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THE RELATIONSHIP BETWEEN GHG EMISSIONS AND AGRICULTURAL LAND PRODUCTIVITY IN THE EU MEMBER STATES AND UKRAINE

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Abstract. *The article is devoted to the quantitative relationship between greenhouse gas emissions and agricultural land productivity in EU member states and Ukraine (a country that continues to integrate into the EU). The author made a comparative analysis of the productivity of agricultural land in EU member states, other leading players in the world agricultural market, Ukraine and the world average value. The method of statistical grouping was used to determine the reason for the different productivity of agricultural land (the value of gross output per 1 hectare of agricultural land) in the EU member states and Ukraine. The author identified the cause of high levels of greenhouse gas emissions (carbon dioxide equivalent) per hectare of agricultural land in the most developed EU countries by the graphical method. Based on the calculated target level of greenhouse gas emissions per hectare of agricultural land in the EU until 2030, required by the European Green Deal, the significant threat to the EU member states and Ukraine in terms of a possible decline in agricultural production has been identified.*

By using the econometric method and the method of regression analysis, the author identified the existence of a positive and strong quantitative relationship between emissions of carbon dioxide equivalent and the value of agricultural production per hectare of land in the EU member states and Ukraine. The magnitude of the increase of carbon dioxide equivalent emissions under the condition of increasing the value of gross output per hectare of agricultural land by one euro is calculated. Based on the results of the study, the author concluded that there is a high probability of reducing the productivity of agricultural land in developed EU countries if greenhouse gas emissions are reduced to the level of the target value. The author also substantiated the practical lack of opportunity for less developed countries of the EU and Ukraine to increase the economic productivity of land, subject to compliance with the requirements of the European Green Deal. Recommendations for avoiding a possible threat in agricultural production of the studied countries are summarized.

Keywords: *greenhouse gas emissions; carbon dioxide; methane; agricultural land productivity; regression analysis; quantitative relationship; EU; European Green Deal*

Introduction.

Under conditions of the European Green Deal, the Commission has an ambitious climate target plan until 2030. The greenhouse gas (GHG) emission reduction target towards 50 or 55% compared with 1990 levels should be achieved (Commission, 2020). It should be noted that agriculture is responsible for 10.3% of the EU's GHG emissions. Furthermore, approximately 70% of the agricultural sector emissions come from the animal sector (EEA, 2019). Thus, also the environmental reform concerns the EU's agriculture that has been represented in the Farm to Fork Strategy. It is aimed to make a resilient and sustainable food system that will bring environmental, health, and social benefits, offer economic gains, especially after the COVID-19 pandemic and the economic downturn. The food system remains one of the key drivers of climate change and environmental degradation (Farm to Fork Strategy, 2020).

However, given the close link between agricultural productivity and carbon dioxide emissions, the fight to reduce GHG emissions is likely to decrease the economic effectiveness of agricultural land use in both developed and less developed EU member states. Hence, to identify the closeness of the quantitative relationship between the above factors to assess the real level of threat to agricultural producers in the EU and Ukraine (a country which has been integrating into the EU) due to the implementation of the European Green Deal is important.

Analysis of recent researches and publications.

The following authors studied the relationship between carbon dioxide emissions and agricultural productivity: Leitão (2018), Edoja, Aye & Abu (2016), Pant (2009), Asumadu-Sarkodie & Owusu (2016), Filiz & Omer (2012), Bakhtiari, Hematian & Sharifi (2015) and other scientists and economists. However, these authors did not research the scientific problem in the case of the EU member states and Ukraine.

Purpose. The purpose of the article is to detect the relationship between GHG emissions (CO_2eq) and agricultural land productivity in the EU member states and Ukraine for estimating the threats under conditions of the European Green Deal.

Materials and methods of research.

In the process of research such scientific methods were used as method of statistical grouping for detecting the reasons of different agricultural land productivity among the EU member states and Ukraine; comparison and graphical methods to determine the states with high and low GHG emissions per hectare of agricultural land; econometric method and regression analysis by *STATISTICA* software to detect the correlation between carbon dioxide equivalent emissions and agricultural land productivity in the EU member states and Ukraine etc.

Results of the research and their discussion.

