had already experienced hunger between 2016-2018. The decline in GDP growth and the shock placed on the global food system due to the COVID-19 pandemic could increase the prevalence of hunger in Indonesia in the future.

One of the key objectives of the Sustainable Development Goals (SDG) is to eradicate hunger and foster food and nutrition security in developing countries. Adequate protein consumption can be used to assess a community's nutritional status and the success of government policy regarding food, agriculture, and health (Ariani, 2010; Salvia

et al., 2019). However, studies focusing on household consumption patterns of animal-sourced food, specifically animal protein in Bengkulu province, are rare but can provide vital information regarding welfare and consumer response to price changes.

Efficient and reliable food elasticity estimates are essential tools used in developing policies geared toward improving consumer welfare and overall well-being, especially in developing nations. This is because elasticities offer an opportunity to study and understand consumer consumption behavior. For example, according to Singh et al. (2011) and Lokuge and Edirisinghe (2015), reliable price and income elasticities help to understand the relationship between prices and income as it relates to consumer demand. In addition, it can also be used to develop effective campaigns and marketing strategies to improve consumer welfare. Therefore, calculating elasticities for various animal-sourced food groups for Bengkulu province could help better understand consumer behavior and can be used as tools to develop effective policies that will help improve the well-being of households in the region.

The law of demand ascertains that there exists an inversed relationship between the price and quantity demanded of a good. The lower the price of an item, the more quantity demanded of those goods increases, and vice versa (Anindita, 2008; Akram, 2020). Apart from price, the demand for goods by consumers is influenced by many other factors, such as income, the price of other goods, tastes and preferences, and future expectations (Ackah and Appleton, 2007; Martin and Ivanic, 2016; Giwa and Choga, 2020). According to Wahyuni et al. (2016), three factors are most important in influencing household consumption: prices, income, and preferences. In addition, other demographic factors such as the area of residence, education level of household members, household size, habits, and culture are all determinants of household demand (Abramovsky et al., 2012; Giwa and Choga, 2020; Negi, 2018).

Research on food demand systems using the Quadratic Almost Ideal Demand System (QUAIDS) approach has been carried out in various countries, such as Italy (Jones and Mazzi, 1996), Brazil (Coelho and Aguiar, 2007), Nigeria (Elijah Obayelu et al., 2009), Kenya (Korir et al., 2018), Saudi Arabia (Al-Shuaibi, 2011; Alnafissa and Alderiny, 2019), Pakistan (Akram, 2020), and Indonesia (Umaroh and Pangaribowo, 2007; Anindita et al., 2019). Demand system studies have also been carried out by Anderson and Blundell (1983) in Canada, Hayes et al. (1990) in Japan, Henneberry and Hwang (2007) in South Korea, Ravikumar et al. (2000), Roley (1983) and Haag et al., (2009). However, similar studies are rarely found in Indonesia, especially in the Bengkulu province. Therefore, this study seeks to analyze the effect of prices, income and socio-demographic factors on animal-sourced food demand using the QUAIDS model. This study uses data on household consumption and expenditure on animal-sourced food. Data was collected by the Central Bureau of Statistics (BPS) from the 2021 Indonesian National Socio-Economic Survey (Susenas) of 5,037 households. Parameter estimates of the QUAIDS model with theoretical restrictions imposed were obtained using Iterated Nonlinear Seemingly Unrelated Regression (ITNL-SUR). Post-estimation, the parameter estimates of the QUAIDS are used to compute price and income elasticities. The estimated parameters will be used to calculate and interpret the animal-sourced food groups' own-price, cross-price, and income elasticities. Showing whether animal-sourced food is elastic, inelastic, or unitary elastic. The study results can be used to develop a policy geared towards improving animal protein consumption and food and nutrition security in Bengkulu province, Indonesia.

## Materials and methods

### Model specification: Quadratic Almost Ideal Demand System (QUAIDS)

The empirical literature is proliferated with studies regarding demand analysis. Over the last two decades, the almost ideal demand system (AIDS) model developed by Deaton and Muellbauer (1980) is one of the most widely used demand models. Although there are other functional forms in the empirical literature that can be used in demand analysis, the AIDS model remains popular among scholars due to it having many favorable properties. Such properties include aggregating perfectly over consumers, having a functional form consistent with available data, satisfying the axiom of choice exactly, and being relatively easy to estimate (Barnett and Seck, 2008). Additionally, the AIDS model allows for the theoretical restrictions of homogeneity and symmetry to be imposed on the parameters and tests empirically. Although many of the existing functional forms in the literature

possess many of the desirable properties noted above, only the AIDS model possesses all of them at the same time. However, demand analysis studies regarding households tend to favor the quadratic version of the AIDS model (QUAIDS) put forward by Banks et al. (1997). According to Banks et al. (1997), some consumer preferences are quadratic contrary to the linear form of the AIDS; therefore, the QUAIDS specification is more appropriate, especially when studying household demand. In addition, the QUAIDS is a theoretically consistent model and possesses all of the favourable demand properties of the traditional AIDS model.

Formally, the share equations of the QUAIDS model, according to Banks et al. (1997), are as follows:

$$\boldsymbol{w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} ln p_j + \beta_i ln \left[\frac{m}{a(p)}\right] + \frac{\lambda_i}{b(p)} \left\{ln \left[\frac{m}{a(p)}\right]\right\}^2 + \varepsilon_i} \quad (1)$$

Where:

$w_i$ = a household's expenditure share for commodity $i$, and it is defined as

$$\boldsymbol{w_i \equiv \frac{p_i q_i}{m} and \sum_{i=1}^{n} w_i = 1} \quad (2)$$

$q_i$ = the quantity of each commodity consumed

$lnp_j$ = is the natural logarithm of the price of the $j^{th}$ animal-sourced food commodity group

$m$ = is the total household expenditure for animal-sourced food consumption

*ln a(p)* = is a price index given in natural logarithm, usually the stone price index given as $\ln p_j = \Sigma_{j=1} w_i \ln p_j$

*b(p)* = is a price aggregator, which is given as

$$b(p) = \prod_{t=1}^{k} p_i^{\beta_i}$$

$\varepsilon_i$ = is a white noise error term

$\alpha_i$, $\gamma_{ij}$, $\beta_I$ and $\lambda_i$ = are all parameters to be estimated in each share equation

In order to be consistent with demand theory, the theoretical restrictions of adding-up, homogeneity, and symmetry are imposed during estimation as follows:

- Adding-up: $\sum_{i=1}^{n} \alpha_1 = 1, \sum_{i=1}^{n} \beta_1 = 0,$
$\sum_{i=1}^{n} y_{ij} = 0, \sum_{i=1}^{n} \lambda_i = 0$ (3)
- Homogeneity: $\sum_{i=1}^{n} y_{ij} = 0$ (4)
- Symmetry: $\gamma_{ij} = \gamma_{ji}$ (5)

Where $i$ is for the $i^{th}$ share equation and $j$ is for the $j^{th}$ commodity. Equation (1) highlights the traditional QUAIDS model. However, this specification does not consider any of the socio-demographic factors that might have an impact on household animal-sourced food demand. Socio-demographic factors can affect household behavior regarding demand and expenditure allocation among goods (Alboghdady and Alashry, 2010; Tefera et al., 2018). Therefore, they should be included and accounted for in the QUAIDS model highlighted in the equation (1). The 'demographic scaling' method was used to consider the effect of socio-demographic factors that might affect household demand for animal-sourced food in this study, as Poi (2012) suggested. In this approach, the effects of a change on the demographics are close to the effect of the price change of animal-sourced foods. Considering $z$ as a vector of S household characteristics, $z$ is a scalar representing the household size in the simplest case. Let $e^R(p,u)$ represent the expenditure function of a reference household with just a single adult. For each household, Ray's (1983) method uses an expenditure function of household characteristics without controlling for changes in consumption patterns. The second term control for a change in relative prices and actual goods consumed. Following Ray (1983) and Poi (2012), QUAIDS is parameterized as:

$$\boldsymbol{\overline{m_o}(z) \text{ as } \overline{m_o}(z) = 1 + \rho z} \quad (6)$$

Where $\overline{m_o}$ is income deflated by the equivalence scale and $\rho$ is a vector of household characteristics parameters to be estimated. The expenditure share expenditure equation highlighted in equation (1) now takes the following form:

$$\boldsymbol{w_i = \alpha_i + \sum_{j=1}^{K} \gamma_{ij} ln p_j + (\beta_i + \eta_i' z) ln \left\{\frac{m}{\overline{m_o}(z)\alpha(p)}\right\} + + \frac{\lambda_i}{b(p)c(p,z)} \left[ln \left\{\frac{m}{\overline{m_o}(z)\alpha(p)}\right\}\right]^2} \quad (7)$$

Where $\boldsymbol{c(p,z) = \prod_{j=1}^{k} p_j^{\eta_i' z}}$ (8)

Moreover, $\eta_i'$ represents the $j^{th}$ column of the $s$ x $k$ parameter matrix $\eta_i'$ (Poi, 2012)[1].

The adding-up condition requires that $\sum_{j=1}^{K} \eta_i' = 0$ for $i = 1,\ldots,s$. (9)

The parameters are estimated by Iterated Nonlinear Seemingly Unrelated Regression (ITNL-SUR) technique in Stata 17. In order to avoid singularity

[1] Full details of how demographic parameters are incorporated into the QAIDS model is outline in Poi (2012) and Ray (1983).

of the variance co-variance matrix, one of the share equations for animal goods is excluded during estimation and then obtained using the adding-up restriction.

Now that a theoretically consistent and viable model is specified for estimating parameters, price and income elasticities can be calculated. Marshallian own-price and cross-price elasticities for each animal-sourced food group are derived using equations (10) and (11), respectively.

$$\boldsymbol{\varepsilon_{ii}^{M}} = -\boldsymbol{\delta_{ij}} + \frac{\mathbf{1}}{\boldsymbol{w_i}}\left(\boldsymbol{\gamma_{ij}}\left[\boldsymbol{\beta_i} + \boldsymbol{\eta_i'z} + \frac{\mathbf{2}\boldsymbol{\lambda_i}}{\boldsymbol{b(p)c(p,z)}}\boldsymbol{ln}\left\{\frac{\boldsymbol{m}}{\boldsymbol{\overline{m_o}(z)\alpha(p)}}\right\}\right] * \right.$$
$$\left. * \left(\boldsymbol{\alpha_j} + \sum_1 \boldsymbol{\gamma_{ij}} \boldsymbol{lnp_j}\right) - \frac{(\boldsymbol{\beta_i}+\boldsymbol{\eta_i'z})\boldsymbol{\lambda_i}}{\boldsymbol{b(p)c(p,z)}}\left[\boldsymbol{ln}\left\{\frac{\boldsymbol{m}}{\boldsymbol{\overline{m_o}(z)\alpha(p)}}\right\}\right]^2\right) \quad (10)$$

$$\varepsilon_{ij}^{M} = -\delta_{ij} + \frac{1}{w_i}\left(\gamma_{ij}\left[\beta_i + \eta_i'z + \frac{2\lambda_i}{b(p)c(p,z)} ln\left\{\frac{m}{\overline{m_o}(z)\alpha(p)}\right\}\right] * \right.$$
$$\left. * \left(\alpha_j + \sum_1 \gamma_{ij} lnp_j\right) - \frac{(\beta_i+\eta_i'z)\lambda_i}{b(p)c(p,z)}\left[ln\left\{\frac{m}{\overline{m_o}(z)\alpha(p)}\right\}\right]^2\right) \quad (11)$$

All of the parameters in equations (10) and (11) are previously defined, except $\varepsilon_{ii}^{M}$ and $\varepsilon_{ij}^{M}$ which are own- and cross-price elasticities, respectively. Delta ($\delta_{ij}$) is the Kronecker delta which takes the value of 1 if we are calculating own-price elasticity and zero otherwise. Marshallian own-price elasticities measure the changes in quantity demanded of a particular animal-sourced food group due to changes in its price. In contrast, cross-price measures the changes in quantity demanded of a particular animal-sourced food group due to changes in the price of another animal-sourced food group. The expenditure or income elasticity for each animal-sourced food group is also calculated by using the formula highlighted in equation (12) below:

$$\boldsymbol{\varepsilon_{ii}^{c}} = \boldsymbol{\varepsilon_{ii}} + \boldsymbol{\mu_i w_i} \quad (13)$$

$$\varepsilon_{ij}^{c} = \varepsilon_{ij} + \mu_i w_j \quad (14)$$

All parameters are defined in equations (13) and (14) previously, except $\varepsilon_{ii}^{c}$ and $\varepsilon_{ij}^{c}$ which are Hicksian own- and cross-prices elasticities.

### Data and source

The data used in this article is secondary data from the National Socio-economic Survey (Susenas) in March 2021. The data analyzed were household consumption and expenditure on animal-sourced food groups, region (urban and rural), the number of household members or household size, and total expenditure on all animal-sourced food groups. The approach used to obtain data on animal-sourced food prices is the ratio of the amount of animal-sourced food consumed by households divided by the price paid by households. This is because price data are not available on household consumption and expenditure. The animal-sourced food groups included in this study were eggs (chicken eggs, local chicken eggs, and duck eggs), poultry (local chicken meat and chicken meat), beef, fish (fresh fish and shrimp including fish, shrimp, squid, and shellfish) as well as milk (milk powder and infant milk). The sample of this research is 5,079 households. All estimation was done in STATA 17.

## Results and discussion

### Estimated parameters of animal-sourced food demand system models

The results of the QUAIDS model with socio-demographic factors and theoretical restrictions imposed for the five animal-sourced food groups are presented in Table 1, which was derived using equation (7). From Table 1, it can be observed that most of the estimated parameters are highly statistically significant. The effect of the own-price variables in each of the respective share equations was found to be positive and highly statistically significant, except for the fish share equation, which was found to be negative. Furthermore, ceteris paribus, it is suggested that a 1% increase in the price of eggs, poultry, beef, and milk is expected to, on average, bring about a 0.389%, 0.568%, 0.060%, and 0.146% increase in expenditure share, respectively. These results are similar to those found by Kharisma et al. (2020), who note that own-price tends to have a direct relationship with expenditure share. However, for the fish share equation, it is suggested that a 1% increase in the price of fish is expected to bring about, on average, a 0.052% decrease in expenditure share, ceteris paribus. Similar results for fish were found by Nendissa et al. (2021). Poultry share had the most responsiveness to changes in price with respect to expenditure share, while beef had the least response.

Table 1 also highlights the income variable for each animal-sourced food share equation. The parameters associated with income in each share equation were found to be highly statistically significant. It was discovered that an increase in household income is expected to increase the expenditure shares of eggs, beef, and milk but a decrease in the expenditure share of poultry and fish. According to Hayat et al. (2016), an increase in the income of households is expected to increase the demand for dairy

and meat products. Regarding the negative relationship between income, poultry and fish, similar results were also found by Kharisma et al. (2020), who notes that this is likely to occur when household income shifts the demand towards more expensive sources of animal-sourced food such as meat and milk. In addition, the results for poultry and fish validate Bennet's Law in Bengkulu province, Indonesia, which states that higher household income levels tend to shift consumption towards better quality foods. According to Rathnayaka (2019), a negative sign attached to the income variable usually means the good is a necessity, while a positive sign means that the good is a luxury good. Hence, the negative sign attached to the income variable in both the poultry and fish share equation suggests that these foods are necessities. In contrast, other animal-sourced food groups are luxuries.

The study also investigated the impact of socio-demographic factors on animal-sourced food expenditure share, which is presented in Table 1. A regional dummy variable was added to each expenditure share equation to determine if there is any difference in animal-sourced food expenditure share between households living in rural areas and those living in urban areas. It was found that households living in urban areas have a higher expenditure share on eggs, beef, and fish than those in rural areas. However, households living in urban areas have less poultry and milk expenditure compared to rural households. The results for poultry and milk show that these animal-sourced food groups play a significant role in fulfilling nutritional requirements in rural areas in Bengkulu. The other socio-demographic factor added to each share equation was the household size which was defined as the number of persons living in the home of each household. It was found that household size statistically impacted the expenditure share of each animal-sourced food group. However, the effect size based on the magnitude of the estimated parameter was relatively small. In addition, it was found that household size negatively affected expenditure shares for eggs and milk. This suggests that expenditure on eggs and milk decreases as household size increases. Deaton and Paxson (1998) note that households with more members consume less food. Abdulai (2002) notes that household parameters negatively affect consumption as large families are often forced to adjust consumption patterns and purchase relatively cheaper foods. This could be because households with more people have more diverse diets and are less likely to purchase eggs and milk as income is allocated toward purchasing other preferred foods or affordable items. It was

| Parameter | Animal Sourced Food Share Equation | | | | |
|---|---|---|---|---|---|
| | Eggs Share | Poultry Share | Beef Share | Fish Share | Milk Share |
| Constant | 0.566*** | -1.341*** | 0.728*** | 0.018 | 1.028*** |
| | (0.017) | (0.022) | (0.011) | (0.013) | (0.014) |
| Eggs Price | 0.398*** | -0.259*** | -0.006*** | -0.039*** | -0.095*** |
| | (0.003) | (0.003) | (0.005) | (0.001) | (0.011) |
| Poultry Price | -0.259*** | 0.568*** | -0.192*** | 0.070*** | -0.187*** |
| | (0.005) | (0.011) | (0.005) | (0.005) | (0.007) |
| Beef Price | -0.006** | -0.192*** | 0.060*** | 0.012*** | 0.127*** |
| | (0.005) | (0.005) | (0.003) | (0.002) | (0.003) |
| Fish Price | -0.039*** | 0.070*** | 0.012*** | -0.052*** | 0.009*** |
| | (0.001) | (0.005) | (0.002) | (0.001) | (0.002) |
| Milk Price | -0.095*** | -0.187*** | 0.127*** | 0.009*** | 0.146*** |
| | (0.011) | (0.007) | (0.003) | (0.002) | (0.006) |
| Expenditure | 0.045*** | -0.318*** | 0.122*** | -0.012*** | 0.162*** |
| | (0.003) | (0.003) | (0.002) | (0.002) | (0.003) |
| Expenditure2 | 0.015*** | -0.021*** | 0.005*** | -0.002*** | 0.003*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Region (Urban =1) | 0.002*** | -0.004*** | 0.001*** | 0.001*** | -0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Household Size | -0.001*** | 0.001*** | 0.000*** | 0.000*** | -0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |

Note: *** p <0.01, ** p <0.05, * p <0.1. Standard errors in parentheses
Source: Own calculation based on data from Susenas, March 2021

Table 1: Parameter estimates of QUAIDS models for animal sourced food demand.

also found that household size positively affected poultry, beef, and fish expenditure share. These results are not surprising as poultry, beef, and fish are significant protein sources in Bengkulu; therefore, having more household members would mean that expenditure would increase on these animal-sourced foods.

## Marshallian price elasticities

Having reliable price and income elasticities available can help to understand household consumption patterns and behavior. This can then help develop and implement an effective policy geared towards improving household welfare and overall well-being. Using the estimated parameters in Table 1, we calculate price and income elasticities for a household in Bengkulu province. Marshallian or uncompensated price elasticity has a price and income effect. It measures the degree of responsiveness of the quantity demand and demand due to changes in prices and income. Table 2 presents the Marshallian own-price and cross-price elasticities for animal-sourced foods in Bengkulu province. In Table 2, Marshallian own-prices elasticities are given on the diagonal. All own-price elasticities for animal-source food groups are statistically significant at the 1% level and carry the expected negative sign, which is consistent with the law of demand, which states that there is an inversed relationship between prices and quantity demanded. It must be noted that although there is a negative sign attached to the own-price elasticities, interpretation ignores this negative sign and considers the elasticity value in absolute terms. In addition, an elasticity value greater than one in absolute terms would mean that the good in question has elastic demand or is very responsive to changes in its price. In contrast, a good with an elasticity value less than one in absolute terms would suggest that the good has inelastic demand or is less responsive to changes in its price. Elasticity values are also interpreted with the ceteris paribus assumption. For instance, in Bengkulu province, the own-price elasticity for eggs was found to be 0.82. Therefore, ceteris paribus, a 1% change (increase or decrease) in the price of eggs is expected to bring about, on average, a 0.82% change (decrease or increase) in the number of eggs demanded by households in Bengkulu province.

