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EXPLORING THE STATISTICAL ASSOCIATION BETWEEN THE ECONOMIC, ENVIRONMENTAL AND INNOVATIVE AREAS OF PERFORMANCE: THE CASE OF EUROPEAN UNION AGRICULTURE

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ABSTRACT

The importance of innovation in agriculture is supported by the effects that innovation has on the growth of the sector's performance in relation to its efforts. The aim of the paper is to identify and to analyse the statistical association between the indicators of agricultural performance, regarding the economic, environmental and innovative aspects at European Union level (EU-28). For this, a study on agriculture from the 28 EU countries was developed using the information available in Eurostat statistics during 2006-2016.

To address the research problem, the association analysis and correlation analysis as data analysis methods were used. The data were processed using the functions of IBM SPSS - Version 20. The analysis of the relations between the three areas of agricultural performance, namely economic, environmental and innovative, highlighted the following aspects: i) on average, there was an inverse relationship between economic performance and the environmental one; ii) on average, attracting borrowed capital and increasing indebtedness can enhance the innovative processes in agriculture; iii) the increase in economic performance was positively correlated with the intensive use of agricultural land and high levels of investments in technology.

A rich economy has the financial resources to invest in research - development - innovation activities in the agricultural sector, which stimulates the economic performance of farmers and others companies in the related fields. The statistical survey highlighted the direct link between the general level of development of a country's economy and the innovative capacity of the strategic sector represented by agriculture.

Keywords: innovation, economy, performance, agriculture, European Union.

INTRODUCTION

In European Union Development Policies, agriculture and the development of rural areas covered by the Common Agricultural Policy (CAP) have a special place. Agriculture is not just a food supplier, it is the basis of the rural communities and the rural environment.

According to the Cork Declaration 2.0 "Better Living in Rural Areas" (2016), following the European Conference on Rural Development, the main key points that must be supported by an innovative, integrated and inclusive rural and agricultural policy in European Union are the following: i) promoting rural prosperity; ii) encouraging actions to harness the climatic potential; iii) stimulating knowledge and innovation; iv) preserving the rural environment; v) managing natural resources.

At the beginning of the CAP in 1962, farmers were encouraged to use modern agricultural machinery, large amounts of intensifying factors (chemical fertilizers, pesticides, mechanization and process automation etc.) to get the highest output.

Through the new policy, they are urged to make use of research and innovation in order to obtain a larger quantity of products, using as few resources as possible.

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From literature review, the following assessments regarding the impact of innovation on agricultural performance indicators were highlighted: i) innovation determines the productivity increase of the production factors (Bloss, 2014; Dogliotti, 2014); ii) innovation reduces the dependence of agriculture on natural factors, less controllable, with a positive effect on economic performance (Mekonnen et al., 2015; Alston and Pardey, 2014); iii) innovation processes reduce production costs in agriculture (Schut et al., 2016); iv) innovation has a positive impact on increasing the company's environmental performance by promoting resource conservation practices (Kingwell and Fuchsbichler, 2011).

Some studies showed that a high degree of technical endowment of agriculture and the renewal of fixed capital, positively influence production growth, improving the economic performance of farms (Subic et al., 2015; Vavřina and Martinovičová, 2014).

Numerous studies in the field attributed to agricultural research a key role in developing new solutions to increase agricultural output (Padgette, 2013), reducing the impact of natural factors on agricultural output and increasing the use of natural resources (Sivertsson and Tell, 2015). Research and development activities are the basis of the innovation process, and the level of the expenses allocated to these activities and the quality of the research personnel directly influence the innovation capacity in the field of agriculture and, implicitly, its performance (Pardey et al., 2013).

MATERIAL AND METHODS

Starting from the analysis of the literature, the aim of study is to identify and to analyse the statistical association between the indicators of agricultural performance, regarding the economic, environmental and innovative aspects at European Union level (EU-28), using the information available in Eurostat statistics during 2006-2016.

To answer the research problem, the following data analysis methods were used in the study: correlation analysis; association analysis. The data were processed using the functions of statistical analysis program IBM SPSS - Version 20.