The EU's agriculture has a relatively high level of economical effectiveness and productivity. In particular, the regional agricultural land productivity (gross production value in agriculture in constant 2014–2016 prices per 1 hectare of agricultural land) equaled $ 2097.84 in 2018 that was 2.4 times more than the

world's average indicator. To compare, the gross value which was produced by the US farmers equaled only $ 912.07 per 1 hectare of agricultural land, by farmers in New Zealand – $ 1489.73, in Brazil – $ 858.83, in Argentina – $ 436.29, and in Ukraine – $ 751.68.

Generally, the EU's agricultural output was balanced: crops production value almost equaled livestock production value (in particular, meat indigenous and milk value together) (Table. 1).

In contrast with the EU, Ukraine had a similar structure to the world agricultural production. In both variants, crops production value exceeded livestock production. Furthermore, the Ukrainian agricultural lands are used with low economic productivity. Among the EU member states, only Baltic countries had a lower gross production value per 1 hectare of agricultural land than in Ukraine. It should be underlined that almost all EU countries which were characterized by a high level of agricultural land productivity (more than average EU's level), excluding Italy and France, had significant livestock productivity. Thus, in the Netherlands and Belgium, farmers produced per 1 hectare of agricultural land more than $ 2600 of meat indigenous, while in Malta and Cyprus, the total milk value per 1 hectare exceeded $ 1500 in 2018.

Probably, agriculture in these member states should emit into the atmosphere a lot of volume of methane. Thus, among the EU countries, the Netherlands, Malta, Belgium, Cyprus, including Luxembourg, Ireland, and Denmark had the largest methane emissions per 1 hectare of agricultural land – above 2 tonnes in CO2 equivalent while the average world's level is 1.26 tonnes (Fig. 1). As the result, if farmers in Spain and Italy produced the total CO2 equivalent emissions per 1 hectare of agricultural land in volume only 1.44 and 2.25 tonnes, then farmers from the Netherlands, Malta, Belgium, and Cyprus emitted 9.72, 7.35, 6.91, and 4.09 tonnes, respectively. To compare the average EU level was 2.34 tonnes, while the average world's level of indicator – 1.25 tonnes, and in Ukraine – 0.71 tonnes per 1 hectare of agricultural land.

In general, the most developed EU member states, excluding Italy, Spain, Portugal, and Sweden, demonstrated a higher level of carbon dioxide equivalent emissions per hectare of agricultural land than the average EU indicator (Fig. 2). Also, as a rule, the less developed countries in the region were characterized by a low level of agricultural land productivity and their farmers emitted CO_2 equivalent per 1 hectare of agricultural land below the average EU level.

However, in terms of the European Green Deal, the GHG emission reduction target towards 50 or 55% compared with 1990 levels should be achieved till 2030. In the case of agriculture, it means that carbon dioxide equivalent emissions should be decreased approximately to 1.35 tonnes per 1 hectare of agricultural land in the EU.

It should be emphasized that all member states, excluding only Greece, Bulgaria, Latvia, and Hungary, have a higher level of the GHG emission reduction target in agriculture (in Ukraine this indicator has equaled to 0.71 tonnes). As the result, there is a threat of agricultural productivity losses for developed members and the impossibility to increase productivity for less developed EU states under conditions of the climate change fight. It may be in case of existence the strong positive relationship between carbon dioxide emissions and agricultural land productivity.

1. Agricultural land productivity by the main items aggregated in the EU-28, world, and Ukraine in 2018

No	Country / World	Gross production value (constant 2014–16 prices) per 1 hectare of agricultural land, $			
		Meat indigenous, total	Milk, total	Crops, total	Agriculture, total
1	Netherlands	2616	3226	2883	9130
2	Malta	2054	2294	3481	8835
3	Belgium	2661	1074	2172	5963
4	Cyprus	1691	1727	1420	5027
5	Italy	751	491	2191	3516
6	Denmark	1328	888	862	3125
7	Germany	878	749	1018	2733
8	Austria	826	613	867	2451
9	France	505	373	1434	2354
10	Luxembourg	491	1173	511	2237
11	Greece	210	246	1469	1990
12	Spain	396	146	1352	1948
13	Ireland	990	604	136	1748
14	Portugal	396	228	1041	1732
15	United Kingdom	690	339	616	1712
16	Poland	515	331	694	1590
17	Slovenia	479	359	580	1453
18	Hungary	319	125	912	1410
19	Romania	137	166	976	1347
20	Finland	355	497	441	1336
21	Czech Republic	243	315	721	1321
22	Croatia	331	171	683	1243
23	Sweden	377	389	387	1232
24	Slovakia	95	161	652	976
25	Bulgaria	96	79	651	853
26	Lithuania	118	149	396	688
27	Estonia	127	258	265	677
28	Latvia	86	145	257	522
	EU-28, total	542	380	1098	2098
	Ukraine	82	59	586	752
	World, total	197	78	540	873

Source: compiled by FAOSTAT, 2021.