In Bengkulu province, all animal-sourced food groups were found to have elastic demand, or they are highly responsive to changes in prices, except for eggs which were found to have inelastic demand. Fish was found to be the most elastic animal-sourced food among all animal-sourced foods, with a demand elasticity of 4.44, which means that a 1% change in fish prices is expected to bring about, on average a 4.44% change in the quantity of fish demanded by households in Bengkulu province. This result is similar to those found by Nendissa et al. (2021) and Rianti and Khoiriyah (2021), who notes that fish had highly elastic demand. However, finding fish to be the most elastic among all other animal-sourced food groups is interesting for Bengkulu province since previous studies were done in different parts of Indonesia, see Rianti and Khoiriyah (2021), Khoiriyah et al., (2019), Khoiriyah et al., (2020) and Maula et al., (2019), found beef to be most elastic animal-sourced food group among other sources of animal-sourced food. This result for Bengkulu might be explained by the fact that the monthly per capita expenditure of fish/shrimp/shellfish/squid is Rp. 36,238, meat group of Rp. 16,594, eggs, and milk Rp. 25,428.

| Food Group | Eggs | Poultry | Beef | Fish | Milk |
|---|---|---|---|---|---|
| Eggs | **-0.816** | 0.162 | 0.026 | 0.032 | 0.064 |
| | **(0.003)** | (0.003) | (0.001) | (0.002) | (0.002) |
| Poultry | -0.155 | **-1.539** | 0.080 | 0.091 | 0.159 |
| | (0.006) | **(0.007)** | (0.003) | (0.003) | (0.004) |
| Beef | -0.327 | 0.826 | **-2.778** | 0.544 | -0.655 |
| | (0.038) | (0.039) | **(0.044)** | (0.028) | (0.035) |
| Fish | -0.516 | 1.564 | 0.779 | **-4.444** | 0.047 |
| | (0.055) | (0.057) | (0.037) | **(0.050)** | (0.047) |
| Milk | -0.511 | 0.424 | -0.177 | -0.015 | **-1.941** |
| | (0.016) | (0.017) | (0.010) | (0.010) | **(0.018)** |

Note: Standard errors in parentheses.
Source: Own calculation based on data from Susenas, March 2021.

Table 2: Marshallian own-price and cross-price elasticities.

Bengkulu fish group expenditure is far higher than the average national expenditure of only Rp. 33,620 (BPS, 2019). Whereas the consumption of some animal-sourced foods in Indonesia is Rp. 67,237. Beef was also found to have high responsiveness to changes in price, followed by milk and poultry, which have own-price elasticities of 2.78%, 1.94%, and 1.54%, respectively.

Table 2 also shows the cross-price elasticity of animal-sourced food. Cross-price elasticity is used to explain the relationship that exists between two goods. It looks at how changes in the price of one good affect the demand for another good. It speaks to whether the relationship between two goods is substitution or complementary. A positive cross-price elasticity would suggest that both goods are substitutes. However, a negative cross-price elasticity would suggest that both goods might be complements. Substitute good tend to have inversed relationships; that is, changes (increase or decrease) in the price of one good is expected to bring about changes (decrease or increase) in demand for another. Complementary goods, on the other hand, tend to have a direct relationship in that a change (increase or decrease) in the price of one good is expected to bring about a change (increase or decrease) in demand for another good. For Bengkulu province, cross-price elasticities were primarily positive, suggesting that substitution relationships existed among various animal good groups. For instance, fish has substitution relationships with beef, poultry, and eggs but is complementary with milk. A 1% increase in the price of fish is expected to increase the household demand for beef by around 0.54%, while a 1% increase in the price of fish is expected to decrease household milk demand by around 0.01% on average. A 1% increase in beef price increases household demand for fish by around 0.78%. It means the substitute for beef is fish in Bengkulu province. Poultry meat was found to have substitution relationship with all other animal-sourced food sources. An increase in the price of poultry meat by 1% increased household demand for fish by 1.56%, beef by 0.83%, milk by 0.42%, and egg by 0.16%.

### Hicksian price elasticities

Hicksian or compensated price elasticity are elasticities when there is only the effect of price changes. Hence, they are often referred to as elasticity of substitution. In addition, unlike Marshallian elasticities, which have both price and income effects, Hicksian price elasticities only have price effects which means that their magnitude tends to be smaller than Marshallian elasticities. Table 3 presents Hicksian own-price and cross-price elasticities. All calculated Hicksian own-price elasticities were statistically significant and possessed the appropriate negative sign. For Bengkulu province, it was discovered that fish had the greatest response to price changes, as a 1% increase in prices, for instance, is expected to bring about, on average, a 4.40% decrease in the quantity of fish consumed by households. Beef had the second highest own-price elasticity, followed by milk and poultry. The four aforementioned animal-sourced food groups were found to have elastic demand since the elasticity values were greater than unity. However, eggs were found to have the smallest Hicksian own-price elasticity, which was 0.51. Therefore, a 1% increase in the price of eggs is expected to, on average, bring about a 0.51% decrease in household consumption. Furthermore, in Bengkulu province, eggs were found to have inelastic demand.

| Food Group | Eggs | Poultry | Beef | Fish | Milk |
|---|---|---|---|---|---|
| Eggs | **-0.514** | 0.330 | 0.038 | 0.041 | 0.106 |
| | **(0.003)** | (0.003) | (0.001) | (0.002) | (0.002) |
| Poultry | 0.620 | **-1.110** | 0.111 | 0.114 | 0.265 |
| | (0.006) | **(0.007)** | (0.003) | (0.003) | (0.004) |
| Beef | 1.032 | 1.579 | **-2.724** | 0.584 | -0.470 |
| | (0.038) | (0.039) | **(0.044)** | (0.028) | (0.035) |
| Fish | 0.946 | 2.373 | 0.836 | **-4.401** | 0.246 |
| | (0.054) | (0.057) | (0.037) | **(0.050)** | (0.047) |
| Milk | 0.751 | 1.123 | -0.127 | 0.022 | **-1.769** |
| | (0.015) | (0.017) | (0.010) | (0.010) | **(0.018)** |

Note: Standard errors in parentheses.
Source: Own calculation based on data from Susenas, March 2021.

Table 3: Hicksian own-price and cross-price elasticities.

Table 3 also presents Hicksian cross-price elasticities for animal-sourced food in Bengkulu province. The results show that there exist mainly substitution relationships between pairs of animal-sourced food. Most cross-price elasticities are positive, which means that an increase in the price of a particular animal-sourced food group would experience a decrease in household consumption in Bengkulu province as households would substitute that particular animal-sourced food with other relatively cheaper sources of animal-sourced. In addition, the results suggest that the price of a particular animal-sourced food strongly influences household consumption demand for other animal-sourced food in Bengkulu. For instance, it was found that beef and poultry are substitutes which means that a 1% increase in the price of beef is expected to bring about, on average, a 0.11% increase in household consumption demand for poultry because as the price of beef increases and poultry prices remains unchanged, poultry becomes relatively cheaper than beef, and so households would substitute beef for poultry. In addition, fish is substituted with all other animal-sourced foods. Therefore, an increase in fish prices by 1% increases household consumption of beef, eggs, poultry, and milk by about 0.58%, 0.41%, 0.11%, and 0.02%, respectively. However, it must be noted that beef and milk were found to be complements in Bengkulu province. This is because an increase in household consumption of beef would mean that more cattle would be produced, which would mean more milk would also be produced. Therefore, an increase in milk production might cause the price of milk to decrease, which makes it more affordable to Bengkulu households, thereby increasing the consumption demand for milk.

## Income elasticity and marginal expenditure share

Income is an important factor in the demand for goods and services. Income elasticity measures how demand changes as income changes. Generally speaking, it is expected that when income increases, consumer welfare improves so that they will demand more of a good. For instance, if the good is normal, there is a direct relationship between income and consumption. The income elasticity, therefore, is expected to be positive. This means that if income increases, demand for that product also increases. However, if a good is an inferior good, then there is usually an inversed relationship between income and consumption of that particular good. Hence, the income elasticity is expected to be negative because an increase in income is expected to decrease the demand for that particular good. Therefore, when it comes to Bengkulu province, all sources of animal-sourced food can be classified as normal goods as the income elasticity values are positive. Furthermore, income elasticity values greater than one would signify that the good in question is a luxury good. Income elasticity results presented in Table 4 show that fish, beef, milk, and poultry are luxuries as their income elasticities are all greater than one. For instance, fish had the highest income elasticity value, which was 2.57. This means that a 1% increase in household income is expected to bring about, on average, a 2.57% increase in household consumption demand for fish products. This result is similar to what was found by Nendissa et al. (2021) in their study of household animal-sourced food consumption in East Nusa Tenggara, Indonesia. Regarding beef, milk, poultry, and eggs, a 1% increase in household income is expected to bring about a 2.39%, 2.22%, 1.36%, and 0.53% increase in household consumption expenditure on those food groups, respectively.

Table 4 also presents the value of marginal expenditure shares (MES). The MES is used to see the long-term effects of changes in income on household expenditure for animal-sourced food (Barigozzi et al., 2012). The MES multiplies expenditure elasticity and budget share for each animal-sourced food. The results of the calculation of MES show that households in Bengkulu province allocate their income more proportionally to beef and milk. Since beef is an animal-sourced food that is luxurious and highly elastic, the local government needs to work to reduce the price of beef so that consumption increases.

| Food Group | Income Elasticity | Marginal Expenditure Share |
|---|---|---|
| Eggs | 0.532 | 0.474 |
| Poultry | 1.364 | 0.301 |
| Beef | 2.393 | 0.076 |
| Fish | 2.574 | 0.643 |
| Milk | 2.219 | 0.071 |

Source: Own calculation based on data from Susenas, March 2021.

Table 4: income elasticity and marginal expenditure share of animal sourced food.

## Policy discussion

Price elasticity of demand reveals that household fish consumption has elastic demand, which means that consumption is highly responsive to price changes. Fish makes up a large portion of household

protein consumption. According to Kharisma et al. (2020), fish consumption contributes to around 26.8% of calories derived from animal sources daily and around 2.1% of total daily calorie intake. Regarding protein consumption derived from animal-sources, in 2017, fish accounted for more than 50% of daily protein consumption. Therefore, price increases for this animal-sourced protein food group have severe implications for household food and nutrition security, especially for individuals living in rural areas. Cross-price elasticities reveal that when fish prices increase, households will substitute other sources of animal-derived proteins such as eggs, poultry, and beef. Results suggest that households' demand for poultry products will increase significantly when fish prices increase. However, if poultry supply cannot accommodate the demand increase, protein deficiency in households can be a severe problem.

Eggs were found to be least responsive to price changes, supported by price inelastic demand. Therefore, changes in egg prices lead to a less than proportionate change in the quantity demanded. Eggs are also found to be substitutes for all other animal sources of protein. According to Vanany et al. (2019), eggs are more regularly consumed than other sources of animal-derived proteins in Indonesia. This could be due to eggs being much cheaper than commodities like fish and beef in Indonesia; hence, it is expected that price increases of other animal-derived protein groups will lead to increased consumption of eggs as a source of protein. In addition, a policy to increase egg production would also aid in increasing poultry production, which has also been found to have a substation relationship with protein sources such as beef and fish. Therefore, policy regarding poultry and egg production must be developed and put in place to ensure that demand can be met since achieving daily protein dietary requirements is paramount. Shaffer (2015) notes that broiler and egg production has increased over the last few years; however, avian influenza has negatively affected production in 2015 and 2016. In order to aid domestic production of poultry and eggs, reliable biosecurity and hygiene concepts should be established to avoid severe outbreaks of diseases and to ensure good performance conditions (Ali, 2014).

In general, the own-price elasticity values were greater than income elasticities, especially for fish, beef, and eggs. This means that the most effective policy to help improve household consumption of these animal-sourced food groups would be to lower the price of these items. Government and policy officials in Bengkulu can offer subsidies to producers of fish, beef, and eggs to help cover production costs, incentivizing them to sell these animal-sourced foods at lower prices to consumers. Fish and beef had the highest own-price elasticities, which means that they are very responsive to price changes. Therefore, to foster increased consumption levels of these two animal-sourced food groups among households, the government and policy officials can use pricing strategies such as a price ceiling to set a maximum price at which these goods can be sold to help households attain higher levels of consumption. Regarding poultry and milk, income elasticities are generally larger in magnitude than own-price elasticities; hence, in order to increase consumption of these two animal-sourced food groups, it is suggested that household income should be increased. This can be done through social welfare programs and maybe food grants which would help improve household welfare in Bengkulu province. In addition, households with more individuals can be given food grants to help improve animal-sourced food consumption. These schemes can help to improve animal protein food and nutrition security and help to foster community resilience in Bengkulu province.

## Conclusion

This paper focused on analyzing animal-sourced food demand in Bengkulu province, Indonesia. This study aims to analyze the impact of changes in prices, incomes, and socio-demographic factors on animal-sourced food demand. The study utilized the Quadratic Almost Ideal Demand System (QUAIDS) model with theoretical restrictions imposed and estimated using the ITNL-SUR technique. The data used was BPS data from the 2021 Susenas data of 5,079 households. Data were analyzed using Stata 17 software. The QUAIDS model results reveal that prices, income, region of residence and household size all affected household consumption expenditure share of various animal-sourced foods. It was discovered that urban households consume more eggs, fish, and beef than rural households. However, urban households' consumption expenditure on poultry and milk is less than that of rural households. It was also discovered that household size positively affects poultry, beef and fish expenditure share while negatively impacting the expenditure shares of eggs and milk in Bengkulu province. The study also calculated price and income

elasticities for various animal-sourced foods. The results showed that in Bengkulu province, fish is the most elastic animal-sourced food among all animal-sourced foods, with an own-price demand elasticity of 4.44%. This was then followed by beef (2.78%), milk (1.94%), poultry (1.54%), and eggs (0.82%). All animal-sourced food groups were found to have elastic demand except for eggs which were found to have inelastic demand. Based on Marshallian cross-price elasticities, various substitution and complementary relationships were found to exist among animal-sourced food groups. For instance, fish is a substitute for beef, poultry, and eggs but is complementary to milk. Hicksian elasticities highlighted that most substitution relationships existed among various animal-sourced food groups. However, it was found that beef and milk were complementary goods. Income elasticity estimates reveal that all animal-sourced food groups in Bengkulu province are normal goods. However, beef, fish, poultry, and milk were found to be luxury goods. Fish were the most responsive to changes in income, with an income elasticity of 2.57%, while eggs were the least responsive to changes in income, with an elasticity of 0.53%. Finally, the study also calculated MES, which showed that households in Bengkulu province allocate their income more proportionally to beef and milk.

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# Correlation between the Greatest Agricultural Products Exporters to the EU: is Ukraine included?

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## Abstract

Due to the challenges we are experiencing nowadays, the importance of food security is gaining in its attention, making the subjects supplying agricultural production and ready-made food products more important and influential either economically or politically. The data under research are the agricultural products exports of Brazil, Canada, China, Ukraine, the United Kingdom and the United States to the European Union. The agricultural products are the goods from SITC (0+1) groups. The timeframe under analysis is eleven years – from 2012 to 2022 included. The purpose of the research is to assess whether the Ukrainian agricultural exports to the EU are correlated with the said exports of Brazil, Canada, China, the UK and the USA, and, if they are, how strong the correlation is. The comparative analysis of the dynamics, simple statistics, differences with the previous periods for the agricultural products exports of the analysed subjects to the EU was conducted. The trend lines for the analysed data during the given timeframe and two following years, were built using the appropriate function. The Pearson and Spearman correlation coefficients and their corresponding p-values were calculated and analysed.

## Keywords

Agricultural products exports, food security, EU, Ukraine, correlation.

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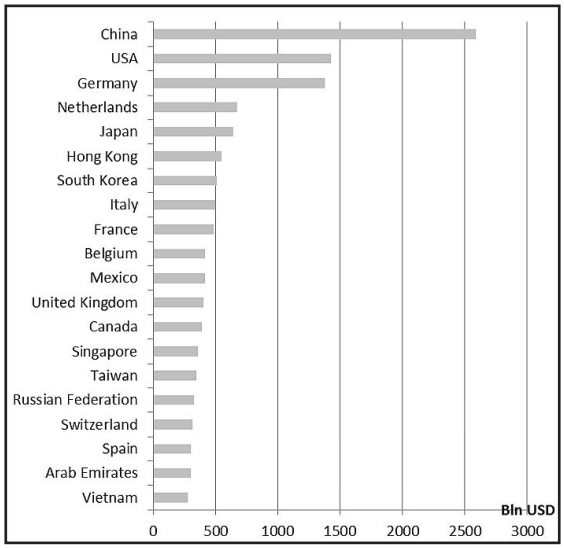
## Introduction

It is very interesting to read about the times of great changes and accomplishments in the historical chronicles, but the life is full of challenges, difficulties and the need to make fateful decisions every single moment in such times. We have such an exceptional opportunity to live through the times, which will surely be described as those of great challenges. It's hard to define the starting point of the times being talked about here. And many of those researching the topic would question the author's viewpoint, but the natural disasters indicating climate change are to be considered those bells the whole humanity should hear, comprehend and react immediately. Though there were certain attempts to make some steps towards the world industrial development alteration, they were not serious enough to make the necessary changes. And the humanity was forced to face another challenge – the COVID-19 pandemic. So, when talking about the challenges mentioned above, we can discuss the percentages and possibilities of whether they were the reaction of the nature on the irresponsible behaviour of the whole humanity or its separate representatives, the next challenge we have to face nowadays is totally the responsibility of the ill behaviour of the people thinking not a single second about other human beings – it's war. But it's not the place and time to discuss trying to assess which of the said challenges is scarier and which should be reacted on as the first. The most important is that all of them threaten the most valuable thing we all have – life, directly or indirectly. And all of them made people think very hard about food security as food is necessary for human survival (Humboldt, 2018).

Being one of the indispensable sectors of the world economy, agriculture is not only one of the highest revenue earners worldwide, but also the one, which caters to the food requirement of the world (Dutta, 2020). Agriculture is one of the oldest industries which includes the primary sectors of farming, forestry, and fishery and aquaculture (Statista, n.d.).

A country that relies on its agriculture produce for its revenue generation is building a base to a strong economy (Dutta, 2020). The last statement is debatable as a country can be highly economically developed and politically influential being absent in the list of the greatest agricultural world producers.

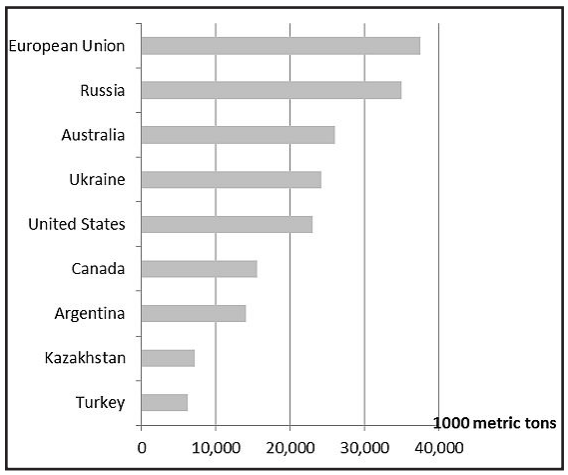
The diversity of the climatic zones, weather conditions, landscapes, water proximity, etc. bring the quick and regular food supply to the fore. So, the agricultural products exporters start to play more and more important role in the economic and therefore political life of single countries, countries unions, continents and the whole world as well. And that is more than logical as food is vitally important for the survival of every single human being in particular and the whole world in general. In addition, it is not enough to produce much food in one or several taken countries, it is more important for every country to secure such an amount of food to ensure its population survival in any given situation. And that therefore means, it is important to find the reliable exporter/s to be able to supply the said amount of food. Let's see what countries are considered to be the leading exporters in 2020 (Figure 1).




Source: author's elaboration on the basis of the data from Statista (2022(a)).

Figure 1: Leading export countries worldwide in 2020, bln USD.

What is interesting to notice in the list of countries presented in the figure given above, only the first two places are taken by the countries considered to be among the biggest ones in terms of their territories. The rest of the list can't be compared to the list of the biggest countries territorially. Another observation – the list is composed of the countries, not the countries unions, so we won't see the EU here, though, six out of top 20 leading exporters in the world are country – members of the EU. One more noticeable fact is that we don't see such serious exporters as Brazil and Argentina in the list but we see Vietnam, the country which was not considered to be worth noticed as an exporter on the global level. Let's compare the list of the leading exporters with the one of the principal exporting countries of wheat, flour and wheat products (Figure 2).




Source: author's elaboration on the basis of the data from Statista (2022(a)).

Figure 2: Principal exporting countries of wheat, flour and wheat products in 2021/2022, 1000 metric tons.

As far as one can see, six out of top ten exporters of wheat and wheat products aren't included in the list of top 20 global exporters. These are Turkey, Kazakhstan, Argentina, Ukraine, Australia and Russia. But, attention should be paid at the fact, that, in Figure 2 either separate countries or countries unions are represented, such as the EU. Such a difference between the figures presented above has become the motivation of the research presented in this article. As you can see, either territorially big or relatively small countries are included in the second list but are not included in the first one. It means, that, on the one hand, the bigger the territory is the more land a country has for agricultural production. But, on the other hand, territory is not the only and main component of the agricultural production successful functioning.

