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The Influence of War on the Agricultural Production of Ukraine: Analysis and Projection Scenarios

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Abstract

Ukraine is one of the world's top agricultural producers and exporters, which plays a critical role in the oilseeds and grains supply to the global market. Though serious economic constraints and ecological problems have had a huge impact on the country's agricultural production. The following methods and tools of the scientific research were used in the research: empirical and comparative analyses, statistical analysis, including time series analysis, modelling and forecasting, the method of trends as well as textual and tabular methods added by bar charts for better data presentation and comparison, the OLS regression, etc. The agriculture of Ukraine faces a lot of challenges, among which, in particular, is the fact, that the Ukrainian agricultural producers are forced to reduce the production of the most productive types of products, such as wheat and corn, due to the logistical problems of the agricultural products exporting and the decrease of the purchase price. The agricultural economy sector of Ukraine enjoys a high adaptivity level, being resilient and flexible enough to withstand, overcome, adapt, making necessary changes, to such a shock as the war, in order to function successfully under the everchanging conditions, which is a pre-requisite to the fast restoration of the country in general and its regions/towns/villages in particular not only in the after-war but in the during-war periods as well.

Keywords: agricultural production; war influence; Ukraine; projection; OLS regression; adaptivity.

1 Introduction

Ukraine has excellent conditions for the successful development of the agricultural economy sector, including favorable climatic conditions, a preferable geographical location, a sufficient amount of water, availability of skilled and relatively cheap workforce, and vast areas of fertile soils. To introduce readers to the researched topic, it should be noted that the most famous rivers of the country are the Dnieper, the Dniester, the Southern Bug, and the Siverskyi Donets, with the Dnieper being the largest one among them. In addition, the territory of Ukraine contains over 3,000 lakes with a total area of over 2,000 square kilometers. They constitute nearly 3.5% of the country's total area, adding to its sufficient water supply. So, agriculture is the third largest source of income for the Ukrainian economy after the services and industry sectors. For example, in 2021, agriculture accounted for 10.9% of Ukraine's GDP, employing approximately 14% of the total number of employees in the country (Roman, 2024). In order to prove the importance of the agricultural economy sector for the successful functioning of Ukraine, the percentage of agriculture in the GDP of the country through the analyzed time frame is given in Figure 1.

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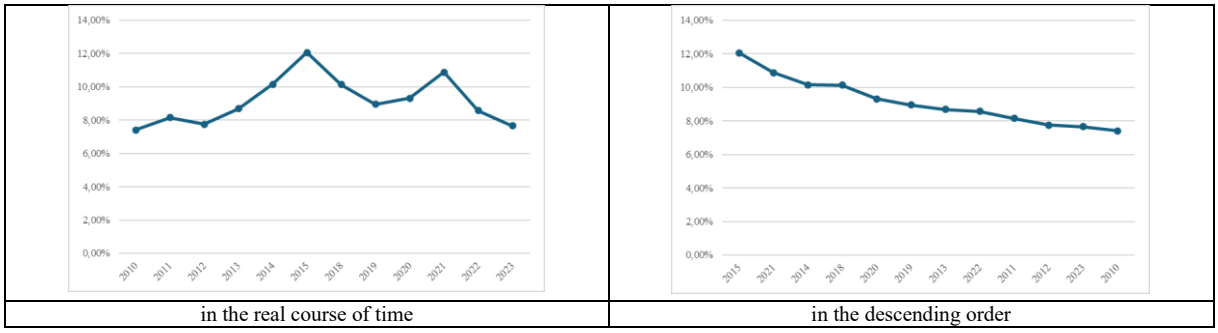


in the real course of time | in the descending order

Fig. 1. Share of Agriculture, Forestry and Fishing in Ukraine's GDP, %

Source: author's elaboration made on the basis of the data from (State Statistics Service of Ukraine, 2024(d) and (Diia, 2024).

As far as it can be seen from the data visualized in the figure given above, the percentage of agriculture in the country's GDP had two major peaks during the time frame under research, with the highest one in 2015. The possible explanation for such a high percentage of agriculture in the country's GDP in the year 2015 is the annexation of those parts of the Luhansk and Donetsk regions, in which the factories for the metallurgical industry were situated. That caused, therefore, the decrease in the percentage of industrial products in the country's GDP, and, thereby, the increase in the percentage of agricultural products. At the same time, the smallest percentage for the agricultural products in Ukraine's GDP can be observed in 2010. It can also be added that the mentioned percentage can be divided into three groups, plus two values unfitting for any of the mentioned three. The first group would include the years with the said percentage from 10 to 11 %, containing the years (in ascending order) 2018, 2014, and 2021. The second group would include the years with the mentioned percentage from 8 to 9 %, containing the years (in ascending order) 2011, 2022, 2013, and 2019. And the third group would include the said percentage from 7 to 8 %, containing the years (in ascending order) 2010, 2023, and 2012. Besides, the years that don't fit into either of the mentioned groups are 2015, with the highest percentage for the agro products in the GDP of the country, and 2020, in which we observe the value of approximately 9,3%. In addition, the percentage for agriculture, forestry, and fishing in Ukraine's GDP never decreased below the level of 7 % through the analyzed time period. On the one hand, the value of 7 % could seem to be not that big at all, but let's compare the said percentage with the ones in the EU member states, considering the same time frame (Figure 2).