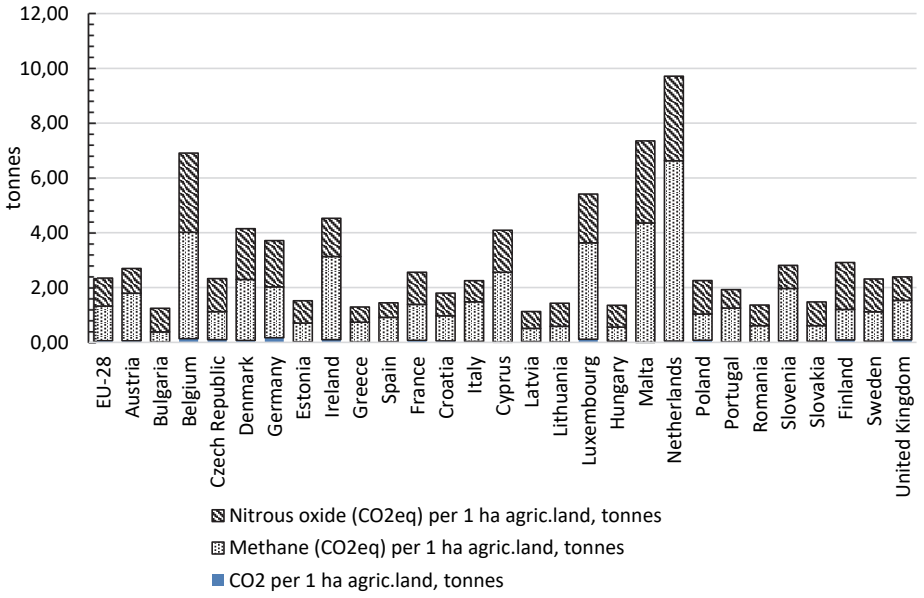

Fig. 1. Carbon dioxide, nitrous oxide, and methane emissions per 1 hectare of agricultural land in the EU (total) and member states in 2019

Source: compiled by Eurostat, FAOSTAT, 2021.

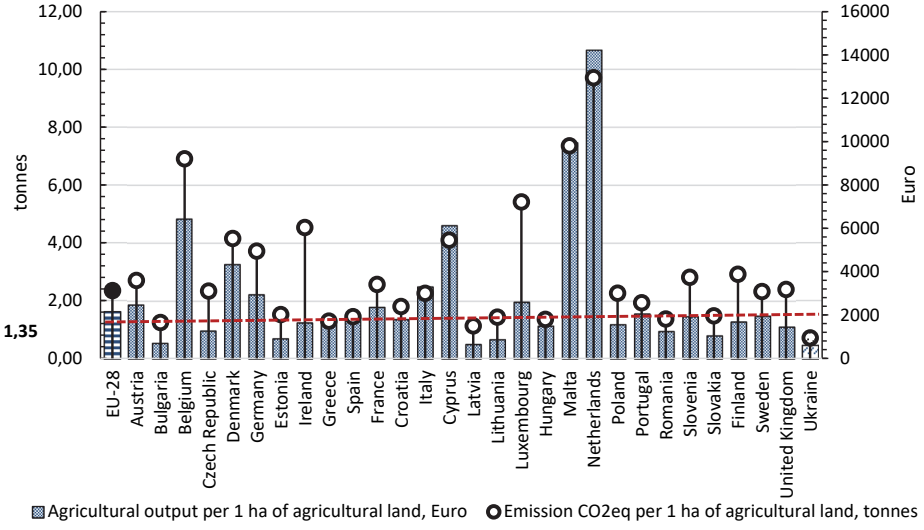

Fig. 2. Agricultural land productivity and carbon dioxide emissions (equivalent) per 1 hectare of agricultural land in EU and Ukraine in 2019

Source: compiled by Eurostat, FAOSTAT, and Ukrstat, 2021.

There is bidirectional causality between agricultural activity and climate change (Leitão, 2018). For example, the scientific research results by Edoja (2016) and Pant (2009) showed that agricultural productivity has a negative impact on CO^2 emissions. Other authors, Asumadu-Sarkodie & Owusu (2016), Filiz & Omer (2012), Bakhtiari, Hematian & Sharifi (2015), and Leitão (2018) consider that agricultural production intensifies climate change.