Having dug through the literature sources available in the World Wide Web, the following observations are to be paid attention at – most scientists engaged into the topics connected with agriculture in general and the exports of agricultural products in particular, concentrate their research efforts

on the role of exchange rate volatility on Iran's agricultural exports, including the modern methods of quantitative risk analysis, specifically value-at-risk and expected shortfall approach, providing comprehensive and coherent risk evaluation throughout entire distribution of outcomes (Goudarzi et al., 2012), Albanian agricultural export with the help of the gravity model approach (Braha et al., 2017), African countries' agricultural trade value chain assessment being made on the example of the case study for Tanzania's cashew nut exports (Krepl et al., 2016), the impact of exchange rate volatility on the export of agricultural products (Jamalipour et al., 2016) as well as the long and short run and causal effects of real exchange rate volatility on agricultural products export in Nigeria (Alegwu et al., 2018), in addition the effects of exchange rate and foreign policies on Iranians dates export (Khalighi and Fadaei, 2017) plus impact of exchange rate volatility on the export of Thailand's key agricultural commodities to ASEAN countries (Jaroensathapornkul, 2021) and the effect of exchange rate volatility on agricultural products export price, the case study of Iran's saffron (Sabuhi-Sabouni and Piri 2008), analysis of the correlation between agricultural innovation ecosystem and economic growth (Xiaona, 2021), the correlation between the agricultural productivity and the export performance of the agro-food foreign trade in the Visegrad Group countries following accession to the European Union (Barath et al., 2010), agricultural exports analysis based on deep learning and text mining (Xu and Hsu, 2022), how energy consumption is related to agricultural growth and export: an econometric analysis on Iranian data (Raeeni et al., 2019), potential impacts of free trade areas and common currency on sustainable agricultural export in Africa (Richardson et al., 2022), the effective factors on export of agricultural products and food industry of Iran with emphasis on competitiveness index of integrated real exchange rate (Abnar et al., 2020), the evaluation of the economic effects of exchange rate depreciation on the rice market in Iran (Mosavi et al., 2014), exporting out of agriculture: the impact of WTO accession on structural transformation in China (Erten & Leight, 2021), impact of agricultural export on inclusive growth in Nigeria (Taofik, 2017), causal relationship between agricultural exports and exchange rate: evidence for India (Ozdemir, 2017), a disaggregated analysis for Ghana's agricultural exports and economic growth (Siaw, 2018), the promotion of the agro-based export as engine of local economy in North-Sumatra, Indonesia (Tampubolon, 2018), export competitiveness of agri-food sector during the EU integration process: evidence from the Western Balkans (Matkovski, 2021), the crop yields correlation with agricultural drought conditions (Puyu Feng et al, 2019), unobservable factors correlation with climate and agricultural outcomes (Shuai Chen and Binlei Gong, 2021), capital and credit constraints correlation with the other agricultural attributes (Twumasi et al., 2019), correlation between trade vulnerability and well-known economic parameters (Civin and Smutka, 2020), and others. As it can be seen from the literature review, the scientists research different aspects of the agricultural economy sector in general and agricultural products exports in particular within one country/ country union. If, then, the matter of correlation/ interaction is researched, the factors within the agricultural economy sector with each other or with the other economy sectors of the same country/ country unions (analysed in a parallel way, that is without examining their correlation) are researched. Thereby, the knowledge gap consisting in the deficiency of the scientific publications researching the correlation between the agricultural products exporters, making stress on the correlation of the agro – exporters different in their territory and/or economy development level makes the research presented in the paper extremely topical and useful for the public administrators, big and small companies employees engaged in international trade in general and agro – exports in particular, decision makers of all the levels as well as representatives of the academic community. Therefore, the scientific questions to be answered in the course of the research are – should a territorially small country be considered a prominent player on the global agricultural market, should it be taken seriously into account and is it correlated then with the biggest market players? That leads us to the scientific hypothesis that even a territorially small country can be considered a prominent player on the global agricultural market, should be taken into account and is correlated with the other market players. So, the aim of the research is to answer the scientific questions mentioned above, proving/rejecting the presented scientific hypothesis, while assessing whether the Ukrainian agricultural exports to the EU are correlated with the said exports of such giants as Brazil, Canada, China, the United Kingdom and the USA, and, if they are, how strong the correlation is.

## Materials and methods

The data under research are the agricultural products exports of Brazil, Canada, China,

Ukraine, the United Kingdom of Great Britain and Northern Ireland (the UK), and the United States of America (the USA) to the European Union (the EU). The agricultural products are meant to be the goods from the SITC (0+1) groups. SITC means Standard International Trade Classification. Group 0 comprises food and live animals while Group 1 comprises beverages and tobacco. The SIT Classification has been chosen as, though the HS classification (Harmonized System) is rather popular among the researchers for being the World Customs Organization's Harmonized Commodity Description and Coding System (ITC, n.d.), the discrepancies appearing while trying to analyse the data from more than five – ten years make the research results a bit vulnerable as the mentioned classification system is being reviewed approximately once in five years with the new codes being added and some old ones being removed, that, in turn, urges the researchers to use the correlation tables of different HS versions. The data for analysis were taken from the Eurostat data base. The timeframe under analysis is eleven years – from the year 2012 to 2022 included.

The trend lines for the analysed data during the said timeframe and two following years, taken for the projection, were built using the appropriate functions, which were chosen from the exponential, linear, logarithmic, polynomial and power ones. The criterion for the choice of the right function was the values of the $R^2$ coefficient. So, a basic exponential function is of the following formula:

$$f(x) = b^x \quad (1),$$

where '$b$' is a constant and '$x$' is a variable (Cuemath, n.d.(a).

There are multiple linear function formulae to find the equation of a line depending on the available information, but the one used in the presented research is of the so-called slope-intercept form, which has the following formula:

$$y = mx + b \quad (2),$$

where ($x$, $y$) is a general point on the line, '$m$' is the slope of the line and '$b$' is y-intercept (Cuemath, n.d.(b).

The equation for the logarithmic function is:

$$y = b \times \ln(x) + c \quad (3),$$

where '$b$' is the slope and '$c$' the intercept (XcelanZ, 2018).

The equation for a polynomial function of order 2, used in the research, is as follows:

$$y = a_2 \times x^2 + a_1 \times x + b \quad (4),$$

where '$a_2$', '$a_1$' and '$b$' are calculated parameters of the function (also named function coefficients or constants) that describe the relationship between '$x$' and '$y$' (Officetooltips, n.d.(a).

The power function is calculated according to the following formula:

$$y = a \times x^b \quad (5),$$

where '$a$' and '$b$' are the parameters of the function found by the least squares method (also named function coefficients or constants) (Officetooltips, n.d.).

The correlation between the researched data sets was calculated by computing the Pearson and Spearman correlation coefficients. The Pearson correlation evaluates the linear relationship between two continuous variables (Minitab, n.d.). The formula for the Pearson's r is complicated, meaning it divides the covariance between the variables by the product of their standard deviations (Bhandari, 2021). Spearman's rho, or Spearman's rank correlation coefficient, is the most common alternative to Pearson's r (Bhandari, 2021). The Spearman correlation evaluates the monotonic relationship between two continuous or ordinal variables and is based on the ranked values for each variable rather than the raw data (Minitab, n.d.).

The research was conducted with the help of comparative and empirical analyses, as well as statistical one, including univariate and multivariate analyses. The research results are presented using such visualization tools as horizontal and vertical bar charts, line charts with markers as well as tabular method. The research itself as well as its results will be interesting and useful for the public administration bodies officials, big and small companies working either in the sphere of agriculture or international trade, decision makers of all the levels, academic community representatives as well as beginners and experienced data analysts.

## Results and discussion

Since the beginning of the so-called "special operation", Ukraine has been much spoken about. Politicians, journalists, experts from many activity spheres speak a lot of the geographical location of the country on the crossroads of European and Asian routes, of its geo-political location

between two political forces, of its available energy sources and its role in the trade flows of the said sources as a transit point, etc. Besides everything mentioned above, let's remember the place Ukraine takes as an agricultural producer. With the favourable geographical location and climatic conditions suitable for the agricultural production as well as having approximately 25% of the world's fertile soils, Ukraine has gained a prominent place among the biggest agro producers and exporters. The main agricultural products of Ukraine are sunflower seeds and oil, rapeseed, wheat, barley, maize, and soybeans. Though being not that big in terms of its territory on the global scale, being the second largest country in Europe, and not considered economically highly developed and therefore not among those most influential global players, Ukraine takes a prominent place among the agricultural producers of the global level. In 2020 Ukraine was the 14th top destination for the EU's agro – exports and the 4th agro – exporter for the EU (European Commission, 2021(a). Though Ukraine lost some of its agricultural exports to the EU in 2021, it still remains on the fourth place among the largest exporters to the European Union (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2021). Before assessing whether Ukrainian agro – exports to the EU are correlated with the said exports of the biggest global agro – producers, let's have a quick look at their strengths in the agro – sphere.

The first country to compare is Brazil, a country of South America that occupies half the continent's landmass and is the fifth largest country in the world (Martins, 2022). The beautiful and modern cities, huge hydroelectric and industrial complexes, mines, and fertile farmlands make it one of the world's major economies (Martins, 2022). The main agricultural products Brazil is famous for as an exporter are soybeans and raw oil, corn, wheat, poultry (Brazil is the world's largest exporter of fresh chicken meat, responsible for about 14% of worldwide production and 30% of global exports) (Brazilian Farmers, 2022). The main destinations for the Brazilian agricultural exports in 2021 were China (20.9%), the European Union (16.3%) and the United States (9.8%) (Brazilian Farmers, 2022). In 2021, Brazil was the 13th largest partner for the EU exports of goods (1.6 %) and also the 13th largest partner for the EU imports of goods (1.6 %) (Eurostat, 2022).

Canada, situated in North America, is the second largest country in the world. But only 7% of the land in Canada can be farmed, the rest can be used to ranch cattle. Among Canada's top agricultural products are canola, cattle and calves, beef and veal, vegetables and poultry (Hein, 2020). On the 21st of September 2017, the EU-Canada Comprehensive Economic and Trade Agreement (CETA) provisionally entered into force. In 2020, Canada was the 10th largest partner for the EU goods exports and the 16th largest partner for the EU goods imports (European Commission, 2021(b).

China, a country in East Asia, is the third world's biggest country and the most populous one. China primarily produces rice, wheat, potatoes, tomato, sorghum, peanuts, tea, millet, barley, cotton, oilseed, corn and soybeans. In 2020 China was the largest exporter and the 2nd largest importer in the world. In 2021 China was the 3rd largest partner for the EU exports of goods (10.2 %) and the largest partner for the EU imports of goods (22.4 %) (Eurostat, 2022(a).

The United Kingdom of Great Britain and Northern Ireland (UK), situated in north – western Europe, consists of the island of Great Britain, the north-eastern part of the island of Ireland and many small islands. The total area of the agricultural lands used in 2020 comprised 17.3 mln hectares, that is 71% of the whole territory of the country. The specialities of the United Kingdom agriculture are wheat, barley, vegetables, horticultural and livestock products (USDA, 2021). The EU is the UK's biggest trading partner, accounting for almost 50% of the United Kingdom foreign trade in goods in 2019 (48.1%). The UK is the EU's third biggest trading partner (12.6%) (European Commission, 2021(c). In 2021, the United Kingdom was both the EU's largest export destination for agricultural products and the second largest origin of the EU imports, just behind Brazil (Eurostat, 2022(b).

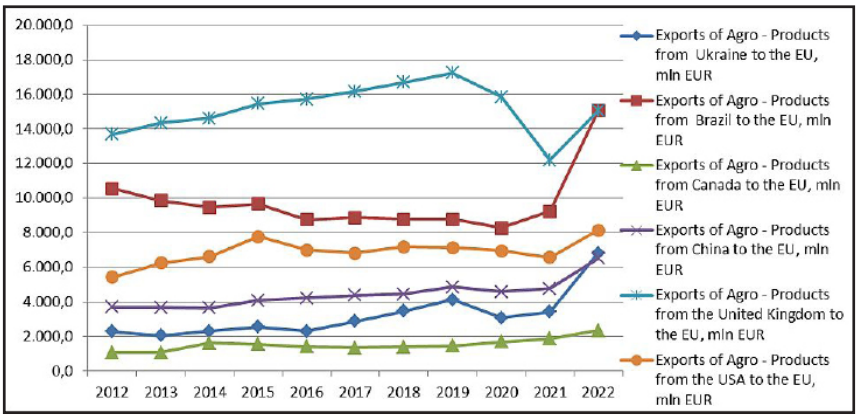
The United States of America (USA), a federal republic of 50 states situated in North America, is the fourth largest country in the world (Pessen, 2022). Due to the diversity of the climatic zones and conditions, many agricultural products are produced in the US, but, most of all, USA agriculture is famous for, among others, meat, soybean, corn, wheat, fruits, vegetables, and nuts. In 2021, the United States of America was the largest partner for the EU exports of goods (18.3 %) and the second largest partner for the EU imports of goods (11.0 %) (Eurostat, 2022(d).

As an introduction to the research and in order to have a general overview of the analysed data, let's follow the dynamics of the agricultural products exports of Ukraine, Brazil, Canada, China,

the United Kingdom and the USA to the EU all in one figure (Figure 3).

The dynamics of all the agricultural products exports amounts are visualised in one figure given above to compare their amounts and dynamics easier. As far as we can see in Figure 3, the least amount of the agricultural products exports to the EU goes from Canada, the dynamics of which can also be called the most flat among the given ones. The agricultural products exports from Ukraine is the last but one as for their amount during the timeframe under analysis. The dynamics of the said exports can't be called flat, but its changes will be analysed further along the research. Another interesting observation is the opposite dynamics directions of the exports amounts mentioned above from the USA and Brazil in 2021, that is we observe the downward change of the said exports by the USA but an upward change by Brazil. One could make an assumption about a negative correlation between the countries' agro – exports, but that will be checked further along the research. The last but not the least, or, better to say the first in terms of the exports amount, is the one of the United Kingdom. Besides being still the biggest in the amount, the agro – exports of the UK can be called the most changeable of all the ones under research, having a negative change in the year 2020 and a complete downfall in the following year. The decrease of the year 2020 by all the subjects except Canada can be explained by the impact of the COVID-19 pandemic. But such a sharp decrease of the UK agro – exports in the following year is nothing but the consequence of the Brexit, among the others. But, even more interesting is the changes of the agro exports amounts in the last year under research – all the analysed subjects experienced the increase of the said exports amounts.

Before assessing the presence/absence of the correlation between the subjects under research, let's compare the simple statistics of the agricultural products exports of Ukraine, Brazil, Canada, China, the United Kingdom and the USA to the EU (Table 1).




Source: author's elaboration on the basis of the data from Eurostat (2022(c))

Figure 3: Dynamics of the agricultural products exports of Ukraine, Brazil, Canada, China, the United Kingdom and the USA to the EU.

| Variable | Minimum | Mean | Maximum | Sum | Standard Deviation |
|---|---|---|---|---|---|
| Agricultural Products Exports of Ukraine to the EU, mln EUR | 2066.7 (2013) | 3214.1 | 6824.1 (2022) | 35355.1 | 1289.97171 |
| Agricultural Products Exports of Brazil to the EU, mln EUR | 8283.8 (2020) | 9753.5 | 15042.3 (2022) | 107288.1 | 1778.51131 |
| Agricultural Products Exports of Canada to the EU, mln EUR | 1076.7 (2012) | 1534.2 | 2343.2 (2022) | 16876.4 | 341.36733 |
| Agricultural Products Exports of China to the EU, mln EUR | 3657.7 (2014) | 4449.1 | 6532.9 (2022) | 48940.4 | 774.68446 |
| Agricultural Products Exports of the United Kingdom to the EU, mln EUR | 12195.7 (2021) | 15178.2 | 17233.1 (2019) | 166960.1 | 1362.63763 |
| Agricultural Products Exports of the USA to the EU, mln EUR | 5432.3 (2012) | 6896.6 | 8143.8 (2022) | 75863 | 690.18891 |

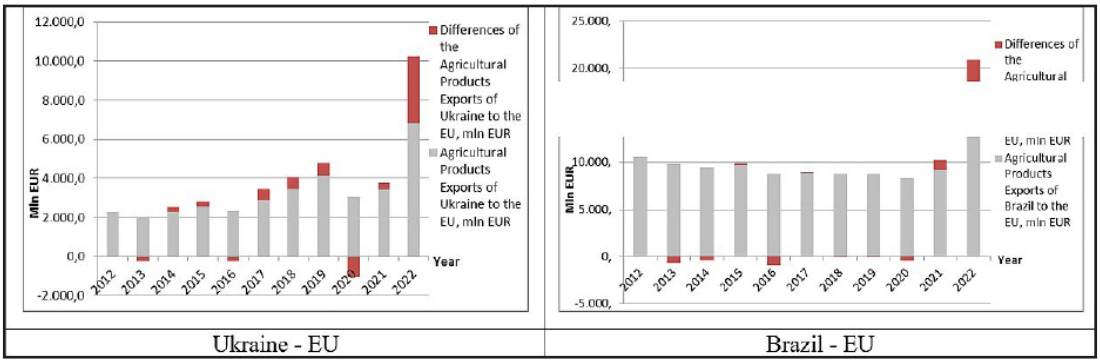
Source: author's calculations (Social Science Statistics, n.d.(c) on the basis of the data from Eurostat (2022(c))

Table 1: Simple statistics of the agricultural products exports of Ukraine, Brazil, Canada, China, the United Kingdom and the USA to the EU.

To make the analysis of the data presented in Table 1 clearer, the explanation of some abbreviations, used in it, should be given. These are: "Minimum" stands for the minimum value and "Maximum" stands for the maximum value of the observations analysed. In addition, the years, in which the maximum and minimum values stated in the table were noted, are indicated in brackets under the said values. If the list of the countries' exports have been made according to their mean from the biggest to the smallest, the order of the countries would look like the data visualised in Figure 3, that is the biggest mean is by the agro -exports of the United Kingdom, then Brazil would come, followed by the USA, China, Ukraine and Canada. The mean of the Ukrainian agro -exports to the EU for eleven years under research is 4.7 times smaller than that of the United Kingdom, approximately 3 times smaller than that of Brazil, almost 2.2 times smaller than that of the USA, 1.4 smaller than that of China and approximately 2.1 times bigger than that of Canada. If we make the list of the countries' exports according to their sums, minimum and maximum values, the list would look like the visual presentation of the data in Figure 3 and the list according to their mean values. Just for the comparison, the differences for the sum of the agricultural products exports values for the timeframe under analysis from Ukraine to the EU and all the other subjects under research are the same as the ones of the means. The minimum value of the agricultural products exports of Ukraine to the EU is 5.9 times smaller than that of the United Kingdom, approximately 4 times smaller than that of Brazil, 2.6 times smaller than that of the USA, almost 1.8 times smaller than that of China and 1.9 times bigger than that of Canada. The difference for the maximum value of the agro - exports of Ukraine to the EU and that of the United Kingdom is 2.5 times in favour of the UK, with Brazil – 2.2 times in favour of Brazil, with the USA – 1.2 times in favour of the USA, with China – 1.05 times in favour of Ukraine and with Canada – 2.9 times in favour of Ukraine. Another observation draws anybody's attention while analysing the maximum and minimum values of the subjects under research, meaning – if the minimum values were experienced by the researched countries in different years, the maximum values were seen in the same year by all the analysed subjects with the exception of the UK. A little bit different the list of the countries' exports would outlook when we compose it judging by the standard deviation. That is, the first place will be still taken by Brazil, followed by the United Kingdom, but the third place is occupied by Ukraine, followed by China, the USA and Canada consequently. This, in turn, means, that the data of the Ukrainian agricultural products exports to the EU for the timeframe under analysis are more dispersed in relation to their mean than those of China and the USA, though taking place after them in terms of the said exports amount.

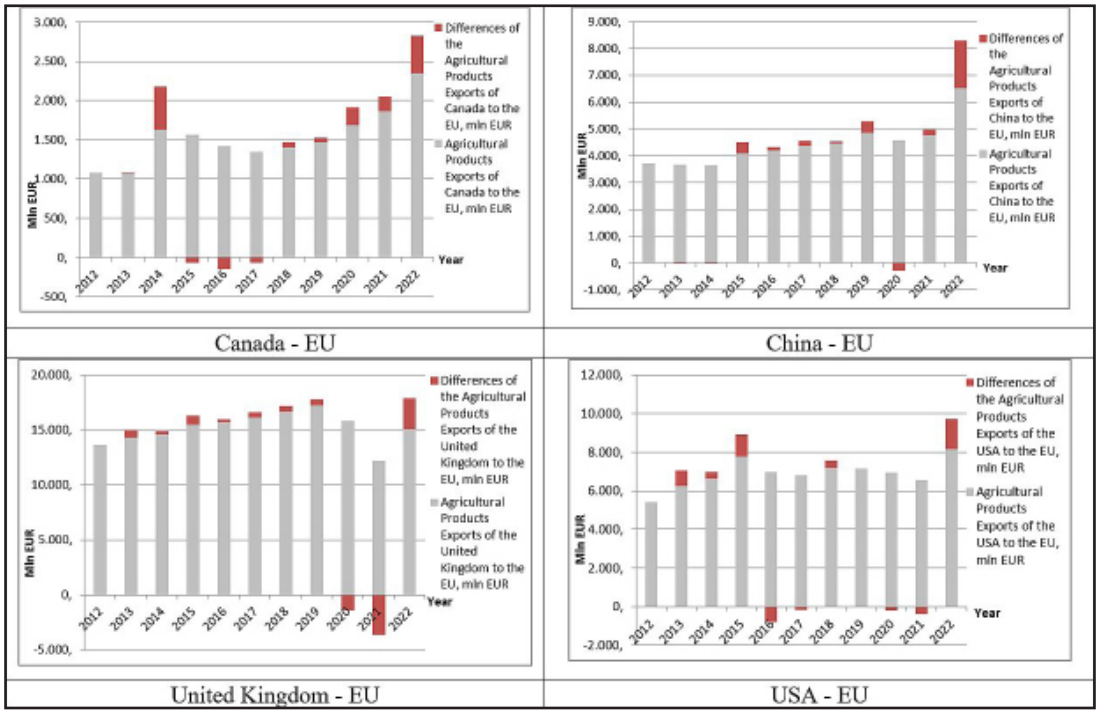
Deepening the research, let's analyse the way the data values of the agricultural products exports of the subjects researched to the EU changed if compared to the previous periods through the whole timeframe under analysis (Figure 4).