Thus, for the analysis of the association relations between the three areas of performance, we considered the indicators presented in Table 1, which were calculated annually during 2006-2016, for all the 28 EU countries.

Table 1. Indicators of agricultural sector performance in EU-28
(relative deviation from the EU-28 average - %)

Categories	Indicators	Symbol
I. Indicators of economic performance	I.1 - Gross value added per agricultural production unit (APU)	GVA_APU
	I.2 - Gross result per APU	GR_APU
	I.3 - Remuneration rate of borrowed capital in GVA	RK_GVA
II. Environmental performance indicators	II.1 - Gross balance of soil nutrients	B_NUTR
	II.2 - Energy intensity of agricultural activities	ENERG
III. Indicators of innovative performance	III.1 - Gross technological innovation per 1,000 euros GVA	INOV_TEH
	III.2 - Efficiency of R&D expenditure in relation to GVA	R&D_GVA

Statistical association relations of economic, environmental and innovative performance of agriculture was based on the calculation and analysis of indicators' relative deviations compared to the annual average of the EU-28 countries, arithmetically calculated.

For the analysis of the statistical relations of association of the economic and environmental performance of agriculture, with the innovative performance of this economic field, the relative deviations of the selected indicators were calculated and analysed, compared to the EU average of 28 countries.

Reporting the values registered by each country to a common reference base allows the use in all correlation and association analysis of all the indicators evaluated by the same unit of measure (percentage).

Indicators of economic performance:

Gross value added per agricultural production unit (APU) is a performance indicator that measures the wealth created in agriculture (thousands of euros), per standard agricultural production unit. The indicator was calculated as a weighted average of the gross value added per hectare and the gross value added per livestock unit (LU).

Gross value added is the macroeconomic indicator underlying the gross domestic product (GDP), commonly used in macroeconomic analyses (Beltran-Esteve et al., 2019; Pelin and Kala, 2017).

Gross result per APU is the gross profit or loss per standard agricultural production unit, expressed in thousand euros per APU. The gross result quantifies the remuneration of entrepreneurial risk in agriculture, and its size influences the interest of shareholders in the business continuation or development, as well as the ability to self-finance future investments (Chen and Waters, 2017).

Remuneration rate of borrowed capital in GVA is the share of gross value added allocated to the payment of interest and other financial expenses, related to loans for financing the agricultural activities. This indicator reflects, to a certain extent, the degree of financial dependence of farmers on external sources of capital and the pressure of interest on the agricultural sector (Onori, 2018).

Environmental performance indicators

Gross balance of soil nutrients provides information on the relationship between the use of agricultural nutrients, their loss in the environment and the sustainable use of soil nutrients (Adenuga et al., 2018).

This indicator was calculated in Eurostat statistics as the difference between inputs and outputs of nitrogen and phosphorus nutrients per hectare of agricultural land, expressed in kg of active substance per hectare. A high positive balance indicates a potential risk of environmental pollution through the retention of additional fertilizer in the soil.

Energy intensity of agricultural activities is the ratio between the gross domestic energy consumption for agricultural activities, quantified by the indicator "tons of oil equivalent – TOE" and the gross agricultural value added (GVA). The increase in environmental performance is due to reduced energy intensity and minimal energy consumption for obtaining economic goods.

Indicators of innovative performance

Gross technological innovation per 1,000 euros GVA expresses the efficiency of investments in technical progress, in relation to the GVA obtained in the agricultural sector. This indicator represents the gross value of technologies with a maximum age of 3 years, used in the agricultural sector (machinery, equipment, software and other intangible assets), related to a gross value added of 1,000 euros. A high value of this variable shows, on the one hand, the existence of well-equipped agricultural holdings adapted to current technologies and, on the other hand, indicates a substantial financial effort to obtain agricultural economic goods (Nabieva and Davletshina, 2015).

Efficiency of R&D expenditure in relation to GVA is an indicator that expresses the value of public and private spending for R&D activities in agricultural sciences, reported to 1,000 euros gross agricultural input, generated at country level. According to the literature, financial allocations for R&D activities contribute to development of the economic sectors and to increase of their performance (Pardey et al., 2013).