In this article, the econometric model was used to detect the correlation between carbon dioxide emissions and agricultural land productivity in the EU member states and Ukraine. Here, carbon dioxide emission (CO_2eq) is the dependent variable measured in metric tons per 1 hectare of agricultural land. The data is coming from the Eurostat and FAOSTAT databases. In turn, the independent variable introduced in the regression is agricultural land productivity (*LAND*). Thus, carbon dioxide emission is thought to be directly related to this function:

$$CO_{2eq} = f(LAND) \quad (1)$$

Statistically, the following model is run:

$$Y = a_0 + a_1 X + u \quad (2)$$

where Y – represents carbon dioxide emissions per 1 hectare of agricultural land; X – agricultural land productivity (agricultural output per 1 hectare of agricultural land in constant prices 2010, euro).

The STATISTICA software was used to estimate the econometric results.

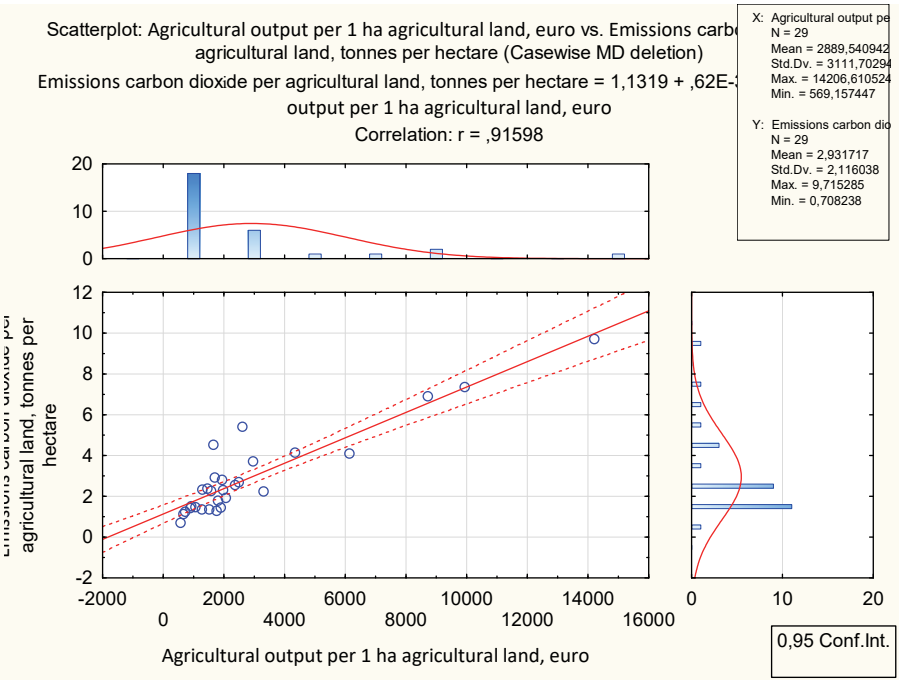

Fig. 3. Scattering diagram between carbon dioxide emissions (equivalent) per hectare of agricultural land (tonnes) and the agricultural output per hectare of agricultural land (constant prices 2010, Euro)

Source: compiled by STATISTICA software.

3. Regression analysis

N=29	Regression Summary for Dependent Variable: Emissions carbon dioxide per agricultural land, tonnes per hectare (Spreadsheet1) R= ,91597819 R?= ,83901605 Adjusted R?= ,83305368 F(1,27)=140,72 p<,00000 Std. Error of estimate: ,86459					
	b*	Std.Err. of b*	b	Std.Err. of b	t(27)	p-value
Intercept			1.1319	0.2209	5.1238	0.0000
Agricultural output per 1 ha agricultural land, euro	0.9160	0.0772	0.0006	0.0001	11.8625	0.0000

Source: compiled by STATISTICA software.

Correlations between variables are shown in Table 2, 3, and Figure 2.

Despite the significant variation of the studied variables, there is a clear relationship between them. The relationship between carbon dioxide equivalent emissions and output per agricultural area is directly strong, showing a correlation coefficient of 0.916 (Fig. 3).