Having compared the differences of the agricultural products exports of six countries under research to the EU visualised in the figure given above, let's analyse their peculiarities to capture the common and distinctive features of the subjects under research. As for the Ukrainian agro – exports to the EU, we see, that there were three decreases in their amounts, namely in the years 2013, 2016 and 2020. During the rest




Source: author's elaboration on the basis of the data from Eurostat (2022(c))

Figure 4: Differences of the Agricultural Products Exports of Ukraine, Brazil, Canada, China, the United Kingdom and the USA to the EU, mil EUR (to be continued).




Source: author's elaboration on the basis of the data from Eurostat (2022(c))

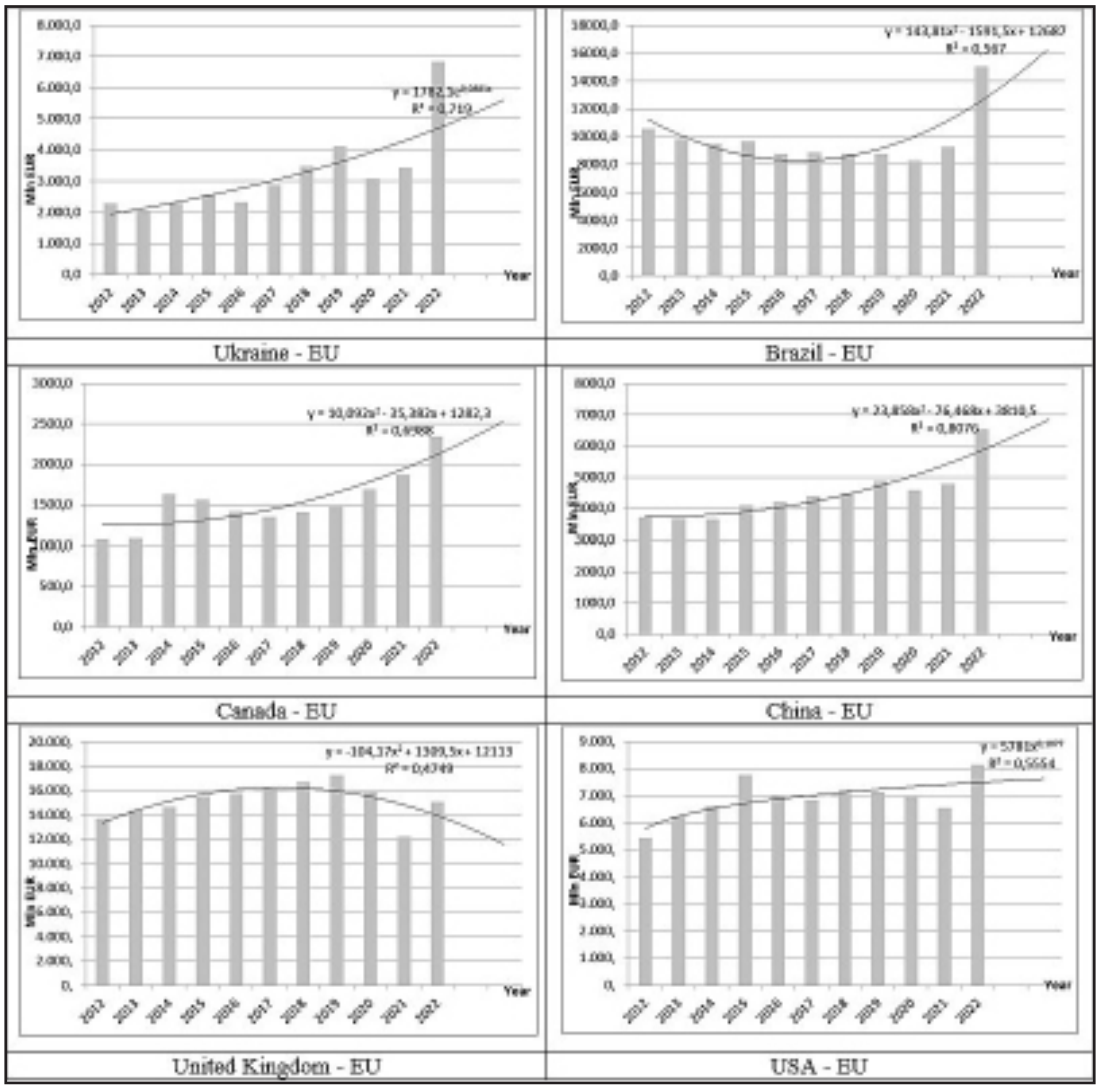
Figure 4: Differences of the Agricultural Products Exports of Ukraine, Brazil, Canada, China, the United Kingdom and the USA to the EU, mil EUR (continuation).

of the years the positive changes of the said exports amounts were observed. The mentioned decrease in 2013 was probably caused by the turbulences in the political life of Ukraine. The one in 2016 occurred because of the inadaptability of the Ukrainian laws and rules to the EU ones necessary to trade in accordance with the AA/DCFTA provisions. The said decrease in 2020 has become the consequence of the COVID-19 pandemic impact. In addition, the biggest decrease of the mentioned exports was in 2020, while the biggest increase could be observed in the last year under research, and that, in turn could be considered rather contradictory, taking into account the horrible events taking place in the country. Thus, the difficulties imposed by Russia on the Ukrainian agro exports made Ukraine search for different exports routes, many of which flew through the EU member states, having a common border with the country. As the exports become the very exports while crossing a country's border, the mentioned explanation of such a big exports increase seems to be quite logical. The changes pattern of the Brazilian agro – exports to the EU varies from that of the Ukrainian one, having negative changes in the said exports amount in 2013, 2014, 2016 and 2018 – 2020. During the rest of the years, that is 2015, 2017, 2021 and 2022, the positive changes were observed. The biggest increase of the Brazilian agro – exports to the EU was in 2022 while the biggest decrease – in 2016. As for the Canadian agro – exports to the EU, it could be divided into three clear periods, that is the first period, the upward one, is from 2012 till 2014 included, the second, the downward one, - from 2015 till 2017 included and the third, another upward one, is from the year 2018 till the end of the timeframe under analysis. The biggest increase of the agro – exports from Canada to the EU can be observed in 2014 while the biggest decrease – in 2016. The agricultural exports of China to the EU experienced decreases of their amounts in 2013, 2014 and 2020, the biggest of which was in 2020. During the rest of the years the said exports increased, mostly in 2022. The dynamics of the agricultural exports of the United Kingdom to the EU reflects the changes in the political relations between the subjects – the agro – exports dynamics is upward from the beginning of the timeframe under analysis till the year 2019 included and experienced the first big decrease in 2020, the year of Brexit, followed by even bigger decrease in 2021. Though, the biggest increase of the mentioned exports can be observed in 2022 while the biggest decrease – in the year 2021. Another country having experienced the decrease of the agro – exports amount

in both 2020 and 2021 is the USA. But, unlike the UK, these were not the only years with the negative change of the mentioned exports. In addition, in the years 2016, 2017 and 2019 the amount for the agro – exports of the USA to the EU also decreased. The rest of the years experienced the increase of the said exports. The biggest increase of the agricultural products exports of the USA to the EU can be observed in 2022 while the biggest decrease – in 2016.

Having compared the changes dynamics for the agricultural products exports of the subjects analysed to the EU, let's build the general trend lines for each data under research taking two following periods, in this case years, for the projection making (Figure 5).

Before analysing the data presented in the Figure 5, it should be stated, that the trend lines for the data under research were built using the appropriate functions, having chosen from the exponential, linear, logarithmic, polynomial and power ones. The criterion for the choice of the right function was the $R^2$ coefficient values. Firstly, let's look at the dynamics of the Ukrainian agricultural exports to the EU. It looks rather changeable but the general trend line is upward both during the timeframe under analysis and two following periods taken for the projection making, though, according to the projections for the following two years the said exports amount is supposed to be smaller than that of the last analysed year. The trend line for the data was built using the exponential function. The dynamics of the agricultural products exports of Brazil to the EU looks differently from that of Ukraine – it's not that changeable. In addition, the trend line for the data was built using a different




Source: author's elaboration on the basis of the data from Eurostat (2022(c))

Figure 5: Agricultural Products Exports of Ukraine, Brazil, Canada, China, the United Kingdom and the USA to the EU, mil EUR

from the previous function, that is with the help of the polynomial one. Though the trend line is upward starting approximately from the year 2019 and continues to be of the kind either till the end of the timeframe under analysis or during two following periods taken for the projection, in the first year following the last analysed one the agro – exports amount of Brazil to the EU is supposed to decrease, increasing again in the second one. The dynamics of the Canadian agro – exports to the EU has a different outlook from the previous two ones. The trend line for the said data was also built with the use of the polynomial function. The trend line of the agro -exports of Canada to the EU is upward through the whole timeframe under analysis and two following periods. But there is still a similarity between the trend lines of the Brazilian and Canadian agro – exports – both trend lines are upward at the end of the timeframe under analysis and two following years, but, comparing to the real data of the last analysed year, the projection for the first projected year is the decrease of the said exports with the following increase during the second projected year. The trend line of the agricultural products exports of China to the EU was also built with the help of the polynomial function just like in the case with the Brazilian and Canadian exports. The trend line is upward during the whole timeframe under analysis and during two following years taken for projection. Comparing the trend line with the real data of the last analysed year, the projection for two following years looks similar to that of the previous analysed subject. We see a completely different picture when looking at the UK agro – exports to the EU dynamics – it is upward till the year 2017, starting to decline afterwards till the end of the timeframe under analysis, continuing its decline during two more years taken for the projection. The trend line was built using the polynomial function. And last but not the least, the agricultural products exports of the USA to the EU, the trend line of which was built using the power function. The said trend line is slightly upward, though indicating the possible decrease of the last analysed subject agro – exports to the EU during two following years taken for the projection making. It should also be added here, that the trend lines for the analysed subjects through the researched time frame as well as for two following years taken for the projection making, were built ceteris paribus.

Having conducted a profound analysis of the agricultural products exports of Ukraine, Brazil, Canada, China, the United Kingdom and the United States to the EU, let's assess whether Ukraine is correlated with each/some/all the subjects under research in terms of their agro exports amounts and whether the said subjects are correlated between each other, and, if they do, how strong the correlation is. In order to do that, the Pearson correlation coefficients (under the H0 of Rho equals zero) as well as their corresponding p-values were calculated and presented in Table 2.

| | Agricultural Products Exports of Ukraine to the EU, mln EUR | Agricultural Products Exports of Brazil to the EU, mln EUR | Agricultural Products Exports from Canada to the EU, mln EUR | Agricultural Products Exports of China to the EU, mln EUR | Agricultural Products Exports of the United Kingdom to the EU, mln EUR | Agricultural Products Exports of the USA to the EU, mln EUR |
|---|---|---|---|---|---|---|
| Agricultural Products Exports of Ukraine to the EU, mln EUR | 1 | 0.7413<br>*p=0.009034* | 0.8007<br>*p=0.003065* | 0.9744<br>*p<0 .00001* | 0.1556<br>*p=0.647779* | 0.6592<br>*p=0.027363* |
| Agricultural Products Exports of Brazil to the EU, mln EUR | 0.7413<br>*p=0.009034* | 1 | 0.5882<br>*p=0. 05699* | 0.6691<br>*p=0. 024354* | -0.2274<br>*p=0.502063* | 0.3649<br>*p=0.26985* |
| Agricultural Products Exports from Canada to the EU, mln EUR | 0.8007<br>*p=0.003065* | 0.5882<br>*p=0.05699* | 1 | 0.8337<br>*p=0.001428* | -0.1068<br>*p=0.756418* | 0.7<br>*p=0.016471* |
| Agricultural Products Exports of China to the EU, mln EUR | 0.9744<br>*p<0 .00001* | 0.6691<br>*p=0. 024354* | 0.8337<br>*p=0.001428* | 1 | 0.1434<br>*p=0.674022* | 0.6939<br>*p=0.017856* |
| Agricultural Products Exports of the United Kingdom to the EU, mln EUR | 0.1556<br>*p=0.647779* | -0.2274<br>*p=0.502063* | -0.1068<br>*p=0.756418* | 0.1434<br>*p=0.674022* | 1 | 0.4794<br>*p=0.135679* |
| Agricultural Products Exports of the USA to the EU, mln EUR | 0.6592<br>*p=0.027363* | 0.3649<br>*p=0.26985* | 0.7<br>*p=0.016471* | 0.4816<br>*p=0.1587* | 0.4794<br>*p=0.135679* | 1 |

Source: author's calculations with the help of Social Science Statistics (n.d.(a)) on the basis of the data from Eurostat (2022(c)).

Table 2: Pearson correlation coefficients of the agricultural products exports of Ukraine, Brazil, Canada, China, the United Kingdom and the USA to the EU.

First of all, let's analyse the values of the Pearson correlation coefficients presented in Table 2.

The Ukrainian agro-exports to the EU has positive close to perfect correlation with the Chinese, positive strong correlation with the Brazilian, Canadian and the US exports as well as positive weak correlation with the UK ones. The Brazilian agro – exports to the EU have positive strong correlation with the Ukrainian and Chinese ones, positive moderate correlation with the Canadian ones, positive weak correlation with the US ones and negative weak correlation with the UK exports. The Canadian agro – exports to the EU have strong positive correlation with the Ukrainian, Chinese and the US ones, positive moderate correlation with the Brazilian and negative weak correlation with the UK agro exports. The Chinese agro -exports to the EU have, besides those mentioned above, positive weak correlation with the UK and positive strong correlation with the US agro exports. The UK agro-exports to the EU have, besides those mentioned above, positive moderate correlation with the US ones. The results presented above are only a half way to the conclusions making. The next step of our research is to assess whether the given results are statistically significant. With the 95% of confidence intervals, that is with $\alpha = 0.05$, let's analyse which corresponding p-values indicate the obtained results to be statistical significant and which - not. The close to perfect positive correlation between the Ukrainian and Chinese, the strong positive correlation between the Ukrainian and the Brazilian, Canadian and the US agricultural products exports to the EU, the strong positive correlation between the Brazilian and the Chinese agro exports, the strong positive correlation between the Canadian with the Chinese and the US agro exports as well as the positive strong correlation between the Chinese and the US agro exports are to be considered statistically significant and allow us reject the H0. The rest of the corresponding p-values indicate the obtained results not to be statistically significant and don't allow us reject the H0.

To make the research results more credible and to double check the presence/absence of the correlation between the subjects under analysis, the Spearman correlation coefficients and their corresponding p-values were calculated and presented in Table 3. There was another motivation to conduct the Spearman correlation test, that is – the Pearson correlation test needs the data to be normally distributed. Having conducted the normality testing, none of the data sets under research appeared to be perfectly normally distributed, though the deviations from the normality were not that big in some cases. So, in order to be perfectly sure in the research results, the Spearman correlation coefficients (under the H0 of Rho equals zero)

| | Agricultural Products Exports of Ukraine to the EU, mln EUR | Agricultural Products Exports of Brazil to the EU, mln EUR | Agricultural Products Exports from Canada to the EU, mln EUR | Agricultural Products Exports of China to the EU, mln EUR | Agricultural Products Exports of the United Kingdom to the EU, mln EUR | Agricultural Products Exports of the USA to the EU, mln EUR |
|---|---|---|---|---|---|---|
| Agricultural Products Exports of Ukraine to the EU, mln EUR | 1 | -0.23636<br>*p=0.48409* | 0.59091<br>*p=0.05558* | 0.93636<br>*p=2E-05* | 0.49091<br>*p=0.1252* | 0.69091<br>*p=0.01857* |
| Agricultural Products Exports of Brazil to the EU, mln EUR | -0.23636<br>*p=0.48409* | 1 | -0.06364<br>*p=0.85254* | -0.25455<br>*p=0.45004* | -0.65455<br>*p=0.02886* | -0.14546<br>*p=0.66958* |
| Agricultural Products Exports from Canada to the EU, mln EUR | 0.59091<br>*p=0.05558* | -0.0636<br>*p=0.85254* | 1 | 0.55454<br>*p=0.07665* | -0.08182<br>*p=0.81099* | 0.45454<br>*p=0.16015* |
| Agricultural Products Exports of China to the EU, mln EUR | 0.93636<br>*p=2E-05* | -0.25455<br>*p=0.45004* | 0.55454<br>*p=0.07665* | 1 | 0.37273<br>*p=0.25893* | 0.53636<br>*p=0.08895* |
| Agricultural Products Exports of the United Kingdom to the EU, mln EUR | 0.49091<br>*p=0.1252* | -0.65455<br>*p=0.02886* | -0.08182<br>*p=0.81099* | 0.37273<br>*p=0.25893* | 1 | 0.6<br>*p=0.051* |
| Agricultural Products Exports of the USA to the EU, mln EUR | 0.69091<br>*p=0.01857* | -0.14546<br>*p=0.66958* | 0.45454<br>*p=0.16015* | 0.53636<br>*p=0.08895* | 0.6<br>*p=0.051* | 1 |

Source: author's calculations with the help of Social Science Statistics (n.d.(a)) on the basis of the data from Eurostat (2022(c)).

Table 3: Spearman correlation coefficients of the agricultural products exports of Ukraine, Brazil, Canada, China, the United Kingdom and the USA to the EU.

and the p-values corresponding to them have been decided to be calculated.

Just like with the Pearson correlation coefficients, let's, first of all, take a look at the values of the Spearman correlation coefficients, presented in the table given above. Judging by the Spearman correlation coefficients values, the Ukrainian agricultural products exports to the EU have negative weak correlation with the Brazilian ones, positive moderate correlation with the Canadian and the UK ones, positive close to perfect correlation with the Chinese ones, positive strong correlation with the US agro exports. The Brazilian agro – exports to the EU have negative weak correlation with the Canadian, Chinese and the US ones and negative strong correlation with the UK agro exports. The Canadian agricultural products exports to the EU have positive moderate correlation with the Chinese and the US ones and negative weak correlation with the UK agro exports. The agro-exports of China to the EU have positive weak correlation with the UK and positive moderate correlation with the US agro exports. The agro-exports of the UK to the EU have positive moderate correlation with the US ones. The countries mentioned once in the Spearman correlation coefficients explanation were not repeated again. With the 95% of confidence intervals, that is with $\alpha = 0.05$, let's analyse what corresponding p-values indicate the obtained results to be statistical significant and what will allow us reject the H0. Judging by the corresponding p-values, positive strong close to perfect correlation of the Ukrainian agro-exports to the EU with the Chinese ones, positive strong correlation of the Ukrainian agro exports to the US ones, negative strong correlation of the Brazilian agro – exports to the EU with the UK ones are to be considered statistically significant and allow us reject the H0. The rest of the corresponding p-values don't allow us reject the H0.

The right for food security is an essential need of every human being, no matter who or what they are and where they live. On the one hand, the government of every country must secure sufficient amount of food for the population of its country as it is one of its duties, but, on the other hand, having its population fed and satisfied is of the best interests for every government, though not everyone understands this realness as the turbulences of nowadays show. In order to supply one's population with the sufficient amount of food, countries' officials search for the new trade partners, sign new contracts, establish new logistic routes, make new unions. Neither the economic development level nor the territory greatness plays any role in this case. The only thing that matters is what agricultural products, how much and how quickly the new partner can provide. In this manner, the global agricultural products market is being reorganised due to the appearing changes/needs/challenges of nowadays. The research presented above is only the first step in the attempt to clarify the way the global agro – market functions. The matter under research is extremely interesting and topical nowadays due to the turbulences in all the spheres of the human activity. The correlation between the agro – market subjects analysed in the paper doesn't imply the causation, which, in turn, could be the possible direction of the research expansion. Another matter interesting to be researched is the interaction of the countries unions from different continents as the subjects of the global agricultural products market. The correlation of the countries of one continent as the agro – market subjects is the following issue interesting to be discussed. And these are not the only directions of the presented research expansion as the matter of the agro – products trade and their subjects' interaction is vitally important for human survival and life quality. Despite the vital importance of the matter under research, there are certain limitations that could harden the research flow. These are, added to the existing ones mentioned above, the differences in the statistical data gathering, assessment, storage, processing and presentation, the availability of the statistical data on the matter under research, the availability of the statistical software to analyse the researched data, the readiness of the scientific journals to publish the research results without paying attention on the political issues between the analysed subjects, as well as the force majeure circumstances, that can appear unexpectedly and can turn the fixed matter, according to which things are functioning, upside down, etc.