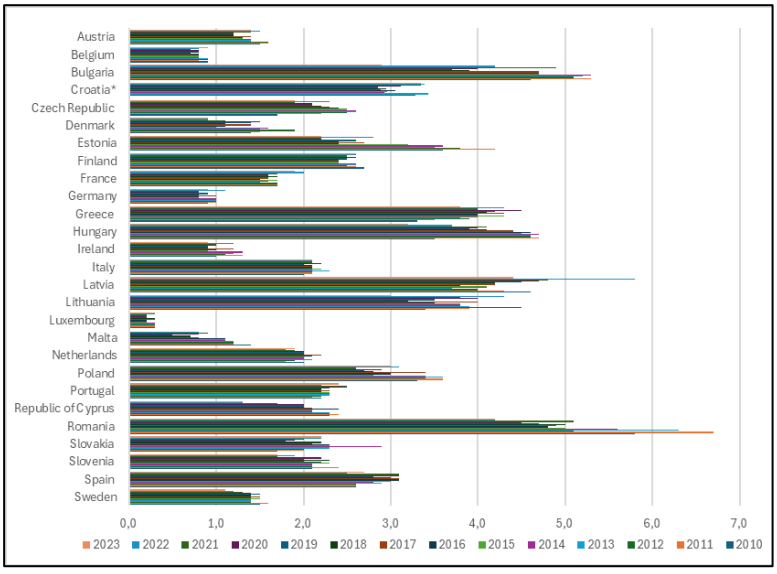
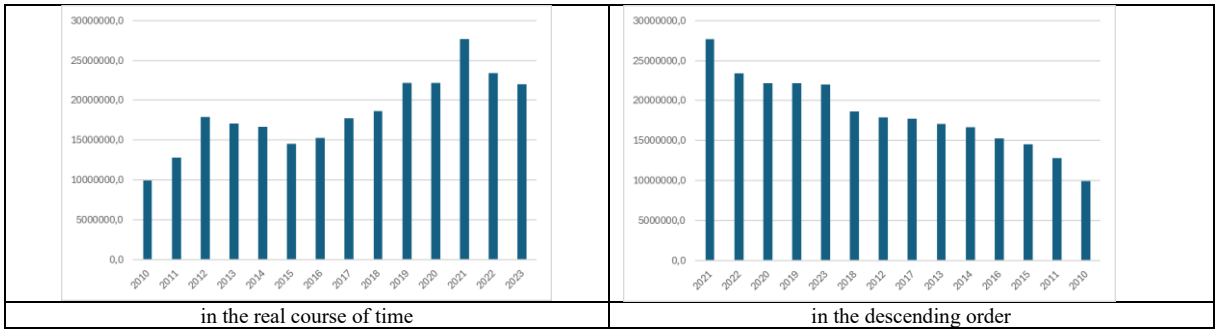


Fig. 2. Share of Agricultural Products in the EU member states' GDPs, %

Source: author's elaboration made on the basis of the data from (UNECE, n.d.). and (Trading Economics, n.d.).

As can be seen in the figure given above, the highest percentage of the mentioned economy sector in the GDP can be observed in Romania in the year 2011 (around 6.7 %), Latvia in 2022 (around 5.8 %), and Bulgaria in 2011

and 2014 (around 5.3 %). So, as you see, the biggest percentage values for agriculture in the GDP of the EU member states are lower than the smallest mentioned values of the same economic sector in the GDP of Ukraine. It should also be noted that crop production is more developed than animal production in Ukraine, with sunflower, wheat, and maize being among the most frequently sown. But, as with any seasonal production, the crops one depends on the climatic/weather conditions. Agriculture is important not only for the economy of Ukraine, for its successful inland functioning, but for its agricultural production exports as well. The dynamics for the agricultural products exports of Ukraine during the analyzed time frame can be followed in Figure 3.



in the real course of time	in the descending order

Fig. 3. Exports of Agricultural and Food Production of Ukraine, thsd USD

Source: author's elaboration made on the basis of the data from (State Statistics Service of Ukraine, 2023) and (State Statistics Service of Ukraine, 2024(a).

Having observed the data visualized in the figure given above, it can be noted, that the dynamics of Ukraine's agro exports has some kind of cyclicality and can be hypothetically divided into two periods: the first one – from 2010 to 2015 and the second one – from 2016 to the end of the analyzed time frame. It can also be added that the biggest value for the analyzed exports was in 2021, while the smallest one – in 2010. The smallest value for the agricultural products exports of Ukraine overlaps with the smallest percentage for the said products in the GDP of the country in the year 2010, as the industrial products took a bigger share either in the GDP or in the export amount of the country in the mentioned year. Being one of the most important global agro producers and exporters, Ukraine also contributes to the insurance of food security in many African and Middle Eastern countries. The interruptions in the grain exports of Ukraine, caused by the Russian invasion, proved the mentioned statement more than true. Thereby, the successful functioning of the Ukrainian agriculture with the uninterrupted production process is vitally important not only for Ukraine itself, but for the whole world as well.

It is a matter of common knowledge that any production process needs factors of production, the classical triad of which was recognized by economists before the twentieth century (Brun, n.d.). Then, in "Principles of Economics", which was published in 1890, Alfred Marshall introduced a fourth factor, called by him "organization and entrepreneurship" (Kondo, 1993). It should also be added that some economists divide factors of production into primary and secondary, referring to land-and-labor or labor-and-capital or land-labor-and-capital as the primary factors and the rest as the secondary ones (Gong, 2023). The technical relationship, which transforms inputs (factors of production) into outputs (commodities/services produced), is to be described by a production function, the generally accepted formula of which is:

$$y = f(x), \tag{1}$$

where 'y' is an output

'x' is an input (Debertin, 2012).