Increasing the economic efficiency of R&D activities is given by achieving a maximum result, evaluated by the gross agricultural value added, with the lowest effort, assessed through R&D expenditures.

RESULTS AND DISCUSSION

Characterization of selected variables distribution was performed by using descriptive statistics, for the following characteristics: the number of available observations; the minimum value of the variable; the maximum value and the standard deviation of the variable (Table 2). Since the variables were calculated as a deviation relative to the EU-28, their average value is equal to zero.

The standard deviations with values over 50% (Table 2) showed that there were major differences in the analysed countries, regarding the economic, environmental and innovation performance indicators in agriculture.

Table 2. Descriptive statistics of variables (relative deviation from the EU-28 average - %)

Variable	Minimum	Maximum	Standard dev.
I.1 - Gross value added per APU	-82.74	193.50	66.35
I.2 - Gross result per APU	-179.33	444.98	83.45
I.3 - Remuneration rate of borrowed capital in GVA	-191.75	822.11	110.07
II.1 - Gross balance of soil nutrients	-120.05	256.23	77.86
II.2 - Energy intensity of agricultural activities	-87.12	290.74	64.63
III.1 - Gross technological innovation per 1,000 euros GVA	-100.00	242.00	68.09
III.2 - Efficiency of R&D expenditure in relation to GVA	-90.33	242.56	70.36
Number of valid cases	308		

Data source: own processing of Eurostat data.

The lowest differences were registered at the level of: energy intensity of agricultural activities; gross value added per APU and gross technological innovation per 1,000 euros GVA, with standard deviations less than 70%. Therefore, we can appreciate that the performance in EU-28 agriculture, evaluated at economic, environmental and innovation level, is very heterogeneous, being influenced by many natural, social, economic and political factors specific to each EU country.

The analysis of the variables included in the model was performed in terms of statistical relationships between indicators, through the analysis of linear bivariate correlation and through the multiple regression analysis.

The null hypothesis from which the nonparametric *Chi-square test* - χ^2 was derived was *H0: There is no association between these two variables.* To test the null hypothesis it is necessary to compare the value of *Chi-square coefficient* - χ^2 distribution with a reference value for a number of freedom degrees:

$$df = (p-1) \times (q-1),$$

where "p" - the number of columns of an arbitrary distribution, and "q" - the number of rows.

Given the dichotomous character of the variable, there is only one degree of freedom (df = 1). A chi-square coefficient is significant when it corresponds to a probability <0.05, which shows the association between variables (Sticlaru, 2012).

Pearson's correlation coefficients "r", with a value in the module greater than 0.750 (with sig = 0.000), indicate the existence of very strong links between the indicators and a value in the module between 0.500-0.750 (with sig $\leq$ 0.001) shows a moderate link between variables (Wiedermann et al., 2015).

The dependent variable in the statistical study carried out is represented by the "gross value added per APU - the relative deviation from the EU-28 average", which reflects the economic performance of the agriculture, reached in the period under review (2006-2016). The results of correlations analysis between performance indicators were presented in Table 3.

Table 3. Testing the linear correlation between the agricultural performance variables at EU-28 level

Variable		GVA_APU	GR_APU	RK_GVA	B_NUTR	ENERG	INOV_TEH	R&D_GVA
I.1-GVA_APU	r	1	0.756**	-0.113*	0.644**	-0.287**	-0.238**	-0.116*
	Sig.		0.000	0.048	0.000	0.000	0.000	0.042
I.2-GR_APU	r	0.756**	1	-0.338**	0.527**	-0.348**	-0.357**	-0.299**
	Sig.	0.000		0.000	0.000	0.000	0.000	0.000
I.3-RK_GVA	r	-0.113*	-0.338**	1	0.114*	0.310**	0.362**	0.598**
	Sig.	0.048	0.000		0.045	0.000	0.000	0.000
II.1-B_NUTR	r	0.644**	0.527**	0.114*	1	-0.049	-0.075	0.172**
	Sig.	0.000	0.000	0.045		0.396	0.189	0.002
II.2-ENERG	r	-0.287**	-0.348**	0.310**	-0.049	1	0.509**	0.546**
	Sig.	0.000	0.000	0.000	0.396		0.000	0.000
III.1-INOV_TEH	r	-0.238**	-0.357**	0.362**	-0.075	0.509**	1	0.510**
	Sig.	0.000	0.000	0.000	0.189	0.000		0.000
III.2-R&D_GVA	r	-0.116*	-0.299**	0.598**	0.172**	0.546**	0.510**	1
	Sig.	0.042	0.000	0.000	0.002	0.000	0.000	