## Conclusion

The challenges we all are facing nowadays, being it climate changes, COVID-19 pandemic, turbulences within or between countries, all of them threaten our lives, and not only the way of life we are used to, but the very life itself. And no life is possible without food being it a single human being or the whole humanity. That's why, every single human being, the governments of all the countries, the decision makers of different levels consider food security to be vitally important and needed

to pay constant attention at. Due to the turbulences we have experienced and are still experiencing, we think whether we have enough food not only for today, but for the nearest future, making some food supplies not only on the local, but global level as well. Therefore, the subjects supplying agricultural production and ready-made food products are becoming more and more important and influential. Among the biggest global goods exporters, we see either the biggest territorially or the most highly developed countries, like China, the USA, Germany, the Netherlands, Japan and others. But, when we talk about the countries, which are the biggest exporters of the agricultural products, the list looks a little bit differently, including a mix of either big or small and highly developed and not that developed countries, like the EU (as a country union), the Russian Federation, Australia, Ukraine, the United States, Canada, Argentina, Kazakhstan, Turkey, etc. On the one hand, a big territory means more land for the agricultural production and the high level of the country's economic development means the availability of better mechanisms and technologies to reach better results, that is higher amount of the end products. But, as far as we can see, either relatively small or not that developed countries can also take leading places among the most influential global agro – exporters, becoming therefore noticeable players on the global market.

Ukraine, as an example of such a relatively small and not considered a highly developed country, was taken by the author to assess whether such a country's agricultural products exports to the EU correlate with the ones of the biggest and the most influential global agro – exporters, that is with Brazil, Canada, China, the UK and the USA, and if they do, how strong the correlation is. All the said countries take prominent places among the producers and exporters of certain agricultural products, that is Ukraine – of sunflower seeds and oil, rapeseed, wheat, barley, maize, and soybeans; Brazil – of soybeans, corn, wheat, poultry; Canada – of canola, cattle and calves, beef and veal, vegetables and poultry; China – of rice, wheat, potatoes, tomato, sorghum, peanuts, tea, millet, barley, cotton, oilseed, corn and soybeans; the United Kingdom – of wheat, barley, vegetables, horticultural and livestock products; the USA – of meat, soybean, corn, wheat, fruits, vegetables, and nuts.

The comparative analysis of the agricultural products exports dynamics of the subjects under research point to the fact, that the least amount of the said exports during the presented timeframe can be observed by Canada and the biggest one – by the United Kingdom. The countries mentioned in the previous sentence take also the opposite places in terms of their exports dynamics flatness – the agricultural products exports of Canada to the EU dynamics is the flattest while the UK's one – the most spiky. Ukraine takes the fifth place among the six given countries as for the agro-exports amount and the third place in terms of the data dispersion. An observation worth taking a special attention at is the change of the agro-exports to the EU amount in 2022 – all the analysed countries noted the positive changes in the agro exports to the EU amount, moreover, in the cases of five out of six, except Canada, those changes were the biggest during the analysed timeframe. In addition, if the minimum values of the agricultural products exports to the EU were experienced by the researched countries in different years, the maximum values were seen in the same year by all the analysed subjects with the only exception of the UK. The increased inflation made its influence on the data mentioned previously, but the turbulences between two European countries made the fixed exports routes be changed in order to ensure food security for the African and Eastern countries, making the agricultural products exports from Ukraine flow through the EU member – states mostly, that, in turn, gave the results presented above. That means, that the repeated blockage of the Grain Deal implementation, resulting in the dozens of the Ukrainian ships transporting agro production, mostly grain, to the African and Asian countries, being blocked in the Black Sea, made Ukraine and its allies search for the new routes and means to export the Ukrainian agricultural production from Ukraine to those in need. As Ukraine borders on, among the others, Hungary, Poland, Slovakia and Romania, which are the EU member – states, most of the agricultural production exports, which could not be transported through the blocked water ways, started to be transported through the territories of the mentioned countries. Since the fact of export is being stated at the time of the goods crossing the border, the often suspensions of the Grain Deal implementation and the urge to export the Ukrainian agricultural production through the territories of the EU member – states impacted the increase of the agro exports being under research.

The trend lines for the subjects under analysis were built using the appropriate functions, chosen from the exponential, linear, logarithmic,

polynomial and power ones, judging by their $R^2$ coefficient values. The said trend lines are upward in all the analysed cases, except the UK – the EU agro exports, though the projections for the agricultural products exports of the analysed subjects were made ceteris paribus. The results of the Pearson correlation coefficients calculations of the agricultural products exports of six analysed countries to the EU with their corresponding p-values point to the close to perfect positive correlation between the Ukrainian and Chinese, the strong positive correlation between the Ukrainian and the Brazilian, Canadian and the US agricultural products exports to the EU, the strong positive correlation between the Brazilian and the Chinese agro exports, the strong positive correlation between the Canadian with the Chinese and the US agro-exports being considered statistically significant, allowing us to reject the H0. Having calculated and analysed the Spearman correlation coefficients of the agricultural products exports of six mentioned countries to the EU with their corresponding p-values, it can be stated, that positive strong close to perfect correlation of the Ukrainian agro-exports to the EU with the Chinese ones, positive strong correlation of the Ukrainian agro exports to the US ones, negative strong correlation of the Brazilian agro – exports to the EU with the UK ones are to be considered statistically significant, allowing us reject the H0.

So, having conducted the research presented in the article, the scientific hypothesis, that even a territorially small country can be considered a prominent player on the global agricultural market, should be taken into account and is correlated with the other big market players, is considered to be proven. Despite the fact, that Ukraine is not considered to be among the territorially biggest countries in the world, it takes leading places among the producers and exporters of such agricultural products as sunflower seeds and oil, rapeseed, wheat, barley, maize, and soybeans. The agricultural products exports of Ukraine to the EU have positive close to perfect correlation with the Chinese ones and positive strong correlation with the US ones. As a result, any turbulences even in the smallest country, that can threaten its agricultural production and exports, should be regulated and diminished not to threaten the food security of either the said single country or many other bigger countries and, as a consequence, the global food security. Having filled in the knowledge gap stated above, the presented research and its results are of great interest and use for public administration officials of all the levels, companies' employees engaged into international trade in general and of agricultural products trade in particular, decision makers, academic community representatives as well as beginners and experienced statisticians and data analytics.

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# Iot-Sensor-Equipped Food Waste Bio-Composter to Households and to Advance Egovernment in Municipality Authorities' Waste Management Practices

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## Abstract

Background: Finnish policymakers issued a new community waste law in 2022, that aims to increase household food waste recycling. The municipalities have launched the implementation of the waste law and are responsible for supervising the development of this new project.

Problem: The implementation and supervision of the waste law increases authorities' workload and also public costs. Public servants manage the households' compost register and carry out compost audits on-site.

Challenge: The challenge is to put in place the new waste management law at the lowest public cost.

Purpose: The research addresses the validation of a pioneering IT solution that supports and advances households' bio composting and aims to ease waste management authorities' workload by fostering eGovernment.

Methods: The intervention consists in delivering the IoT-sensor-equipped bio-composter and associated applications. The research adopts a mission-oriented approach, and establishes a place-based, multi-actor, participatory, and open innovation testbed at Living Lab. It leverages the Lean Startup process and SWOT analysis. The research method complies with the principles of Responsible Research and Innovation.

Conclusions: The IoT-sensor-equipped bio-composter is a feasible solution. Municipality waste management authorities do not regard/consider the IoT-sensor-equipped solution as beneficial from their perspective. The eGovernment strategy is not a driver in this case since bio-composter mapping and monitoring could be a future tool for real estate maintenance companies.

## Keywords

Legislation, municipality, food waste, recycling, bio-composter, Living Lab, Internet of Things, eGovernment, city region, food systems.

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## Introduction

In 2020, around 127 kilograms (kg) of food per inhabitant were wasted in the European Union (EU). Households generated 55% of food waste, accounting for 70 kg per inhabitant (EUROSTAT, 2022; EUROSTATa, 2023; EUROSTATb, 2023).

United Nations Sustainable Development Goal (SDG) number 12 is Responsible Consumption and Production. SDG target number 12.3 proposes to halve per capita global food waste at the retail and consumer levels by 2030 (FAOa, 2023; FAOb, 2023).

The European Commission is in the process of proposing legally binding targets to reduce food waste across the EU. The EU Waste Framework Directive 2023 will assess the feasibility of setting food waste reduction targets to implement the Union's commitments under the UN Sustainable Development Goals and the Farm to Fork

Strategy and limit the food supply chain's impact on the environment and climate. European Commission (EC) will inform the targets by the end of 2023 (ECa, 2023; ECc, 2023; ECd, 2023; ECe, 2023; ECf, 2023).

The waste reduction hierarchy includes prevention, preparing for reuse, recycling, recovery, and disposal. Preventing waste is the preferred option, and sending waste to landfill should be the last resort (EC, 2020).

This research addresses the recycling of Finnish households' food waste into new compost soil by using bio composting. Finnish households should improve their community waste collection and recycling, which, in 2020, covered merely 42 percent. EU countries' target for community waste recycling is 55 percent by 2025 and 65 percent by 2027. Finland's community waste keeps on increasing and the recycling rate is too low at this pace. Reaching the EU target looks far away. Under the circumstances, and as specified before, households must improve food waste separation from mixed waste to enable food waste recycling into new products (LUKE, 2021; Circwaste, 2022; Ympäristö, 2018; Hina et.al., 2022; Dhir et.al., 2020).

In 2021, the Finnish government updated the waste management law, with the aim of improving households' food waste recycling. It came into force this year (2023). Communities with more than 10,000 inhabitants are legally required to organize food waste collection (Finnish Ministry of Environment, 2021).

The new law increases inhabitants' general awareness of food waste value, and it emphasizes food waste separation from other household waste and recycling of food waste. The aim is to increase the quantity and quality of collected food waste to promote recycling. The industrial processes which produce biogas, compost soil, and biochar make use of collected food waste.

The new waste law also promotes households' small-scale bio-composting on their own premises. Composting reduces food waste transportation from households to centralized food waste processing units, which, in the long term, reduces household food waste management costs. Food waste composting outcome, which is compost soil, is a valuable resource for gardeners. Compost soil improves garden soil quality which, in turn, enhances growth and yield. Households' bio composting and gardening go very often hand-in-hand.

The new waste law requires that local waste management authorities keep a composter register on food waste. This register includes data on households that manage a bio-composter. Thus, the composter register assists authorities in watching and guiding the households' composting practices. Authorities can make compost audits of households, gather data on the households' quantity of food waste and its recycling, and record the data in the statutory composting register. Finally, the authorities use food waste data to calculate Finland's food waste recycling rate.

The implementation of the new waste management law inevitably increases e public costs. The public bodies and operators put effort into upkeeping the composter register, auditing households on site, and collecting data on waste food quantity. The waste management authorities and operators in the city region work with tax funds. They invoice the costs from the households via community waste billing. At the end of the day, the households will pay the increased community waste management costs. The payment takes place either through increased taxes or community waste bills.

The **problem** is that the implementation and supervision of the new waste law increase the authorities' work and public costs. Public servants manage the compost register, compost audits, and data collection. The **challenge** is to put in place the new waste management law with the lowest possible public service costs.

This means that the manner to build the composter register needs to be as automatic as possible. The amount of human work should be reduced to the minimum, which involves carrying out auditing sessions without physically going to households. The bio-composter auditors' work must be done remotely. This also means that the data collection on households' food waste recycling volume should be reconsidered, in terms of reducing manual workload in data collection to the minimum possible hours.

European Commission fosters transition to effective digital public services and eGovernment, which develops smart tools, rethinking organisations and processes, and changing behaviour so that public services are delivered more efficiently to people (EC eGovernment, 2023).

**The key intervention** in the research is an IT architecture and application. The IT solution, which is associated with food waste bio composter, is pioneering. The IoT sensors and LoRaWan technology have not before been introduced

and piloted in the context of households‘ food waste bio composting (Digita, 2023).

In this research, three households in Finland test an IoT-sensor-equipped bio composter, which leverages LoRaWan technology for data transfer.

Further, the municipality waste management authorities and other biowaste collection and recycling-related stakeholders were invited to participate in the research action. Their role was to assess and give feedback on IoT-sensor-equipped bio composter taking into account the new waste management law requirements and consequent new tasks for municipalities.

**The research questions are as follows:**

RQ1: What is IoT-sensor-equipped bio-composter feasibility?

RQ2: What kind of weaknesses, strengths, opportunities, and threats do the involved households, the product owner (Biolan Oy), public waste management authorities, and other stakeholders envision in the IoT-sensor-equipped bio-composter uptake and execution?

## Materials and methods

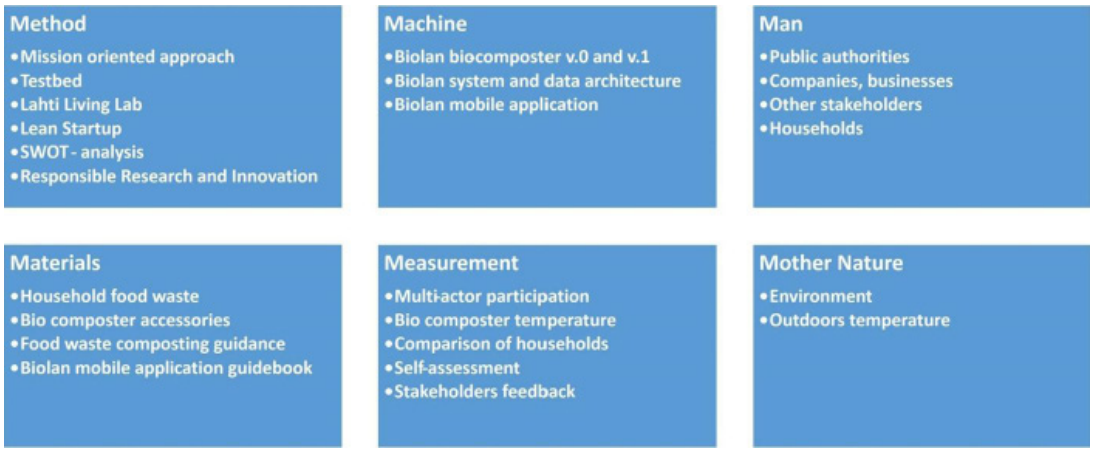
The research framework includes six elements, namely: method, machine, man, material, measurement, and mother nature. Figure 1 outlines the main sub-variables for each element, and every element is analysed in this chapter.

### Method

The purpose of this applied science research is to test and assess the pioneering IT solution whose aim is to ease public waste management authorities' bio-composting-related tasks in households and foster eGovernment. The research applies a wide range of approaches and methods that are mission-oriented, place-based, multi-actor, participatory, open innovation, structured, analytical, and ethical.

Mission-oriented approach: The research aim is to contribute to the European Commission’s vision and objectives, namely Food 2030 policy via innovation actions that are conducted in the Horizon2020 project Cities2030 (Cities2030, 2020). The main missions of the Food 2030 policy are as follows: 1) Nutrition for sustainable and healthy diets. 2) Food systems supporting a healthy planet. 3) Circularity and resource efficiency. 4) Innovation and empowering communities. This research contributes to the third and fourth missions (ECb, 2023). The research also contributes to achieving the specific objective of the Cities2030 project i.e. "Enhance circularity and local food belts". The research responds to the challenge of promoting the circulation of nutrients contained in urban household food waste from the table back to the soil.

Testbeds: Three households tested the solution on their own premises in Eura, Rauma, and Lahti. Further, one of the testbeds invited the municipality waste management authorities to join in and assess, respectively, provide feedback on the solution. This extended testbed was established in the city of Lahti. Lahti is a city of 120,000 inhabitants and about 31,000 households. Lahti is located in southern Finland, in the county of Päijät-Häme. The local community waste management operator is Salpakierto Oy, that is responsible for implementingt the waste management law. Lahti municipality waste management authorities control




Source: Smart & Lean Hub Oy, Tuula Löytty

Figure 1: Research framework

and guide Salpakierto's processes and performance. Salpakierto food waste management experts have estimated the number of households' composters and, accordingly, 10-15% of Lahti households own a bio-composter. This means that Salpakierto Oy will register and audit at least 3,100 households in the city of Lahti (Salpakierto, 2021; Salpakierto, 2023).

Lahti Living Lab: Cities2030 project fosters urban food system transformation by carrying out innovation actions e.g., experiments and capacity-building actions in a local setting. The operational multi-actor platforms for innovation actions are place-based Living Labs. Living Labs' aim is to generate innovations and empower multi-stakeholder communities in an open innovation environment. Lahti Living Lab from Finland is part of the Cities2030 labs, and contributes to achieving the Lahti Vision 2030, namely "Lahti is a sustainable and carbon neutral city region". Lahti Living Lab is a multi-actor, participatory, and open innovation environment and testbed for IoT-sensor-equipped bio-composter (Lahti Living Lab, 2023; Bogers et.al, 2017; Hirvikoski et.al, 2020).

Lean Startup: The research procedure applies the Lean Startup methodology, which is based on the following concepts: Ideate - Build - Monitor - Learn. The Ideate phase is dedicated to planning the research procedure. The building phase is twofold: a) food waste bio composter preparation in the test site and b) ICT architecture, sensor-, IoT- and data collection and architecture solutions at Biolan Oy. The monitoring takes place in three steps: Biolan Oy's self-assessment, households' self-assessment, and waste management authorities and bio waste stakeholders' consultative assessment and feedback. The last phase, i.e. Learning purpose, is to answer to following business and proposed questions: "Does this product serve as a solution to the set challenge?" "Should this product be built?" and "Can we build a sustainable business around this set of products and services?" (Lean Startup, 2023).

SWOT-analysis: SWOT analysis is a brainstorming tool that facilitates participants' communication and assessment on the topic regarding current strengths and weaknesses and future opportunities and threats as well. The waste management authorities and stakeholders' consultative assessment and feedback are included in the SWOT analysis (Benzaghta et al., 2021).

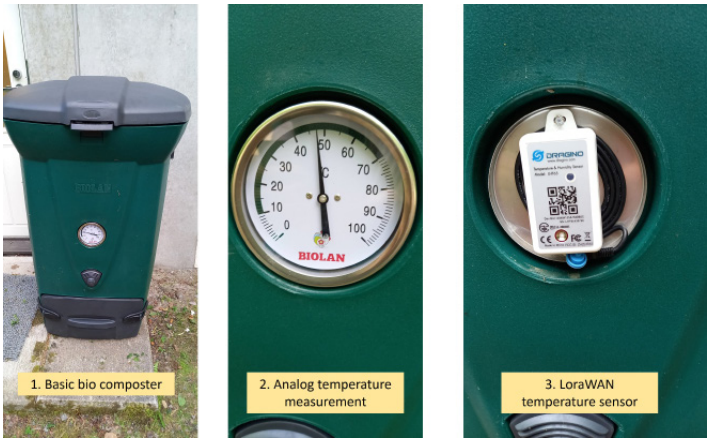
Responsible Research and Innovation (RRI): The research is conducted as a part of Cities2030 project which is funded by EC's Horizon 2020 program. Cities2030 delivers a project RRI framework to contribute to the EC's vision of an inclusive, innovative, and reflective society. The basic RRI toolkit comprises 6 themes: Ethics, Gender Equality, Governance, Open Access, Public Engagement, and Science Education (RRI, 2023). The purpose of the Cities2030 project is to ideate, co-create, implement, and pilot RRI tools and concepts under research and innovation actions, which are meant to structure a Cities2030 RRI framework for the responsible co-creation, pilot, and deployment of innovations.

### Machine

The Machine - element refers to facilities, systems, tools, and pieces of equipment employed for the research.