It should be stated, that in the case of more than one input, the production function mentioned above can be expressed in the following way:

$$y = f(T, L, K, O), \tag{2}$$

where 'y' stands for the quantity of output,

'T, L, K, O'– for such input factors as land, labour, capital and organization with the output being the dependent variable and inputs - the independent ones (Managerial Economics and Financial Analysis, n.d.).

The factors of production (inputs) as parts of a production function can also be divided into variable and fixed factors. The variable factors can be changed during the course of the short run, varying with the level of output (examples - labor, power, fuel, etc.), while the fixed factors are those, that cannot be changed in the short run, remaining constant even when there is no production (examples - land, capital, building, etc.) (GeeksforGeeks, 2023). That's why, in order to assess the agricultural production of Ukraine as well as the production factors used for it, the OLS regression function was used in the research.

Being a competitive advantage for the geo-economy of Ukraine, its natural wealth became an apple of discord for some of the country's neighbors or even global geo-political players. Therefore, the purposes of the research was to assess the agriculture of Ukraine adaptivity to such a shock as the war through making a model for the production factors for the agriculture of Ukraine; build trend lines with the prognoses for the analyzed production factors of the country's agriculture for the following years with the 2021, 2022 and 2023 last year's data; compare the projected and the real data in order to assess the war's impact on the agricultural sector production factors, and see the production factors prognoses under the scenarios of the war being over in 2022 or 2023. The assessment of the prognoses for the following four, three and two periods, made without the data of 2022 and 2023 and with them, helps us assess either how big the war's impact on the agricultural output and its production factors are as well as how the addition of the real time data changed the projections for the next periods It will give all the subjects involved in the agriculture and the relative industries of Ukraine valuable information as a helping hand to make the right decisions while adjusting the country's policy in general and the agricultural one in particular to the changing conditions of the current events the country is undergoing. And that testifies to the extreme significance of both the conducted research and its results presented in the given article.

2 Literature Review

Ukraine and everything connected with the country has become rather topical nowadays due to the war going on in the country and the impact it has on the country itself, or the food security of many countries. Among the scientists, exploring different aspects of the agricultural production of the country, one should mention, among the others, E. Régnier and A. Catallo making an overview of the Ukrainian agricultural sector and the challenges it faces in the light of the country's possible European Union enlargement (Régnier & Catallo, 2024); S. Matuszak made a research on Ukraine's agricultural production amount in 2021 and 2022 (Matuszak, 2023); E. Shahini and their colleagues stressed the need to find ways to increase the profitability of agricultural production in the difficult economic conditions of Ukraine (Shahini et al., 2023); Jean-Jacques Hervé wrote about the European and Ukrainian agricultures complementing each other (Hervé, 2024); A. Skrypnyk and his team made an econometric analysis of the impact of climate change on the sustainability of agricultural production in Ukraine (Skrypnyk et al., 2021(a); O. Shubravska and K. Prokopenko explored the problem of ensuring food security of Ukraine in the post-war context (Shubravska & Prokopenko, 2022); D. Fedchyshyn wrote about the peculiarities for the theoretical bases of formation and development of agricultural organic production in Ukraine in modern economic conditions (Fedchyshyn, 2020); a group of authors with the lead of V. K. Zbarsky indulged into the discussion about the social and economic determinants for the development of resource potential of small forms of agrarian production in Ukraine (Zbarsky, 2020); N. Kovalenko and her co-authors concentrated on the exploring of the economic efficiency and internal competitive advantages of grain production in the central region of Ukraine (Kovalenko et al. 2021); A. B. Kaminskyi, M. V. Nehrey and L. M. Zomchak discussed the impact of the Covid-19 on the agricultural economy sector of Ukraine in genegal and its agricultural production in particular (Kaminskyi, 2021); A. Skrypnyk with a group of co-authors discussed the prerequisites and prospects for sustainable development of grain production in Ukraine (Skrypnyk et al. 2021(b); L. Moldavan and O. Pimenova discussed the phenomenon of "holdingization" of the agricultural sector of Ukraine, its consequences and ways of prevention, stressing its impact on the agricultural production of Ukraine (Moldavan & Pimenova, 2021); Y. Dziurakh with a group of co-authors made an economic assessment and state regulation of the agri-industrial sector in Ukraine, exploring the solutions for ensuring food security through modelling and analysis, studying, in particular, the production and consumption of the main agricultural crops, like sunflower (Dziurakh et al. 2022), etc.

The following researchers wrote about the impact of the war on the agricultural production of Ukraine: J. A. Teixeira da Silva and their co-authors gave an insight into the impact of the Russo Ukrainian war on local, regional and global food security in the context of the Ukrainian agricultural production (Teixeira da Silva et al. 2023); J. Glauber analyzed Ukraine's and global agricultural markets in the course of two years of the war lasting (Glauber, 2024); a group of authors, led by M. Laber, investigated the shock propagation from the Russia–Ukraine conflict on international multilayer food production network determines global food availability, researching the Ukrainian agricultural production impact on other countries ones (Laber et al. 2023); Bin Chen with a group of co-authors made a quantification of losses in agriculture production in eastern Ukraine due to the Russia-Ukraine war (Bin