According to the results of the statistical analysis, it was investigated that 83.9% (R^2) of CO_2eq emissions are formed under the outflow of economic activity, which is represented in the form of agricultural land productivity. The significance of the studied relationship is confirmed by the Std. Dev T-test, the empirical value ($F_f = 5.0$) which is greater than the theoretical ($F_t = 2.05$) at a significance of $\alpha = 0.05$ (Table 2).

The degree of impact of the indicators was estimated using regression analysis, which has shown a positive relationship between variables. Moreover, it means to increase agricultural output per 1 hectare by 1 euro, carbon dioxide equivalent emissions per 1 hectare should increase by 0.0006 tonnes, i.e., by 600 grams (Table 3).

The significance of the studied regression parameters is evidenced by Student's t-test at the level of 11.86 at a theoretical value of 2.05 at degrees of freedom n-m and a significance level $\alpha = 0.05$.

Conclusions and future perspectives of the study.

Hence, the results of the research have proved that the relationship between the greenhouse gas emissions (CO_2eq) and agricultural land productivity in the EU member states and Ukraine is positive and directly strong. Therefore, according to the European Green Deal goal regarding the greenhouse gas emissions reduction until 2030 the agricultural land productivity will decrease in the most developed EU countries if the production technologies will remain the same. Furthermore, as a rule, land productivity in agriculture of the less developed member states under the current production conditions will not obtain the opportunity for economic growth. Also, it will be difficult to ensure the gross value per hectare of agricultural land increase for Ukraine as the country integrating into the EU, considering the carbon dioxide equivalent emission limits.

To eliminate this threat in the EU member states and Ukraine, agricultural producers should widely use smart and sustainable farming approaches: digital and no-till systems for crops production, organic farming practices, carbon sequestration technologies, sustainable feed for animals, reduction of cattle stocks and increasing pig and chicken stocks, etc.

Further research may concern the relationship between the greenhouse gas emissions and the main European Green Deal requirements for agriculture (Farm to Fork Strategy): reduction of chemical pesticides and fertilizers, decreasing the nutrient losses by soil, reduction of antimicrobials sales for farmed animals and aquaculture and increasing farmland under organic farming.

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Анотація. *Стаття присвячена виявленню кількісного взаємозв'язку між викидами парникових газів та продуктивністю сільськогосподарських земель у країнах-членах ЄС та в Україні (державі, яка і далі інтегрується до ЄС). Автор здійснив компаративний аналіз продуктивності сільськогосподарських земель у країнах-членах ЄС, іншими країнами – провід-*

ними гравцями на світовому аграрному ринку, Україною та середнім світовим значенням. За допомогою методу статистичного групування було з'ясовано причину різної продуктивності сільськогосподарських земель (вартість виробленої валової продукції в розрахунку на 1 гектар сільськогосподарських угідь) у країнах-членах ЄС та в Україні. Застосувавши графічний метод, автор встановив причину високого рівня викидів парникових газів (еквівалент діоксиду вуглецю) у розрахунку на гектар сільськогосподарських угідь в найбільш розвинених державах ЄС. На основі розрахованого цільового рівня викидів парникових газі в на гектар сільськогосподарських земель у ЄС станом на 2030 р., що вимагається в рамках Європейської Зеленої Угоди, визначено вірогідну загрозу для країн-членів ЄС та України щодо можливого зниження продуктивності аграрного виробництва.

За допомогою економетричного методу й методу регресійного аналізу автором виявлено існування прямого й сильного кількісного взаємозв'язку між викидами еквіваленту діоксиду вуглецю та вартістю виробленої сільськогосподарської продукції в розрахунку на гектар угідь у країнах-членах ЄС та Україні. Обчислено величину збільшення викидів еквіваленту діоксиду вуглецю за умови зростання вартості виробництва валової продукції на гектар сільськогосподарських угідь на один євро. На основі результатів проведеного дослідження авто зробив висновок про високу імовірність зниження продуктивності сільськогосподарських земель у розвинених державах ЄС за умови скорочення викидів парникових газів до рівня цільового значення. Також автор обґрунтував практичну відсутність можливості для менш розвинених держав ЄС та України збільшити економічну продуктивність угідь за умови дотримання вимог Європейської Зеленої Угоди. Узагальнено рекомендації щодо уникнення можливої загрози в сільськогосподарському виробництві досліджуваних країн.

Ключові слова: *викиди парникових газів; діоксид вуглецю; метан; продуктивність сільськогосподарських земель; регресійний аналіз; кількісний зв'язок; ЄС; Європейська Зелена Угода*