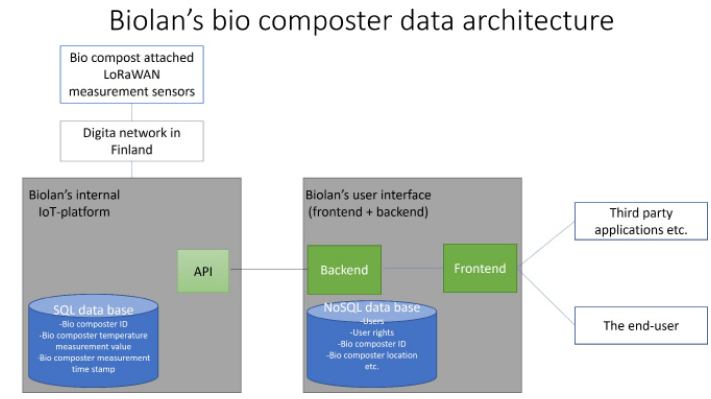
Biolan bio composter: Biolan Oy is a Finnish family business specialising in developing, manufacturing, and marketing products that help reduce the environmental impact of daily human activities (Biolan, 2023). The basic bio composter, version 0, which is addressed particularly to households is a Biolan Quick Composter 220eco. It is equipped with an analogue temperature measurement (see Figure 2). Biolan Oy developed the first version of the digital sensor-equipped bio-composter in 2018-2019. The idea was to substitute the analogue temperature gauge with a digital sensor to enable continuous temperature monitoring in the bio-composter, and to connect the bio-composter to the internet. It was a pilot of an Internet of Things (IoT) solution. At that time, data transfer become a barrier and thus Biolan Oy left the idea aside for a couple of years. In 2022, Biolan Oy picked up on the old concept and upgraded it to exploit LoRaWAN technology by using DRAGINO's LHT65 LoRaWAN temperature sensor (see Figure 2). One IoT sensor costs about 50 EUR. The LoRaWAN technology has become one of the key enabling technologies for the development of Internet of Things architectures. It has been very popular and useful in Smart City applications, including public waste management (Biolan, 2023; DRAGINO, 2023; Baldo et.al., 2021; Cruz et.al., 2021).

The first version of Biolan's bio composter is pioneering. The IoT sensors and LoRaWAN technology have not been introduced and piloted before in the context of households' food waste bio composting.




Source: Smart & Lean Hub Oy, Tuula Löytty

Figure 2: 1. Basic bio composter; 2. Analogue temperature measurement; 3. LoRaWAN temperature sensor.

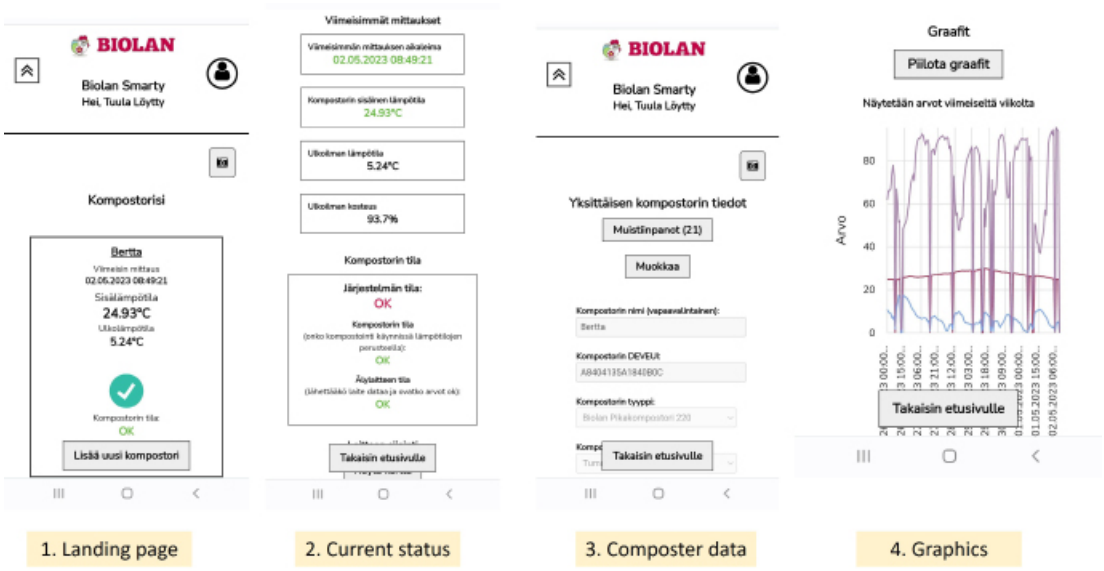



Source: Biolan Oy, Sami Rantamäki

Figure 3: Biolan's system and data architecture schema.

Biolan system and data architecture: Data collection was done utilising sensors connected to composts. Sensors send data every 15 minutes to Biolan SQL-database (System Query Language) through the Internet (Figure 3). In SQL-database, the data coming from the composter IoT-sensors is made into tables in SQL-database. This means that the sensor data is normalised into constructional data which can be easily used in reporting or other applications. Data from sensors is send first to SQL-database instead of directly sending it to programs that utilise the data. This is done because it is easier to control the users of the data, it's easier to share the data to applications which utilise the data in their work and apply additional layer of cyber security. Utilising SQL-database between the IoT-sensor and the applications crates a master database and guarantees that different applications which utilise IoT-sensor are all using the same data from the master database.

Table columns are visualized in Figure 4. After data normalization, data is moved through API (Application Programming Interface) into another database. This is done to prevent end-users and third-party applications from accessing the master database. From NoSQL database composter data is then spread to end-users and into third-party applications, such as Power BI (Figures 6 and 7).




Source: Biolan Oy, Bioapps-application, Sami Rantamäki

Figure 4: Screenshot of Biolan's mobile application.

## Man

The Man-element refers to all operative and participating people who are involved and contribute to the delivery of a process and accompanied research. The people represent policymakers, public authorities, businesses, education, science, and households. The term "Man" does not refer to gender, quite the opposite, the gender-balanced research is one of the aims. The research complies with the multi-actor approach in human participation (EIP-Agri, 2017), and establishes a multi-actor stakeholder community to facilitate knowledge exchange and transfer, capacity building and innovation actions, as well as networking among bio- and food waste stakeholders.

Public authorities: The extended solution testbed was established in the city of Lahti, under the wings of Lahti Living Lab. The waste management authorities of the city of Lahti are responsible for implementing and monitoring the new waste law in the city. Authorities establish the compost record, audit households composting practices, and collect data for European Commission about food waste recycling in the region. The aim of the study is to facilitate and easy waste management authorities work with a new approach. Lahti's waste management authorities represent and give a voice to all regional waste management authorities and operators, although from a scientific perspective, their feedback and insight into the solution are not representative. In 2022, 31 regional waste management authorities and operators were mapped in Finland (Karlsson-b, 2022). They are responsible actors for community waste management in all 220 municipalities of Finland.

Companies and businesses: Biolan Oy is a Finnish family-owned SME company whose main products are bio composters, associated goods, and consumables. Biolan Oy owns the intellectual property rights of the IoT sensor-equipped bio composter. Their interest is to extend their market share via new innovative services (Biolan, 2023).

Other stakeholders: Households' biowaste management in Finland interests a wide group of stakeholders, namely actors that are on bio-composting goods and consumables, guidance, logistics, law, regulation, and EU communication. There are also some associations that work for the inhabitants' benefit giving advice and support. And there is a large group of institutions, organizations, associations, entities, and projects that provide services on education, advisory, research, development, innovations, and data.

Households: This study engaged three households willing to test IoT-sensor-equipped bio-composters. The households are located in Lahti, Eura, and Rauma. Eura and Rauma bio composters are internal to Biolan Oy, meaning that the actors are working for Biolan Oy. The household in Lahti is the first external user of Biolan Oy's solution.

Figure 5 shows the mapping of the place of households that took part in the research. The localisation and visualization take place based on Biolan's mobile application registration data.

## Materials

Household food waste: The household's normal food waste is the raw material for bio composter process e.g., fruit and vegetable peels, meat and fish waste, etc. food residues, coffee and tea reindeer with filter bags, old flower soil and plant waste, soft and moist papers, crushed eggshells, natural fibers in small pieces.

Bio composter accessories: To maintain and speed up the composting process ongoing, it's possible to add now and then accessories such as composting accelerator and bulking material.

Food waste composting guidance: Although composting is not difficult, it's beneficial for newcomers to familiarize themselves with the procedures of bio-composting. The Internet provides a lot of information on such practices. One reliable source is the bio-composter producers' web page (Biolan, 2023).

Biolan's mobile application guidebook: Biolan delivered a guidebook for the users of the new mobile application. It provides detailed guidance on how households can independently register themselves as a user of the solution and how to further use the mobile application.

## Measurement

This chapter addresses the issues of research monitoring and measurement systems.

Multi-actor participation: The goal was to build a multi-actor environment to test and assess the IoT-sensor-equipped bio-composter. To that end, stakeholder reach-out and engagement measures were documented and measured: how many stakeholder members were contacted, what was the typification of the stakeholder, and what was the gender of the stakeholder member. Only one person in this study was responsible for stakeholder engagement and management, and thus the measurement system is considered reliable and traceable.

Bio-composter temperature: As already explained in the chapter Machine, the IoT-sensor equipped bio-composter enables remote monitoring of the bio-composter inside temperature. The collected data is visualised in the mobile application and also in the Power Bi application. The mobile application shows a short time frame of about 12 days. The Power Bi application shows a long-time trend starting from the beginning of August 2022 (Figure 6) (Karlsson-a, 2022).

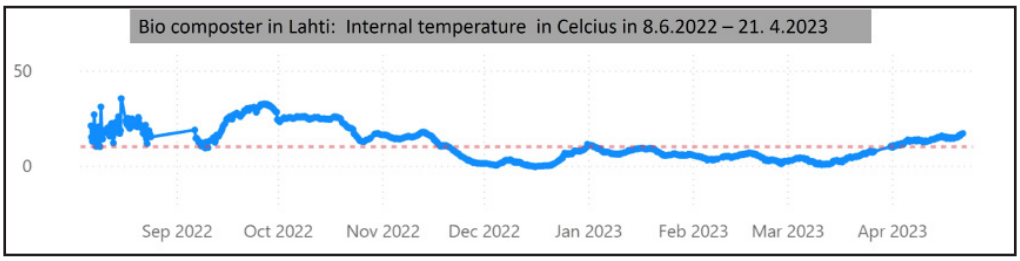
Comparison of three bio composters: The Power Bi application gathers the data of the three test bio composters into one view (Figure 7).

Households' self-assessment: Households' subjective assessment of what is the added value of the IoT sensor and data in the bio-composting process.

Biolan's self-assessment: Biolan Oy, as a solution owner, assesses the business potentiality

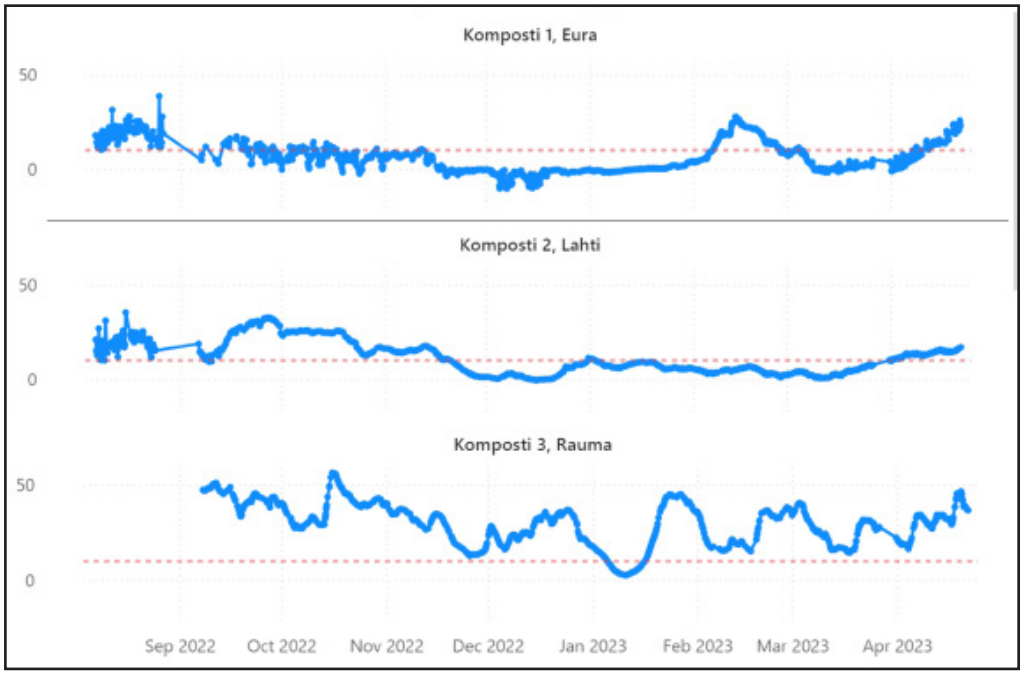

Source: Smart & Lean Hub Oy, Kalle Karlsson, PowerBi visualisation

Figure 5: Placemaking of bio composters and households that participate in the research.




Source: Smart & Lean Hub Oy, Kalle Karlsson, PowerBi visualisation

Figure 6: The long-time trend of the bio composter.




Source: Smart & Lean Hub Oy, Kalle Karlsson, PowerBi visualisation

Figure 7: Comparison of three bio composters temperature.

of the solution. The question is what is the payback time of the investment?

Stakeholders' assessment: The assessment took place in an online meeting. In addition, some stakeholders also gave feedback by email. In the meeting, the IoT sensor-equipped bio composter and associated solutions and applications (i.e., ICT architecture, mobile application, and Power Bi application) were shown and explained to stakeholders. The purpose was to assess the solution value and feasibility to ease public waste management authorities' work in the implementation and supervision of new waste law. Stakeholders were also urged to identify other potential users who could benefit from the solution. The waste management authorities and other stakeholders' consultative assessment and feedback are structured in the SWOT analysis format (see Table 1).

## Mother Nature

Environment: In this research, the multi-actor approach is complemented by the fifth component of the Quintuple Helix Model (Carayannis et.al., 2012). The fifth component refers to environmental factors which influence the research and are influenced by the potential solutions.

Outdoor temperature: The external factor that impacts households' bio-composter performance is the outdoor temperature. In Finland, the bio-composter process slows down or totally stagnates in wintertime due to the low outdoor temperature. The best time for testing the bio-composter in Finland is hence from April to September.

| | |
|---|---|
| **Strengths**<br>New solution: An interesting solution, which did provoke some thoughts<br>Green Deal: Collecting and transporting biowaste from smaller properties to centralized process utilities is not environmentally friendly. Composting at own premises is a better eco-deed.<br>Value adding service: Gives the household new information and a new kind of service. | **Weakness**<br>The solution does not facilitate the work of the waste management authority, where the main part is receiving basic information (name, address, etc.) and a composting notification from the composters.<br>The solution is not suitable for all households that compost food waste.<br>The authority is not able to focus on composting households so precisely.<br>The task of the waste management authority is not to provide composting advice. |
| **Opportunities**<br>Composting advice and guidance online: At its best, the solution offers households composting advice in a new way (algorithms, mobile application)<br>The solution is suitable for pioneer users i.e., "digitally oriented engineers".<br>The most potential target group are small house companies that have already received composting announcements.<br>The introduction of remote monitoring can bring a competitive advantage and new services to the real estate maintenance company. | **Threats**<br>Users' i.e. households ability to handle digital systems.<br>Privacy policy.<br>Households do not want to tell authorities or outsiders about composting.<br>Negative experience of being "supervised by big brother". |

Source: Smart & Lean Hub Oy, Kalle Karlsson, PowerBi visualisation

Table 1: SWOT-analysis of stakeholders' assessment and feedback.

## Results and discussion

### Method

Mission-oriented approach: The EC policies and consequent new waste management law in Finland, and Cities2030 objectives act as a driving force of the research. In addition, the Cities2030 project provided the proper environment for initiating and carrying out the research.

Testbeds: The three household testbeds worked well without any disruption (Figure 5). The installation of IoT sensors and the upload of mobile applications were easy and well-guided. The Biolan's ICT system worked fluently enabling continuous data collection. The number of testbeds is adequate to show the feasibility or problems of the prototype. In the case of Lahti, we extended the testbed to cover community waste management authorities' participation. They have shown interest in the study and ICT solution and even addressed 3 people to reflect and give feedback on the study. This is a positive sign because the implementation of the new waste law is in progress and public servants' resources are bound to it.

Lahti Living Lab: Lahti Living Lab is a framework that highlights open innovation, participation, problem-solving, and digitalization with and for the community. The framework worked well in the research, there were no contradictions. The Living Lab concept is neither odd nor unknown among stakeholders. This research communicates the better-known Living Lab concept both in Lahti and beyond.

Lean Startup: The Lean Startup methodology is practical and easy to adopt for experimental cases. Ideate-Build-Monitor-Learn phases assist to proceed systematically and logically. The internal documentation of the study is aligned with the methodology. The last phase of the Lean Startup, namely "Learn", also addresses the business modelling. In this case, the owner of the innovation and potential business is Biolan Oy. The business modelling is conducted internally at Biolan Oy.

SWOT analysis: The dialogues, reflection, and feedback from stakeholders deliver the SWOT analysis (Table 1). The observations and SWOT analysis are built upon individual people's comments and insights. They may give ideas for future pathways for stakeholders, but they do not provide a scientifically reliable result.

Responsible Research and Innovation (RRI), Ethics: GDPR and Consent Form are considered in relation to the participation of humans in the research. The ethics-related issues, such as "privacy policy" and "big brother supervision", were mentioned in the SWOT analysis. It is quite clear that they cause concern and thus an ethical code must be well prepared if the solution is taken into use. Multi-actor approach: The study applies a multi-actor approach that fosters a multi-

faced perspective into research reflection and supports public engagement and inclusion. Gender equity: The participants represent both genders in a balanced manner. Open access and transparency: Duringthe research the material is shared with participants openly via email and cloud-based platforms.

Science Education: The research not only demonstrates the pioneering digital technical solution but also raises awareness of opportunities, builds capacity, and transfers knowledge among participants. Governance: The main aim of the study is to advance eGovernment by demonstrating a feasible and operative digital solution.

### Machine

Biolan bio-composter: There are no problems or breakdowns with the IoT-sensor-equipped bio-composter operation. It works quite well both in summer and winter.

Biolan system and data architecture: In the case of Biolan, end-users and PowerBi application designer's point of view is that the Biolan ICT system operated well. There are no detected problems or breakdowns.

Biolan mobile application: From the end-users' point of view, the Biolan ICT system worked well. No problems or breakdowns were detected. There are no detected problems or breakdowns.

The IoT-sensor-equipped bio-composter is technically a feasible solution. It is operational in real use and creates value for the household. The tested and assessed overall solution is one of the main results of the study.

### Man

The research methodology is built upon multi-actor approach which means that we invite and engage into action multi-stakeholder members to enhance diverse points of view e.g., public bodies, companies, non-governmental organisations, and citizens. Based on monitoring data (see below in chapter "Measurement"), we succeeded to reach out a relatively large number of stakeholders (members). However, their interest and availability to participate in the research reach only a satisfactory level. Different projects and actions compete for the same people's attention. They cannot join in all and hence they have to prioritize their participation carefully.

### Material

Household food waste: The different quality and quantity of household food waste and the differences in composter management practices are the main reasons for the variation between the three households (See Figure 7).

Food waste composting guidance: The data comparison raises questions and curiosity about what are the data-based best practices in bio-composter management. The data combined with composter management practices can generate a useful knowledge base for composting training for households.

Food waste composting guidance, namely Biolan's mobile application guidebook: Biolan delivers a guidebook for new mobile application users. It is an exploitable result of the research.

### Measurement

Multi-actor participation: In the research time span, the engaged stakeholders represent public authorities, businesses, science & education, and households. Totally 27 people, most of them women (18), have been reached out to. 10 stakeholder members participated in the online consultative meeting, of which 4 were women. Personal contacts and the built community are the results of the study.

Bio composter temperature: For the end-user the long-term trend of the temperature is an interesting indicator. The graphic also shows how bio-composter treatments (e.g., emptying) impact the temperature. The analogue gauge does not receive the temperature as easily as the IoT sensor. The data is useful for the end-user but not necessarily vital to enhance bio-composter performance.

Comparison of the three bio-composters: The data visualisation indicates that data collection is successful, and there are no gaps in the data set. The data also show that the three bio-composters' temperatures and trends differ from each other's. Households' different composting practices and variations in competencies cause variations in bio-composter temperatures. However, in this study, the goal is not to analyse the causes of the variation. The temperature sensor is in the same place in the composter as the traditional analogue temperature gauge. Thus, the IoT-sensor measurement location is as good as it is in a traditional, version 0, bio-composter. This study

does not give an answer to the question if the IoT sensor temperature data are the same as with the measured analogue gauge or if there is a significant difference.

Households' self-assessment: The bio composter temperature data analysis is a value-adding element for some digital nerds, but necessarily it's not a tempting feature for all. Some households may benefit from the possibility of monitoring remotely the composter. For example, if the household possesses several bio composters in different locations, then remote monitoring could assist in keeping the composter on.