Chen et al., 2024); M. Chepeliev, M. Maliszewska & M. F. Seara e Pereira dived into the discussion on the issues connected with the war in Ukraine, food security and the role for Europe (Chepeliev et al. 2023); Faqin Lin with a group of co-authors assessed the impact of Russia-Ukraine conflict on global food security (Faqin Lin et al., 2023); C. Welsh and J. Glauber researched the notion of "food" as the "Silent Weapon" under the circumstances Russia's Gains and Ukraine's Losses (Welsh & Glauber, 2024); a group of authors, led by K. Deininger, quantified the war-induced crop losses in Ukraine in near real time to strengthen local and global food security (Deininger et al., 2023); D. Laborde Debucquet and their colleagues assessed the impact of the Russia-Ukraine war on African agriculture, trade, poverty, and food systems (Laborde Debucquet, 2023); a group of co-authors, led by B. Rice, wrote about the Russia-Ukraine war exacerbating international food price volatility (Rice, et al., 2022); V. Skribans and his colleagues discussed how the grain export routs changed for Ukraine in 2022-2023 (Skribans et al., 2024); W. L. Filho and a group of co-authors discussed how the War in Ukraine Affects Food Security (Filho et al., 2023); S. Devadoss and W. Ridley assessed the impacts of the Russian invasion of Ukraine on the global wheat market (Devadoss & Ridley, 2024); C. Hebebrand and J. Glauber researched the year impacts of the Russia-Ukraine war on fertilizer production, prices, and trade flows and the likely impacts going forward for agricultural production and food security (Hebebrand & Glauber, 2023); H. El Bilali and T. Ben Hassen made a systematic review of how Ukraine – Russia war influences global food systems through the influence of the internal agri – food production of Ukraine (El Bilali & Ben Hassen, 2023); a group of authors, led by H. van Meijl, discussed how the Russia-Ukraine war decreases food affordability but could reduce global greenhouse gas emissions, studying the medium-term effects of the war on agricultural production (van Meijl et al., 2024); B. R. Rexhepi, B. I. Berisha and B. S. Xhaferi analyzed the impact of the war on the economic state of agriculture in Ukraine in general and its agricultural production in particular (Rexhepi et al., 2023); J. Janzen and C. Zulauf researched the Russia-Ukraine war influence on the changes in Ukraine corn and wheat supply from the point of view of its impacts on the global agricultural markets (Janzen & Zulauf, 2023), etc. So, the analysis of the available literature sources indicates some interesting observations – mostly Ukrainian authors write about the agricultural production of Ukraine in general, while non-Ukrainian ones – about the impacts of the Russian invasion on either Ukrainian or global agriculture and agricultural markets. And that, further on, lets us indicate the scientific gap the conducted research will perfectly fit in, proposing the scientifically calculated scenarios of the Ukrainian agriculture development in the cases of the war ending in the years 2022 or 2023, with the eventual further projections of the four main production factors' development.

3 Material and Methods

The following methods and tools of the scientific research were used while conducting the research presented in the given article: empirical and comparative analyses, statistical analysis, including time series analysis, modelling and forecasting, the method of trends as well as textual and tabular methods added by bar charts for better data presentation and comparison, the OLS regression, etc. The data, analyzed in the research, were taken from the official publications of the State Statistics Service of Ukraine. The data for the years 2010 – 2013 are provided taking into account the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol, and part of the temporarily occupied territories in Donetsk and Luhansk regions. The data for the years 2010 – 2021 are provided without taking into account the temporarily occupied territory of the Autonomous Republic of Crimea and the city of Sevastopol. The data for the years 2014 – 2021 are provided without taking into account part of the temporarily occupied territories in Donetsk and Luhansk regions. The data for the years 2022 – 2023 are provided without taking into account the territories temporarily occupied by the Russian Federation and parts of the territories where hostilities are (were) ongoing. In addition, the data for the years 2017 – 2019 are given, taking into account changes in the NBU balance of payments indicators. More than that, the values for the agricultural output of Ukraine were taken in the constant prices of 2021 in order to minimize the inflation influence on the said variable.

The specific notions were used in the research in the following meanings: "capital investments – expenditures on acquisition or own production of tangible and intangible assets" (State Statistics Service of Ukraine, 2023); "number of hired employees includes average-account number of members of the enterprise staff and members not on the permanent staff" (State Statistics Service of Ukraine, 2023); "constant prices are the weighted average prices of the year, accepted as the basis for comparison" (State Statistics Service of Ukraine, 2023); "agricultural products at constant prices – the cost of agricultural products, produced during a certain period of time, at constant prices" (State Statistics Service of Ukraine, 2023); "the area of agricultural crops is the area that was actually planted with agricultural crops in the spring (the area of pre-served winter crops and the area of spring crops), taking into account the sowing of late crops for the harvest of the current year (summer plantings)" (State Statistics Service of Ukraine, 2023), etc.

The explored data were composed in three data sets: 2010 – 2021, 2010 – 2022, and 2010 – 2023, that is, there were three time frames of the analyzed data sets of 12, 13, and 14 time periods, in this case, years. The projections were made for the four following periods for the 2010 – 2021, for three periods for the 2010 – 2022, and for two periods for the 2010 – 2023 datasets. Such a difference in the projections' time periods was made in order to compare the projections values as well as trend lines directions for two periods following the year 2023, taking into account the changing real time data for the years 2022 and 2023, drawing the conclusions on the war impact on the agricultural production as well as the agricultural production factors of Ukraine. It should also be added that the mentioned projections were made under the assumption that the circumstances would remain unchanged. Only the two following periods were decided to be projected after the year 2023 because of either the uncertainty of the current situation Ukraine is living through or an abundance of factors having a different level of influence on all the spheres of the country's functioning because of the war.

The trend lines for the analyzed data sets were built with the help of an appropriate function, which was chosen from the exponential, linear, logarithmic, polynomial, and power functions. The criterion for the choice of the appropriate function was the R^2 coefficient values as a measure of the trendline's reliability (Microsoft, 2022). Though the said criterion has its limitations, it is commonly used as one of the goodness-of-fit statistics. The technical expression of the exponential function is as follows:

$$f(x) = a^x \quad (3),$$

where 'a' > 0 and not equal to 1,
'x' is any real number (BYJU'S, n.d.).