Biolan's self-assessment: Biolan Oy, as a solution owner, assesses the business potentiality of the solution and explores new product and service development ideas. The research is interesting and relevant from the bio-composter producer's point of view because the producer is eager to upgrade the bio-composter to the digital era and provide thus new services for their customers i.e. households and others. However, the SWOT analysis does not support solution development for public waste management authorities, instead, the needs of the real estate maintenance companies may be worth exploring.

Stakeholders' assessment: One result of the SWOT analysis is that waste management authority does not see value in the IoT-sensor-equipped bio composter for themselves. They do not envision associated eGovernment solutions. Authorities' attitude is that they will continue building a manual bio composter register, and audits on-site. On the other hand, the waste management authority is currently under pressure to cope with the new waste law implementation. Apparently, the timing is not right to introduce a new solution. Perhaps, in the future, the digitalised bio composter and eGovernment services that enable it are brought on the authorities' agenda.

In the researcher's opinion, the future is multi-faced: households will own both analogue and digital bio-composters. Thus, public authorities should adjust their activities accordingly. Both analogue and digital bio-composter supervision are doable options.

Real estate maintenance companies may be potential users of the solution. The digital mapping of composters and their remote monitoring may be useful for them and bring more efficiency.

### Mother Nature

Households' bio-composting is a strength according to the SWOT analysis. In the researcher's opinion, municipality waste management authorities' task is to enhance the inhabitants' possibilities to be pro-environmental.

## Conclusion

The IoT-sensor-equipped bio-composter is technically a feasible solution. It is operational in real use and creates value for the household. The most likely users among households are those who are data-driven and digitally oriented or who value the option of monitoring the bio-composter performance remotely.

Municipality waste management authorities do not consider the IoT-sensor-equipped solution beneficial from their perspective, although some households could be registered automatically and audited remotely by using the collected data.

Municipality waste management authorities do not consider the eGovernment policy and strategy is applicable in this case.

Participants considered that the study methods and process advanced awareness of food waste recycling, built capacity, and fostered knowledge exchange and transfer among stakeholders.

The remote mapping and monitoring of real estate bio composters could be a future tool for real estate maintenance companies.

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# EU Sanctions Against the Russian Federation and Their Implications for the Foreign Trade of the Czech Republic

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## Abstract

Modern European integration entails the common foreign and security policy. In February 2022, the Russian aggression against Ukraine moved the deplorable situation from 2014 to another level calling for an EU reaction via legal instruments. Based on them, ten sanctions packages have emerged with significant consequences. The aim of this paper is to analyze it, in particular the connection of these ten sanctions packages and foreign trade between the Czech Republic and the Russian Federation. This aim is achieved by addressing three sets of goals: (i) the legal analysis of EU trade policy instruments, (ii) an advanced statistical and critical analysis of the trade between Czech Republic and Russian Federation and (iii) a creation of a timeline of the application and its ramifications. This reveals interesting propositions about the impact of these sanctions packages on the Czech foreign trade and about the effectiveness of the EU´s trade policy.

## Keywords

EU, Russian Federation, foreign trade, invasion, restrictive measures, sanctions.

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## Introduction

Modern European integration is a complex unification procedure (Večeřa, 2012), which extends to a myriad of types of integration, such as cultural, normative, communicative and functional (Landecker, 1951; Hajdukiewicz and Pera, 2023). The level and degree of modern European integration is open to a critical and multi-disciplinary discussion (MacGregor Pelikánová and MacGregor, 2020), but there is no doubt that at its very center was, is and will be the economic integration (Machlup, 1977). At the very begin was the famous declaration presented by the French foreign minister, Robert Schuman, on 9th May, 1950, which was inspired by Jean Monnet. Seven decades later, the idea of economic development toward the integration while advancing the internal signal market with four freedoms and the set of shared values and principles is the reality. However, as prodigally expressed by the moto of EU "United in diversity", this means neither the unanimous consent about the priorities nor a consent about their balancing (Balcerzak et al, 2023). The economic integration dominates, but crises magnify differences and intensify pre-existing trends (D´Adamo and Lupi, 2021) and undoubtedly the Covid-19 pandemic has accelerated the move of the pendulum of the EU policies and law (MacGregor Pelikánová and MacGregor, 2021). In addition, the leadership and role assumed by EU institutions, in particular the European Commission and its President, have been shaped by such events (Kassim, 2022).

In 2014, the EU witnessed a set of dramatic events in the Ukraine. The provided answers and reactions to it resulted in the readiness to sign a landmark trade agreement between the EU and Ukraine and the imposition of sanctions by the EU against the Russian Federation. Eight years later, in 2022, forces of the Russian Federation entered the separatist republics in eastern Ukraine. This moved the EU and EU member states to impose new and stronger sanctions against the Russian Federation (Horská et al., 2023).

However, the modern European integration does not mean merely an advancement of a shared legal and ethical dimension within the EU (MacGregor Pelikánová et al., 2021) or only a reduction and/or elimination of regulatory differences by the application of negative integration rules or the European (federal) harmonization of national regulatory standards (MacGregor Pelikánová and Rubáček, 2022). Indeed, the EU constitutional

trio includes the Treaty on EU (TEU), the Treaty on Functioning of EU (TFEU) and the Charter of Fundamental Rights of the EU (Charter) and each of these critical important legal documents address the distribution of competencies (conferred, exclusive, shared) of the EU and their exercise towards the set goals while observing shared values, including the rule of law (Art. 2 TEU), and common aims, including the promotion of peace and establishment of the internal market (Art. 3 TEU). Based on the principle of conferral, the EU has competences only if they are conferred by each and every EU member state (Art. 5 TEU) and even the conferred competencies cannot be applied in a discretionary manner, instead the principles of subsidiarity and proportionality apply (Art. 5 TEU). Each EU member states, i.e. since 2004 including the Czech Republic, have to facilitate the achievement of the EU's tasks and refrain from any measure which could jeopardize the attainment of the EU's objectives (Art. 4 TEU).

The EU's competence in matters of common foreign and security policy and its exercise is subject to specific rules and procedures (Art. 24 TEU). It is implemented by the European Council and the Council of EU (called as well Council of ministers) acting unanimously. The adoption of legislative acts shall be excluded and all decisions are to be taken by the European Council and the Council of EU acting unanimously (Art. 31 TEU).The common foreign and security policy shall be put into effect by the High Representative of the Union for Foreign Affairs and Security Policy (High Representative) and by Member States, in accordance with the Treaties (Art. 24 TEU).. The Council shall adopt decisions which shall define the approach of the EU to a particular matter of a geographical or thematic nature and EU member states have to conform to that (Art. 29 TEU).

Hence, in the case of EU restrictive measures against the Russian Federation, restrictive measures are laid down in Common Foreign and Security Policy (CFSP) Council decisions. A proposal is made by the High Representative and is examined by Council preparatory bodies, including the Committee of Permanent Representatives (COREPER II), and the decision is then adopted by the Council by unanimity. If the Council Decision includes an asset freeze and/or other types of economic and/or financial sanctions, those measures need to be implemented in a Council Regulation, which lays down the precise scope of the measures and details for their implementation. The CFSP Council decision and the Council Regulation are adopted together to allow for both legal acts to produce their effects at the same time. Therefore, all ten sanction packages of the EU were approved by EU member states represented in the Council, including the Czech Republic, and these states have to comply to it and in particular observe their implementation method via matching Council Regulations. And this can bring dramatic multi-spectral consequences for foreign trade.

Therefore, the aim of this paper is to analyze the course of foreign trade of the Czech Republic with Russian Federation, both with regard to its development and changes in its structure. This entails in particular the analysis and connection of these ten EU sanctions packages and the foreign trade between the Czech Republic and the Russian Federation. This aim is achieved by addressing three sets of goals: (i) the legal analysis of EU trade policy instruments, (ii) an advanced statistical and critical analysis of the trade between the Czech Republic and the Russian Federation and (iii) the creation of a timeline of the application and its ramifications. Such an aim with three sets of goals inherently demands multi-disciplinary research and the collection of data from various sources and their proper methodological processing and the presentation of results along with their critical discussion leading to pioneering semi-conclusions and propositions for future studies.

## Materials and methods

Since the aim of this paper is to analyze the course of foreign trade of the Czech Republic with the Russian Federation, both with regard to its development and changes in its structure, three sets of goals built upon three different sets of data and methods are to be employed. The conceived purpose of the article calls for multidisciplinary research and a data collection from various sources and their adequate processing and presentation of the results, together with a critical discussion leading to conclusions and proposals for future studies. Ultimately, the proposed article is based on a relatively simple combination of theoretical approaches.

Firstly, the framework of these packages based on EU policies and law, special Council Decisions and Council Regulations, has to be identified and both critically and comparatively analyzed. A legal analysis is carried out in order to determine the area of operations and time implementation,

respectively the validity of the given standard. The EU has to observe the tradition (Siniša, 2017), as well the as the importance and particularities of implementation mechanisms (Korkea-aho, 2015). Since such data is heterogenous and has a set of features, while legal aspects prevail, conventional mechanisms for the interpretation are to be employed, while, as expected, the teleological, contextual and development approaches dominate (MacGregor Pelikánová and MacGregor, 2020). The ultimate interpretation balancing test needs to reflect both positivism and the natural dimensions with ethical connotations and a contextual appreciation (MacGregor Pelikánová and MacGregor, 2021). The interpretation of EU law must be based upon the recognition of values, pluralism, uniformity and effectiveness (Petrić, 2023) within the multistakeholder model (Balcerzak et al., 2023). This endeavor is performed by various subjects with different backgrounds which are trying to achieve a workable compromise (Siniša, 2017). The true meaning of the EU law can be firmly established only after it has been fleshed out in implementation (Korkea-aho, 2015) and has passed the case law test (MacGregor Pelikánová and MacGregor, 2020).

In the next part of the article, the methods of descriptive statistics and critical analysis of trade between the Czech Republic and the Russian Federation are used, while a basic analysis of the development of foreign trade is carried out with the use of statistical tools in the form of a targeted territorial selection for foreign trade and, secondarily, from the point of view of the commodity structure. The monitored period is the time interval from January 2020 to March 2023, i.e., with monthly periodicity. Data on the development of foreign trade are obtained from the CZSO foreign trade database, which is modified on the basis of the Eurostat regulation on territorial division according to the GEONOM international standard (CZSO, 2023). The commodity structure is based on the Free on Board (FOB) methodology, or Cost, insurance, and freight (CIF).

The last goal of the paper is to create a timeline for the application of partial EU sanctions measures in the context of the development of the Czech Republic's foreign trade with the Russian Federation. The result is an assessment of the impact of the implemented EU measures on territorial trade in a direct time context, which allows for monitoring the intensity and interconnection of the sanctions packages on the Czech Republic's foreign trade.

## Results and discussion

On 22nd February 2014, the fourth president of Ukraine, Viktor Yanukovych who previously served as the governor of the Donetsk Oblast and became the Prime Minster of Ukraine, was removed from his office during the Revolution of Dignity. On the 27th February 2014 unmarked Russian groups took over the Autonomous Republic of Crimea and Sevastopol. On 16th March 2014, took place the controversial Crimean referendum and on 18th March 2014 the Russian Federation annexed the Autonomous Republic of Crimea and the city of Sevastopol. The Rubicon had been crossed and key international law subjects moved from words to acts. Already on 17th March 2014, the United States, the EU, and Canada decided to impose specifically targeted sanctions, followed by other general as well as individual measures, such as the freezing of assets and prohibiting travel to Vladimir Putin, Sergey Lavrov and Viktor Yanukovych. On 17th July 2014, MH17/MAS17/KL4103 was shot down while flying over eastern Ukraine, Donetsk, resulting in the death of all 15 crew members and 283 passengers of which 193 were Dutch. This was the last straw, perhaps due to the strong and persistent attitude of Dutch representatives and other EU member states representatives, and the turning point regarding the legislative anchoring of measures against Russian destabilization of the situation in Ukraine. Namely, at this point there was enacted the most well-known restrictive measures - Decision 2014/512/CFSP and Council Regulation (EU) 833/2014.

On 31st July 2014, the Council of the EU under the presidency of Sandro Gozi, adopted two fundamental measures - Decision 2014/512/CFSP concerning restrictive measures in view of Russia's actions destabilizing the situation in Ukraine ("Decision 2014/512/CFSP") and Council Regulation (EU) 833/2014 concerning restrictive measures in view of Russia´s actions destabilizing the situation in Ukraine ("Regulation 833/2014"). These two measures were based on Art. 215 TFEU which states that a decision to interrupt or reduce economic and financial relations with a third country is to be made by the Council acting with a qualified majority, while the necessary measures are adopted by the Commission, and the Parliament is to be informed about this. Such a decision to interrupt or reduce economic and financial relations is further envisaged by Art. 77 et foll. TFEU. However, regarding restrictive measures against Russia, it needs to be pointed

out that Art. 215 TFEU is to be applied along with Title II Chap. 2 TEU (Art. 23 to Art. 41 TEU), i.e., in the area of the common foreign and security policy (Art. 23 et foll. TEU), decisions are taken by the European Council and the Council acting unanimously (Art. 31 TEU). Hence, the Council has decided and decides by unanimity on adopting, renewing, or lifting EU restrictive measures (sanctions), on the basis of legislative proposals from the EU High Representative. Once political agreement is reached among EU Member States, the necessary legal acts, in the form of a Council Decision and an accompanying Council Regulation, are prepared by the High Representative/Vice President and the Commission, and submitted to the Council for adoption. In sum, the Council is the only EU intergovernmental institution and its decisions are done by relevant ministers from all Member states, while generally the qualified majority 55% (72 %) of states + 65 % of population is sufficient. However, regarding specific issues on the edge of the competency spectrum of the EU, such as restrictive measures against Russia, the unanimity is required. By the operation of Art. 80 TFEU, their implementation is governed by the principle of solidarity and fair sharing of responsibility, including its financial implications, between the Member States.

Decision 2014/512/CFSP represents a strong instrument endorsed by all Member States represented by their ministers in the Council and has a broad implementation impact. It prohibits sales and other dealings with financial instruments, such as bonds, of major Russian financial institutions or subjects from a list (Art. 1 Decision 2014/512/CFSP), the sale and transfer of military material or dual-use material to Russia (Art. 2 and Art. 3 Decision 2014/512/CFSP), and the sale or transfer of technology for oil exploration (Art. 4 Decision 2014/512/CFSP). It took effect on the day of its publication, i.e., 1st August 2014, with the expected application going until 31st July 2015. Due to the following dramatic events, Decision 2014/512/CFSP has been many times updated and expanded and, pursuant to its current version, it should apply until 31st July 2023, but it is extremely likely that it will be further extended.

Regulation 833/2014 is a legal instrument having a different legal nature, but basically the same consequences for its targets as a decision such as Decision 2014/512/CFSP, especially considering that decisions regarding restrictive measures are not typical decisions of the Council requiring a mere qualified majority. Indeed, even regulations regarding restrictive measures are not typical regulations voted on by the Council and Parliament. Regardless of the manner of their enactment, pursuant to Art. 288 TFEU, both a regulation and decision are binding in its entirety, while a regulation has a general direct application and a decision which specifies those to whom it is addressed is binding only on them. The Council has been using not only these two types of legislative acts (decisions and regulations), but as well has employed implementing acts.

The original version of Regulation 833/2014 was very short, included only 14 articles and Annexes I, II and III and extended only onto 11 pages. It prohibited to sell, supply, transfer or export dual-use goods and technology to any subject in Russia or for use in Russia if the item is or may be intended for military use and financial instruments of major Russian institutions and institutions indicated in the Annex III (Art.2 and Art. 3 and Art. 5 Regulation 833/2014) and to provide related services (Art. 4 Regulation 833/2014). Annex I listed Websites for information on the competent authorities and the address for notification to the European Commission, while Annex II listed concerned technologies and Annex III indicated all five concerned financial institutions (Sberbank, VTB Bank, Gazprombank, Vnesheconombank (VEB) and Rosselkhoszbank). Regulation 833/2014 was adopted on 31st July 2014, and took effect with its publication on 1st August 2014. Its end of validity is not indicated and it has been updated and extended 24 times. Its current version is shaped by the Regulation (EU) 2023/427 of 25th February 2023 and has many subparagraphs and is very long, in total 23 annexes. For example, the list of subjects has been expanded from five to over 500. However, Decision 2014/512/CFSP and Regulation (EU) No 833/2014 were neither the first nor the last restrictive measures.

Already on 5th March 2014, there was made Decision 2014/119/CFSP and Regulation (EU) No 208/2014 about the freezing of assets of certain persons. On 17th March 2014, there came Decision 2014/145/CFSP and Regulation 269/2014 prohibiting the entry of certain persons to the EU. On 25th June 2014, came about Decision 2014/386/CFSP and Regulation 692/2014 prohibiting imports from Crimea and Sevastopol.

Eight years later, on 15th February 2022, the President of the Russian Federation, Vladimir Putin, recognized Donetsk and Luhansk,

in the Donbas region of Ukraine, as independent republics, and on 24th February a new Russian full-scale military invasion was launched (Baracani, 2023). The EU reacted promptly and on February 23rd 2022, there was made Decision (CFSP) 2022/266 and Regulation (EU) 2022/263 for the prohibition to import from the Donetsk and Luhansk oblasts of Ukraine and sanctioning 351 members of the Duma – the first sanction package aka restrictive measure package emerged. Swiftly more radical and broader packages followed, targeting financial, economic, traveling, military and other dimensions and industries under the radiant motto "Supporting Ukraine is costly, but freedom is priceless" expressed by the president of European Commission, Ursula von der Leyen (Hunder, 2022).

Then, as of May 2023, in view of the Russian invasion of Ukraine, a large number of legislative instruments were issued and this was done in two waves in 2014 (eight) and 2022-2023 (two). Based on these two legislative instruments from the 2nd wave taking the legal form of a Council Decision and Council Regulations, so far in total ten restrictive measure packages were issued. Interestingly, the first wave was in the era of Jose Manuel Barroso and Jean-Claude Juncker as the President of the Commission and Catherine Ashton and later on Federica Mogherini as High Representative, while the second wave is the era of Ursula von der Leyen and Josep Borrell Fontelles. It needs to be emphasized that Ursula von der Leyen had a 'turbulent ascendance to the Commission presidency' (Müller and Tömmel 2022) because she did not have the democratic legitimacy of a *Spitzenkandidat*, i.e., she was a plan B compromise candidate suggested by the French president Emmanuel Macron (Baracani, 2023). However, ostensibly this does not slow her in her endeavors, see the Green Deal or these ten packages, in particular the third package removing selected Russian banks from the SWIFT messaging system (Baracani, 2023).

Since March, 2014, the EU has launched a myriad of both general and individual sanction instruments against the Russian Federation and its subjects. All of them are valid (at least according to the firm conviction of the EU) and (hopefully) enforceable, they cover one or more of four fields (arms embargoes, restrictions on admission aka travel bans, asset freezes and other economic measures such as restrictions on imports and exports). Some of them are general, while the rest are specifically designed. Their legal backbone overview is presented in Table 1.

These ten restrictive measures are, further, the foundation stone for packages of sanctions of the EU against the Russian Federation and, as a matter of fact, so far ten packages of sanctions have been issued. Typically, they take the form of a set of Council instruments amending the above-mentioned restrictive measures, e.g., by extending the scope, targeted activities and even subjects, and implementing tools. The Council has been issuing press releases about each one of them. Their overview is presented in Table 2.