A linear function is a function that represents a straight line on the coordinate plane (CueMath, n.d.), built according to the following formula:

$$y = mx + b \quad (4),$$

where 'y' – the dependent variable,
'm' – the slope of the line,
'b' – the y-intercept of the line, and
'x' – the independent variable (CueMath, n.d.).

The trend line built, which was built with the help of the logarithmic function, used the following formula:

$$y = b \times \ln(x) + c \quad (5),$$

where 'y' is the dependent variable, 'x' is the independent variable,
'b' is the slope and
'c' – the intercept (XcelanZ, 2018).

A polynomial function is commonly used to catch the major ups and downs of the fluctuating data sets. Therefore, the quadratic trinomials were used for the research, the technical expression of which is:

$$y = ax^2 + bx + c \quad (6),$$

where 'y' is the dependent variable,
'a' and 'b' are coefficients,
'x' – the independent variable,
and 'c' is the constant (Vedantu, 2024).

The technical expression of a power function is the following formula:

$$y = ax^b \quad (7),$$

where 'y' is the dependent variable,
'x' – the independent variable,
and 'a' and 'b' are the parameters of the function, meaning – the unction coefficients or constants, found by the least squares method (Officetooltips, 2023).

In order to create a model for the agricultural production of Ukraine, the ordinary least squares regression was used for the said purpose. The OLS regression is a method that allows us to find a line that best describes the

relationship between one or more predictor variables and a response variable (Bobbitt, 2022). The technical expression of the mentioned function is as follows:

$$\hat{y} = b_0 + b_1 x \quad (8),$$

where: 'ŷ' – the estimated response value,
'b_0' – the intercept of the regression line,
'b_1' - the slope of the regression line
'x' – the independent variable (Bobbitt, 2022).

As the analyzed data sets contain a relatively small (from the statistical point of view) number of observations added by outliers, present in some data sets, which influence the model coefficients calculation results, it was decided to build trend lines with the projected periods using the functions mentioned above, in order to make the research results the most robust possible.

4 Results and Discussion

Ukraine is one of the world's top agricultural producers and exporters, which plays a critical role in supplying oilseeds and grains to the global market (USDA, 2022). However, serious economic constraints (Russian invasion, unemployment, inflation-recession, problems in the privatization process, etc.) and ecological problems (Chernobyl, soil degradation, climatic changes, etc.) have had a serious impact on the country's agriculture (FAO, 2001). Therefore, production and trade activities have been changing and adjusting to the war's effects as access to such resources as fertilizers and fuel has become limited for Ukrainian agricultural producers since the beginning of 2022. That impacted the agricultural production and trade of the country, which was also impacted by the limited human resources (Kalna-Dubinyuk & Dubinyuk, 2024). The main statistical indicators for the aggregated data sets were composed in a tabular form to better compare the said indicators (Table 1).

Table 1. Descriptive Statistics of the Analyzed Data Sets

		2010 - 2021	2010 - 2022	2010 - 2023
Sown Area	**Minimum**	26902	23405	22809
	1st Quartile	27186	27026	26971
	Median	27685	27670	27628
	Mean	27661	27334	27010
	3rd Quartile	28038	28001	27951
	Maximum	28581	28581	28581
Employees	**Minimum**	520.3	448.4	406.4
	1st Quartile	562.0	553.2	531.1
	Median	590.0	581.8	578.0
	Mean	620.0	606.8	592.5
	3rd Quartile	682.3	670.9	670.7
	Maximum	738.6	738.6	738.6
Capital	**Minimum**	11063	11063	11063
	1st Quartile	18993	19059	19147
	Median	40320	50484	50582
	Mean	39676	40581	42356
	3rd Quartile	60408	59130	62965
	Maximum	69950	69950	69950
Agro Output	**Minimum**	881904	881904	881904
	1st Quartile	1109467	1060049	1073902
	Median	1163897	1157251	1155900
	Mean	1153632	1142136	1140231
	3rd Quartile	1214288	1196874	1193333
	Maximum	1344276	1344276	1344276

Source: author's elaboration made with the help of (R Core Team, 2023) on the basis of the data from (State Statistics Service of Ukraine, 2024(b), (State Statistics Service of Ukraine, 2024(d) and (National Bank of Ukraine, 2024).

Among the observations, which are to be made after having studied the data presented in Table 1, one should mention the mean–median differences for the analyzed data sets, being one of the indicators for the datasets' distribution non/normality. Analyzing the "Sown Area" data sets, one should note that among the three data sets of the mentioned variable, the one of 2010 – 2021 is the closest to being normally distributed. An absolutely opposite situation is to be observed in the case of the "Employees" variable, as the difference between the mentioned indicators becomes less with the course of the data addition, showing closer distance to the data distribution normality. The situation, different from the ones described above, can be observed in the case of the "Capital" variable, that is – we see the mean – median difference increase in the 2010 – 2022 data set, compared to that of 2010 – 2021, with the following decrease in 2010 – 2023 data set. The situation similar to that of the "Sown Area" variable can be observed with the one of the "Agro Output" variable, meaning – the increase of the mean – median difference with the adding of the data from the years 2022 and 2023, leading to the further "movement" of the data sets from the distribution normality. In order to have a broader look at the data sets under research, the box plots of the said data sets are presented in the common figure (Figure 4), to make the comparative analysis easier for those interested.

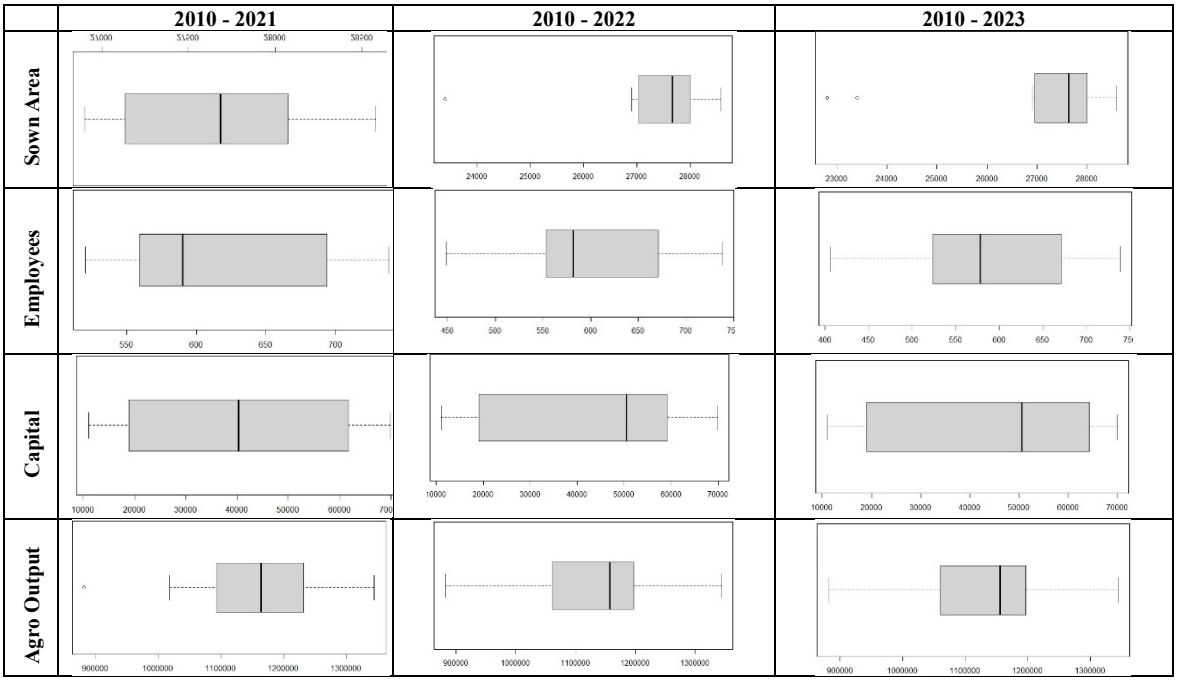


Fig. 4. Box Plots of the Analyzed Data Sets

Source: author's elaboration made with the help of (R Core Team, 2023) on the basis of the data from (State Statistics Service of Ukraine, 2024(b), (State Statistics Service of Ukraine, 2024(d) and (National Bank of Ukraine, 2024).

Having observed the box plots for the analyzed data sets horizontally, we can observe how the data distributions changed with the addition of the data for the following years, meaning 2022 and 2023. The visualization of the data sets under research, presented in Figure 4, confirms the analysis results of the data in Table 1. In order to create a model for the agricultural output of Ukraine with the number of employees, hired in the agriculture, forestry and fishery, an amount of the capital, invested in the said economy sector, and an acreage of the sown area as independent variables, the b_0 and b_1 coefficients were calculated and presented in Table 2.

Table 2. Model Parameters Values for the Agricultural Output of Ukraine

	2010 - 2021		2010 - 2022		2010 - 2023	
	b_0	b_1	b_0	b_1	b_0	b_1
Sown area	-2.001e+06	1.140e+02	-176089.93	48.23	394079.02	27.62
Employees	1928031.5	-1249.0	1542880.8	-660.4	1401833.5	-441.5
Capital	9.785e+05	4.413e+00	9.787e+05	4.027e+00	9.896e+05	3.557e+00

Source: author's elaboration made with the help of (R Core Team, 2023) on the basis of the data from (State Statistics Service of Ukraine, 2024(b), (State Statistics Service of Ukraine, 2024(d) and (National Bank of Ukraine, 2024).

The coefficient values, presented in the table given above, represent the influence/relations of the mentioned variables on the agricultural output of Ukraine. The calculation results are very interesting as we observe the change from the negative to the positive values of the b_0 coefficient along the addition of the 2022 and 2023 data in the case of the "Sown Area" variable. But the values of the b_1 coefficient decreased simultaneously. The b_0 coefficient decreased in value with the addition of the 2022 and 2023 data in the case of the "Employees" variable, while the b_1 coefficient decreased in negative value with the addition of the mentioned years' data. One can have a temptation to talk about the phenomenon of "hidden unemployment" or even "charitable employment" as a possible explanation of such results of the "Employment" variable. But the said notions were characteristic of the socialist or planned economy, and it is rather the availability of better machinery and mechanisms and the improvement of the agricultural technologies and materials, that levels the influence of the number of employees on the amount of agricultural production. The b_0 coefficient increased its values in the course of time insignificantly, with the simultaneous decrease of the b_1 coefficient values, when analyzing the "Capital" variable. In order to make the research results the most robust possible, other research methods, like the method of trends, were used while conducting the research presented in the given paper. The matter is that the calculation results of the model coefficients could be influenced by either the relatively small number of observations, the presence of outliers, or the non-normality of the data sets' distributions under analysis. Therefore, the next step of the research was to check what the prognoses for the analyzed production factors of the Ukrainian agriculture would be for the following years, based on the 2021, 2022, and 2023 data from the last year. The comparison of the projected and the real data would help us assess the war's impact on the agricultural sector production factors. The said method could also be described as the attempt to see the production factors' prognoses under the scenarios of the war being over in 2022 or 2023. The said method would also help us assess the adaptability of the Ukrainian agriculture to such a shock as a war. The common figure of the analyzed variables in the form of three data sets each, meaning the ones for 2010 – 2021, 2010 2022, and 2010 – 2023, with trend lines and projections for the following periods, is presented in Figure 5.