EU sanctions as represented by these ten packages are unilateral measures intended to punish the Russian Federation by causing damage in the economic and military spheres and according to the prevailing opinion they are in compliance with International law. However, a minority opinion stream attempts to argue that these restrictive measures go beyond the scope of the permissions provided by International law (Voynikov, 2022). This is a very interesting point, because the current President of the European Commission, Ursula van der Leyen, is well-known for her perception of the geopolitical role of the EU - to put an end to European wars and to follow International law (Baracani, 2023).

| Measure | Content | Applied since |
|---|---|---|
| Decision 2014/119/CFSP and Regulation 208/2014 | Freezing assets | 6th March 2014 |
| Decision 2014/145/CFSP and Regulation 269/2014 | No entry | 17th March 2022 |
| Decision 2014/386/CFSP and Regulation 692/2014 | No imports from Crimea and Sevastopol | 25th June 2014 |
| Decision 2014/512/CFSP and Regulation 833/2014 | No selling military materials, bond, oil exploring technologies | 1st August 2014 |
| Decision (CFSP) 2022/266 and Regulation 2022/263 | No imports from Donetsk and Luhansk | 24th February 2022 |

Source: Own processing by the authors based on information provided at https://eur-lex.europa.eu/legal-content/EN/LSU/?uri=celex:32022R0263

Table 1: Summary of EU restrictive measures due to the invasion of Ukraine by the Russian Federation.

| | Adopted/Applied since | Content |
|---|---|---|
| 1. | 23rd February 2022/ 24th February 2022 | • Targeted sanctions against the 351 members of the Russian State Duma and an additional 27 individuals;<br>• Restrictions on economic relations with the non-government-controlled areas of the Donetsk and Luhansk oblasts;<br>• Restrictions on Russia's access to the EU's capital and financial markets and services. |
| 2. | 25th February 2022/ 26th February | • Freezing assets of Vladimir Putin, etc.<br>• Sanctions against the financial sector, the energy and transport sectors, dual-use goods, export controls and export financing, visa policy, additional sanctions against Russian individuals and new listing criteria |
| 3. | 28th February 2022/ 2nd March 2022 | • Ban on transactions with the Russian Central Bank<br>• € 500 million support package to finance equipment and supplies to the Ukrainian armed forces<br>• Ban on the overflight of EU airspace and on access to EU airports by Russian carriers<br>• SWIFT ban for seven Russian banks |
| 4. | 15th March 2022 | • Ban on all transactions with certain state-owned enterprises<br>• Ban on new investments in the Russian energy sector<br>• Trade restrictions for iron, steel and luxury goods |
| 5. | 8th April 2022 | • Ban on imports from Russia of coal and other solid fossil fuels<br>• Ban on all Russian vessels from accessing EU ports<br>• Ban of Russian and Belarusian road transport operators from entering the EU<br>• Ban on imports of other goods such as wood, cement, seafood and liquor<br>• Ban on exports to Russia of jet fuel and other goods<br>• Ban on deposits to crypto-wallets |
| 6. | 3rd June 2022 | • Ban on imports from Russia of crude oil and refined petroleum products, with limited exceptions<br>• SWIFT ban for an additional three Russian banks and one Belarusian bank |
| 7. | 21st July 2022 | • A new prohibition to purchase, import, or transfer, directly or indirectly, gold.. |
| 8. | 6th October 2022 | • Ban on steel products, wood pulp and paper, cigarettes, plastics, cosmetics, and stones and precious metals used in the jewelry industry. The new import ban, worth €7 billion, aims to curb more of Russia's revenues.<br>• A price cap related to the maritime transport of Russian oil for third countries<br>• dditions to the list of restricted items which may contribute to Russia's military and technological enhancement |
| 9. | 16th December 2022 | • Ban on exports of drone engines<br>• Ban on exports of dual-use goods and technology<br>• Ban on investments in the mining sector<br>• Ban on transactions with the Russian Regional Development Bank |
| 10. | 25th February 2023 | • Ban on sensitive dual use and advanced technologies<br>• Ban on exports of critical technology and industrial goods<br>• Ban on imports of asphalt and synthetic rubber<br>• Ban on provision of gas storage capacity to Russians<br>• Ban on transit through Russia of EU exported dual use goods and technology<br>• Introduction of reporting obligations to ensure the effectiveness of the asset freeze prohibitions |

Source: Own processing by Authors based on information provided at https://finance.ec.europa.eu/eu-and-world/sanctions-restrictive--measures/sanctions-adopted-following-russias-military-aggression-against-ukraine_en

Table 2: Overview of sanction packages adopted following the invasion of Ukraine by the Russian Federation.

Regardless of their ultimate assessment based on the International law, these measures are established and applied, and so it is appropriate to analyze the course and structure of foreign trade. The subject of the analysis is the international trade of the Czech Republic and the Russian Federation, while the basic goal is to link the implemented EU sanction measures with the foreign trade of the Czech Republic, i.e. to primarily identify their impact on the development and structure of foreign trade with Russia. In the following Table 3, the development of the foreign trade

| Time | Absolutely (in millions of CZK) | | | | Year-on-year index (%) | | |
|---|---|---|---|---|---|---|---|
| | Turnover of goods | Export | Import | Trade balance | Turnover of goods | Export | Import |
| I.20 | 13 555 | 6 410 | 7 145 | -734 | *88.5* | *113* | *74.1* |
| II.20 | 13 030 | 6 644 | 6 386 | 257 | *82.9* | *109.8* | *66* |
| III.20 | 12 501 | 7 024 | 5 478 | 1 546 | *72.7* | *94.5* | *56* |
| IV.20 | 8 698 | 4 611 | 4 087 | 525 | *53.1* | *62.3* | *45.5* |
| V.20 | 9 490 | 6 131 | 3 359 | 2 773 | *61.7* | *82.6* | *42.2* |
| VI.20 | 12 250 | 7 947 | 4 303 | 3 644 | *69.9* | *115.2* | *40.5* |
| VII.20 | 14 196 | 8 408 | 5 787 | 2 621 | *95.8* | *119.2* | *74.5* |
| VIII.20 | 11 429 | 6 220 | 5 209 | 1 012 | *66.3* | *84* | *53* |
| IX.20 | 14 847 | 8 538 | 6 308 | 2 230 | *84.7* | *117.1* | *61.7* |
| X.20 | 15 348 | 9 362 | 5 986 | 3 375 | *79.6* | *110.2* | *55.5* |
| XI.20 | 15 056 | 8 146 | 6 911 | 1 235 | *82.3* | *98.5* | *68.9* |
| XII.20 | 12 539 | 6 260 | 6 279 | -19 | *77.7* | *99.3* | *63.9* |
| I.21 | 12 375 | 5 648 | 6 727 | -1 079 | *91.3* | *88.1* | *94.2* |
| II.21 | 13 668 | 6 148 | 7 520 | -1 371 | *104.9* | *92.5* | *117.7* |
| III.21 | 17 823 | 8 383 | 9 440 | -1 057 | *142.6* | *119.4* | *172.3* |
| IV.21 | 15 733 | 7 173 | 8 559 | -1 386 | *180.9* | *155.6* | *209.5* |
| V.21 | 18 729 | 8 132 | 10 597 | -2 464 | *197.4* | *132.6* | *315.5* |
| VI.21 | 20 397 | 8 222 | 12 175 | -3 953 | *166.5* | *103.5* | *282.9* |
| VII.21 | 18 023 | 6 571 | 11 452 | -4 881 | *127* | *78.2* | *197.9* |
| VIII.21 | 19 702 | 5 824 | 13 878 | -8 054 | *172.4* | *93.6* | *266.4* |
| IX.21 | 24 906 | 6 623 | 18 283 | -11 661 | *167.8* | *77.6* | *289.8* |
| X.21 | 31 443 | 5 325 | 26 117 | -20 792 | *204.9* | *56.9* | *436.3* |
| XI.21 | 19 122 | 6 181 | 12 941 | -6 760 | *127* | *75.9* | *187.3* |
| XII.21 | 20 671 | 6 348 | 14 323 | -7 975 | *164.9* | *101.4* | *228.1* |
| I.22 | 18 849 | 6 871 | 11 978 | -5 106 | *152.3* | *121.7* | *178.1* |
| II.22 | 19 189 | 5 577 | 13 612 | -8 036 | *140.4* | *90.7* | *181* |
| III.22 | 27 963 | 1 894 | 26 069 | -24 175 | *156.9* | *22.6* | *276.2* |
| IV.22 | 35 366 | 1 586 | 33 779 | -32 193 | *224.8* | *22.1* | *394.6* |
| V.22 | 37 545 | 1 923 | 35 622 | -33 699 | 200.5 | 23.6 | 336.2 |
| VI.22 | 30 224 | 2 802 | 27 422 | -24 619 | 148.2 | 34.1 | 225.2 |
| VII.22 | 35 739 | 1 871 | 33 868 | -31 997 | 198.3 | 28.5 | 295.7 |
| VIII.22 | 31 674 | 1 800 | 29 874 | -28 074 | 160.8 | 30.9 | 215.3 |
| IX.22 | 27 880 | 1 974 | 25 906 | -23 933 | 111.9 | 29.8 | 141.7 |
| X.22 | 15 528 | 1 798 | 13 730 | -11 931 | 49.4 | 33.8 | 52.6 |
| XI.22 | 10 021 | 2 164 | 7 857 | -5 693 | 52.4 | 35 | 60.7 |
| XII.22 | 8 202 | 2 005 | 6 197 | -4 192 | 39.7 | 31.6 | 43.3 |
| I.23 | 6 751 | 1 201 | 5 550 | -4 349 | 35.8 | 17.5 | 46.3 |
| II.23 | 6 722 | 1 484 | 5 239 | -3 755 | 35 | 26.6 | 38.5 |
| III.23 | 7 053 | 1 895 | 5 158 | -3 262 | 25.2 | 100.1 | 19.8 |

Source: Czech Statistical Office (2023), data are not seasonally adjusted

Table 3: Statistics of foreign trade of the Czech Republic with Russian Federation.

of the Czech Republic with the Russian Federation for the period January 2020 – March 2023 is characterized in terms of value (i.e., with monthly periodicity for a detailed insight into changes).

Several basic characteristics can be implied from foreign trade statistics. First of all, it is appropriate to state that for the analysis a deliberate selection and breakdown of the monitored period

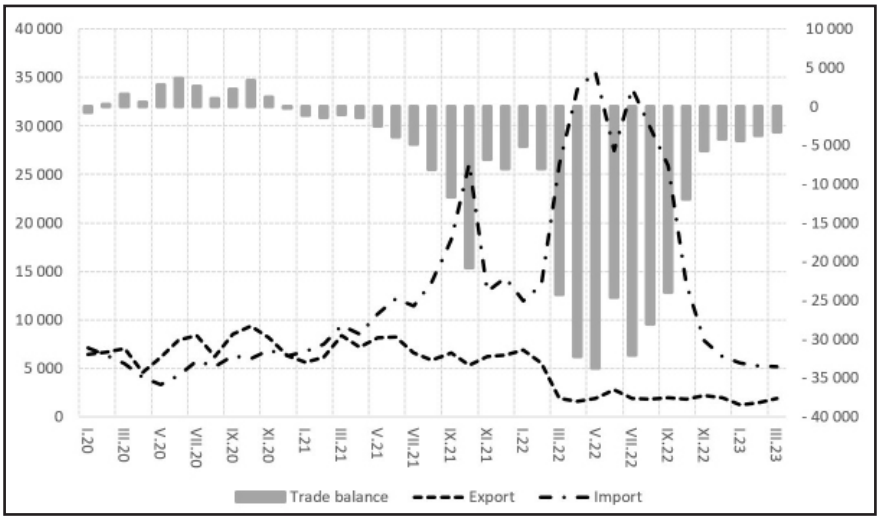
was carried out, taking into account the necessity of characterizing the current volumes of foreign trade under standard geopolitical conditions (here represented by the period of 2020 and 2021) and subsequently by the interval including the Russian invasion of Ukraine, which triggered the subject EU sanction measures (period 2022 – 2023). From the point of view of evaluating the development, it is noticeable that in 2020 the foreign trade of the Czech Republic and Russia took place in relatively constant values of 9-15 billion CZK of turnover with a positive balance of trade in the range of 1-3 billion CZK. In 2021, export values from the Czech Republic to Russia are at an unchanged level, but a sharp increase in imports has begun, which has continuously increased by more than 150% on average. The aforementioned behavior can be attributed to the recovery of the market, which was still significantly modified in 2021 by the effects of the COVID 19 pandemic and the related closure of trade routes.

However, at the end of 2021, there is a noticeable drop in imports to the usual values from the beginning of this year (i.e. around 13 billion CZK), which can probably already be classified as the consequences of fears of a significant change in the behavior of the Russian Federation in world events, which also imply further developments. At the beginning of 2022, there is a sharp increase in imports and a simultaneous drop in exports. The extreme increase in imports is associated with the consequences of Russia's behavior on the energy raw materials market, which caused panic in sub-markets and increased demand for raw materials such as gas and oil, where Russia still had a dominant position at that time.

Figure 1 shows very nicely the already mentioned drop in exports in March 2022, which fully corresponds with the beginning of the Russian military invasion of Ukraine. At the same time as this decline, it is also possible to demonstrate an aggravated situation in the field of energy, where, despite the growing aversion of the EU towards the actions of the Russian Federation, the Czech Republic was faced with the necessity of securing supplies of energy raw materials from almost monopolistic Russia, which is reflected in the development of foreign trade for almost the entire year 2022.

Towards the end of 2022, the Czech Republic's foreign trade with Russia was also stabilize, in connection with the reduction of panic on the energy markets, and, conversely, the increase in the certainty that the EU is able to ensure the supply of key commodities without the need for imports from Russia. Imports drop significantly to around CZK 5 billion, and exports also remain at low values of around CZK 2 billion after the drop. From Graph 1, the overall change in the basic orientation of the foreign trade balance is clearly visible, which was positive until November 2020, but since then it has been negative for the entire monitored period.

The above results also confirm the values from the following Table 4, which shows changes in the structure of foreign trade in the form of year-on-year changes in the turnover of goods for individual commodities.




Source: Czech Statistical Office (2023), own processing

Figure 1: The development of the Czech Republic's foreign trade with Russian Federation (absolutely in mil. of CZK).

| Commodity | 2021 | 2022 |
|---|---|---|
| **Total** | 152.1 | 128.2 |
| Products of agriculture, hunting and related services | 146.3 | 68.4 |
| Products of forestry, logging and related services | 278.0 | 19.4 |
| Fish and other fishing products; aquaculture products; support services to fishing | 17.6 | 227.0 |
| Coal and lignite | 111.1 | 45.5 |
| Crude petroleum and natural gas | 279.3 | 208.0 |
| Metal ores | 148.2 | 26.7 |
| Other mining and quarrying products | 106.5 | 63.4 |
| Food products | 89.8 | 142.0 |
| Beverages | 111.9 | 74.6 |
| Tobacco products | 134.9 | 86.4 |
| Textiles | 109.1 | 70.4 |
| Wearing apparel | 93.7 | 46.4 |
| Leather and related products | 50.5 | 65.1 |
| Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials | 147.9 | 64.3 |
| Paper and paper products | 108.3 | 76.7 |
| Printing and reproduction services of recorded media | 89.6 | 24.6 |
| Coke and refined petroleum products | 72.8 | 99.0 |
| Chemicals and chemical products | 135.6 | 91.9 |
| Basic pharmaceutical products and pharmaceutical preparations | 137.6 | 164.9 |
| Rubber and plastic products | 106.8 | 44.5 |
| Other non-metallic mineral products | 104.1 | 68.5 |
| Basic metals | 166.1 | 71.0 |
| Fabricated metal products, except machinery and equipment | 105.4 | 45.6 |
| Computer, electronic and optical products | 104.6 | 27.9 |
| Electrical equipment | 98.0 | 25.1 |
| Machinery and equipment n.e.c. | 97.3 | 60.8 |
| Motor vehicles, trailers and semi-trailers | 76.7 | 18.6 |
| Other transport equipment | 82.9 | 27.0 |
| Furniture | 156.5 | 26.4 |
| Other manufactured goods | 105.5 | 39.8 |
| Waste collection, treatment and disposal services; materials recovery services | 121.0 | 75.2 |
| Publishing services | 426.9 | 7.4 |
| Motion picture, video and television programme production services, sound recording and music publishing | 83.7 | 52.6 |
| Architectural and engineering services; technical testing and analysis services | 7272.4 | 1.6 |
| Creative, arts and entertainment services | 459.9 | 16.6 |
| Library, archive, museum and other cultural services | 145.0 | 52.7 |
| Other personal services | 618.0 | 315.5 |

Source: Czech Statistical Office (2023), data are not seasonally adjusted

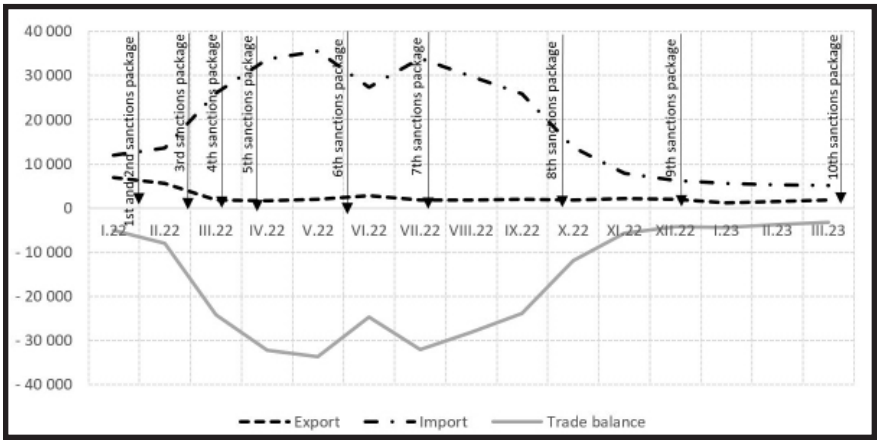
Table 4: International trade in goods with the Russian Federation, Turnover - year-on-year index (%) from current prices.

It can be seen from the presented results of Table 4 that in 2021 the vast majority of commodities had an increasing turnover, while the goods that showed a decrease have a minority share in the value of foreign trade. The year 2022 then brought extreme changes in the commodity structure of foreign trade with Russia, when only 5 categories of the entire range of monitored commodities show growth, of which Crude petroleum and natural gas are the most significant in terms of value. Very interesting is the evaluation of the category of agricultural products and foodstuffs, which are also among the rare groups that have maintained a growing foreign trade turnover in 2022.

At the end of the presented analysis, a graphic form of the timeline of the connection at the beginning of the identified sanction packages with the course of foreign trade of the Czech Republic and Russia is created, see the Figure 2.

The course of foreign trade in the Figure 2 was purposefully shortened only to the period of the relevant application of EU sanctions instruments, i.e. to the period from the beginning of 2022 until the present, however, the conclusions presented above are evident from the course of export, import and overall balance values. In the context of the schedule of EU sanctions measures, individual packages of instruments are captured in the graph, so that it is possible to link EU sanctions with the development of the Czech Republic's foreign trade in a simple way. The application of partial packages is naturally uneven over time - the first 5 packages were implemented in a short period of about 4 months at the beginning of 2022. The next 5 packages are designed in a much longer time horizon and at a distance from each other. However, as can be seen from the graph, the effect of the analyzed measures is only partial. It is very likely that the imposed sanctions contributed to the drop in Czech exports to Russia, which, however, have hardly changed since March 2022, even under the influence of the de facto 7 sanctions packages. Imports of goods from Russia have been growing since the beginning of 2022, despite the implementation of 5 sanctions packages, with a visible decrease only after the implementation of the sixth package of measures. However, this decrease is not necessarily caused by the effects of the analyzed packages. Since this is a drop in the period around June 2022, it is likely that it was rather a stabilization of the energy market. This connection can also be documented by price aspects on the market of basic energy commodities.

The possible connection of the EU's sanctions




Source: Czech Statistical Office (2023), own processing

Figure 2: Connection of sanctions packages with the development of the Czech Republic's foreign (mil. CZK) trade with Russian Federation.

instruments to the foreign trade of the Czech Republic with Russia can be generally seen in the overall course of trade, when it is evident from the presented outputs that at the end of 2022 (i.e. after the implementation of the eight packages) imports are significantly reduced, exports remain at a very low level and thus the overall trade balance is also low.

## Conclusion

The purpose of the paper is, from a legal point of view, to determine and characterize EU trade policy instruments that are currently being applied in a targeted manner in the area of foreign trade restrictions and subsequently to assess their impact on the development of the Czech Republic's trade with the Russian Federation. Based on the legal analysis, individual norms were identified and the starting dates of their legal force were determined. Subsequently, a simple statistical analysis of foreign trade was carried out, from which the basic aspects of development and structure emerged. From the beginning of the monitored period until the end of 2020, foreign trade showed positive results, which is particularly evident in the positive values of the trade balance. From 2021, a change in the characteristics of trade is quite clearly visible, when the Czech Republic's exports remain at similar values until the military crisis at the beginning of 2022, but imports increase greatly, deepening the negative balance of the trade balance. This situation calms down slightly at the turn of 2021 and 2022, but almost immediately after the start of the military conflict, imports increase enormously, and exports, on the contrary, collapse, leading to the highest negative values of the trade balance. On the basis of the legal analysis, the development of the mentioned characteristics of foreign trade was interspersed with the timeline of the sanction's packages. It is evident from the given output that the first wave of sanctions packages had almost no effect on the foreign trade of the Czech Republic, and the first restriction is only visible after the introduction of the fifth measure. The next set of sanctions packages, especially the sixth and seventh already bring significant changes both in the volume and structure of foreign trade. After the application of the 8th sanctions package, the trade balance drops to the minimum necessary level, which is mainly determined by the trade in energy raw materials.

It can be concluded that the partial sanctions packages (especially the series of the first five) affected the foreign trade of the Czech Republic and Russia in two aspects. On the one hand, there is a change in the commodity structure, and on the other hand, the level of exports from the Czech Republic to Russia is falling to below 2 billion CZK. At the same time, it can be stated that the packages did not disrupt the possibility of importing important raw materials from Russia during the artificially induced energy crisis, which can be considered a very good result of the EU's trade policy. Ultimately, it is also evident that the set of sanctions measures is gradually showing itself in foreign trade, and from the end of 2022, imports from Russia will also decrease significantly. With regard to the geopolitical situation, the given conclusion is probably proof

of the EU's effective foreign trade policy, which has the basic goal of limiting the income of the Russian Federation from its own exports, of which the Czech Republic can be a small example.

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