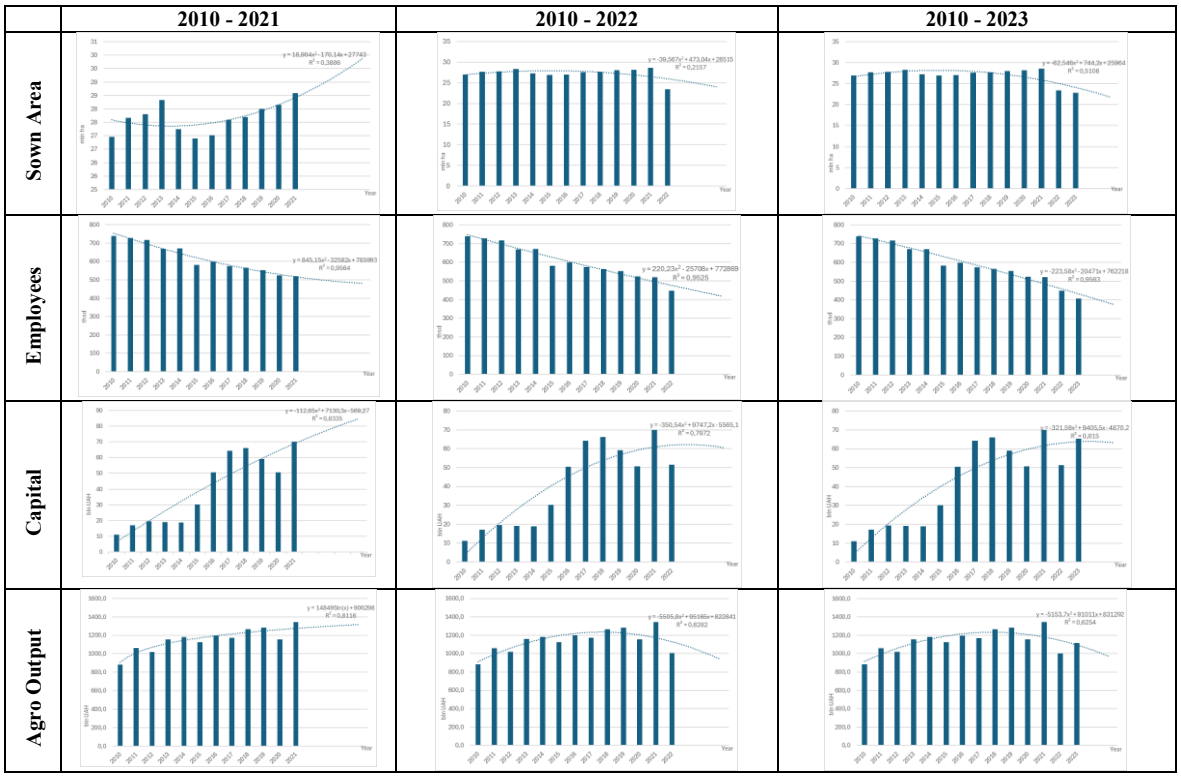


Fig. 5. Trend Lines with Projections for the Analyzed Data Sets

Source: author's elaboration made with the help of (R Core Team, 2023) on the basis of the data from (State Statistics Service of Ukraine, 2024(b), (State Statistics Service of Ukraine, 2024(d) and (National Bank of Ukraine, 2024).

Having observed the data depicted in the figure given above, one can state that only the "Employees" variable didn't change its general trend line, though its amplitude did. The trend line of the 2010 – 2021 data set is downward, showing the continuous decrease of the variables' values. Having added the 2022 data, we can see that

the trend line continued to be of the kind, but its slope appeared to be steeper, showing a bigger decrease in the predicted values. The said process continued in the case of the 2010 – 2023 data set. It should also be added that the trend lines for the 2010 – 2021, 2010 – 2022, and 2010 – 2023 data sets were built with the help of polynomial functions.

The variable, the trend line of which changed the most with the addition of the following two years' data, is the "Sown Area" one. If the 2010 – 2021 data set trend line was steep upward, then in the 2010 – 2022 it became almost horizontal with a slight downward direction for the projected periods, while in the 2010 – 2023 the downward direction of the trend line became steeper, indicating the decrease of the sown area acreage for the following two years. The trend lines for all three data sets under research were built with the help of polynomial functions.

The trend line of the "Capital" variable is steeply upward in the 2010 – 2021 data set, showing a definite increase in the capital investment into the agriculture of Ukraine for the following periods. But in the 2010 – 2022 data set the mentioned trend line, though remaining upwards to the year 2021 included, acquired a horizontal, even a little bit downward at the end, direction, showing the decrease of the invested Capital for the projected periods, if compared to that of 2021, but its increase, if compared to 2022. In 2023, the capital investments into the agriculture of Ukraine increased, improving the prognoses for the following two periods, though indicating them to be either approximately at the same level as in 2023 or a little bit smaller. The trend lines for all three data sets of the said variable under research were built with the help of polynomial functions.

The "Agro Output" trend line of the 2010 – 2021 data set is also upward, but not as steep as the one of "Capital" in the same period. As the agricultural output of Ukraine decreased in 2022, it also changed the trend line of the 2010 – 2022 data set for the downward direction, starting from the year 2019, but showing a slight increase in the said output for the next period. The real data for the year 2023 fitted perfectly into the said trend line, though making it a little bit less steep, showing a decrease in the agricultural output in Ukraine for the following two periods.

The research, presented in the given article, is the continuation of the research conducted by the author previously, but the last year, with the data available, was 2022. The difference between the projected and the real-time data shows how a war can either influence a single economic sector of a country or its projected development. Of course, it's not one single event that made such drastic changes to all the spheres of Ukraine's functioning, but rather a combination of several factors, and the war is the most severe of them. Though having great prospects for further development and expansion, the research topic explored in the given paper contains certain limitations in itself. The war is the biggest limitation, but it is not alone. It is rather all the by-products and by-circumstances, that go along or are caused by that horrible event, such as the unavailability of up-to-date statistical data, the black-outs causing the interruptions in the internet connection, computers and telephones functioning, the insufficient number of workers/employees/officials, because of the emigration and military service, and so on.

5 Conclusions

Ukraine has a developed agri–food complex, which is capable of either fully providing the country's population with agricultural and food products or contributing to the country's becoming one of the leading players on the international markets (NISS, 2024). But the hostilities taking place in Ukraine, being resulted by the large-scale aggression of the Russian Federation on the country, led to the deterioration of the food security in Ukraine, which is caused, in particular, by the disrupted logistics chains, destroyed infrastructure, farms and enterprises, causing a decrease in the amount of the produced food (NISS, 2024). According to the FAO assessments, the damages made to the Ukrainian agriculture include, among others, partial or full destruction of machinery and equipment, storage facilities, livestock, and perennial crops, as well as stolen inputs and outputs and agricultural land that needs re-cultivation. The losses also include production loss, including unharvested winter crops, higher farm production costs, and lower farm gate prices due to the export logistic disruptions (FAO, 2022).

Despite the challenges and damages mentioned above, Ukraine is to function further on with its agriculture functioning successfully. It should be able to supply enough agricultural and food products for its own population and produce enough surplus to export abroad, ensuring foreign currency inflow into the country's budget and the companies involved. The companies involved in broad agriculture are to be able to pay taxes fully and on time to support the country's ability to withstand the current challenges. The analysis of the 2010 – 2021 data set, the pre-war agricultural production factors of Ukraine assessment, indicates the upward trend by all the factors except for the number of employees. That is, in case no war had occurred, the agriculture of Ukraine had all the prerequisites to develop successfully further on, showing upward tendencies in three out of four production factors for the projected time periods. The addition of the real-time data from 2022 changed either the real-time or the projections trend lines for all the analyzed variables for the downward ones, indicating the absolutely negative scenario of the Ukrainian agriculture development, if made under the conditions of the 2022 data. The addition of the real-time

data from 2023 improved the general overview of the analyzed data sets only in two of them, meaning agricultural output and capital, though leaving the trend lines either for the real-time periods or the projected ones downward. The real-time data from 2023 for the rest of the variables, that is, the sown area and the number of employees, confirmed the negative tendency in either their real-time or the projected development. It should also be stated here that all the projections were made under the assumption that the conditions would remain unchanged.

According to the research results, meaning the increase of either the capital, invested into the agriculture, forestry and fishery of Ukraine, as well as the agricultural products output (in constant 2021 prices), the agricultural economy sector of Ukraine enjoys a good adaptivity level, being resilient and flexible to withstand, overcome, adapt, making necessary changes, to such a shock as the war, in order to function successfully under the everchanging conditions. The other two analyzed variables showed their real-time decrease, which can be explained by a direct war impact. The decrease of the "Sown Area" variable values occurred because a certain amount of the agricultural land was taken by the aggressor, some agricultural land is being under military actions, while some is damaged or mined as a consequence of the said actions. Although the decrease in the number of employees was obvious in the pre-war period as well, the war intensified this process with the increased number of people fleeing either from the occupied territories, the ones with the active military actions going on, or simply seeking a safe place to live. It should be stressed that the adaptability of Ukrainian agriculture is a prerequisite for the fast restoration of the country in general and its regions/towns/villages in particular, not only in the post-war period but also during the war. The adaptive and flexible agriculture contributes to the development and intensification of the adjacent economic spheres and activities, including, but not limited to, food processing, agricultural machine building industries, fertilizers, bio-fuel production, the IT sector, etc.

Besides its good level of adaptivity and flexibility, the agriculture of Ukraine faces a lot of challenges, among which, besides those caused directly or indirectly by the war, is the fact that the Ukrainian agricultural producers are forced to reduce the production of the most productive types of products, such as wheat and corn, due to the logistical problems of the agricultural products exporting and the decrease of the purchase price. As a consequence, the structure of the crops sown had to be changed, actually through one market year, to overcome the export/logistical obstacles mentioned above. In addition, due to the said challenges and obstacles, the structure of the agricultural-food production should have been changed, placing stress on the development of the processing and food industries rather than raw agro products exporting.

The research as well as its results, presented in the given article, would be of great interest, help and use for the public administrators of all the levels and country's functioning spheres, the owners and employees of the agricultural enterprises of all the forms of ownership and size, all the subjects of the local/regional/international agricultural products markets, politicians and decision makers of the local/regional/international level, academic community representatives as well as statisticians and data analytics, either beginners or experienced ones.

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