** The correlation is significant at a level of significance coefficient equal to not more than 0.01.
Data source: own processing of Eurostat data.

The analysis of correlation relationship between the three levels of performance in agriculture revealed the following positive correlations, of moderate to strong intensity ($r \geq 0.500$):

➲ at the level of economic and environmental performance: i) between GVA per APU and gross balance of soil nutrients (r = 0.644); ii) between the gross result per APU and the gross balance of soil nutrients (r = 0.527);

➲ at the level of economic and innovative performance: i) between the remuneration rate of the borrowed capital in GVA and the efficiency of R&D expenditure in relation to GVA (r = 0.598);

➲ at the level of innovative and environmental performance: i) between gross technology innovation per 1,000 euros GVA and energy intensity of agricultural activities (r = 0.509); ii) between the efficiency of R&D expenditure in relation to GVA and the energy intensity of agricultural activities (r = 0.546). The correlation analysis was complemented by the analysis of the association between indicators, based on their transformation into qualitative dichotomist variables taking the following values:

➲ *"1"* - if there is a relative deviation from the EU-28 average, at least equal to zero (positive), or when the national indicator was at least equal to the annual average of the EU-28;

➲ *"2"* - if there is a relative deviation from the EU-28 average, less than zero (negative), or when the national indicator was lower than the annual average of the EU-28.

Following are the main links identified between the performance indicators.

Between dependent variable represented by the gross value added per APU and the gross balance of soil nutrients there is, on average, a moderate positive correlation (r = 0.644), which shows us that they generally vary in the same way. This is also supported by the analysis of the association between the indicators converted to qualitative variables, according to Table 4.

Table 4. The association between “GVA per APU” and “gross balance of soil nutrients” at EU-28 level

Indicator			Gross balance of soil nutrients: above the EU-28 average	Gross balance of soil nutrients: below the EU-28 average	Total
GVA per APU	above the EU-28 average	Number of cases	55.00	58.00	113.00
		% of total	17.86	18.83	36.69
	below the EU-28 average	Number of cases	51.00	144.00	195.00
		% of total	16.56	46.75	63.31
Total		Number of cases	106.00	202.00	308.00
		% of total	34.42	65.58	100.00

Data source: own processing of Eurostat data.

According to Table 4, between 2006 and 2016, 46.75% of the total number of cases analysed at European Union level registered a gross soil nutrient balance below the EU-28 average and a gross value added per APU below the EU-28 average.

Also, in 17.86% of cases, values above the EU-28 average were registered, for both variables. These results indicate an inverse relationship between economic and environmental performance, given that the limited use of organic and inorganic fertilizers reduces environmental pollution, but does not ensure the increase of agricultural output and, implicitly, of the gross value added per standard agricultural production unit.

The reverse relationship between environmental and economic performance was also evidenced by the link between gross result per APU and the gross balance of soil nutrients, whereas 43.50% of cases had values below the EU average, for both indicators (Table 5).

Table 5. The association between the “gross result per APU” and “gross balance of soil nutrients” at EU-28 level

Indicator			Gross balance of soil nutrients: above the EU-28 average	Gross balance of soil nutrients: below the EU-28 average	Total
Gross result per APU	above the EU-28 average	Number of cases	45.00	68.00	113.00
		% of total	14.61	22.08	36.69
	below the EU-28 average	Number of cases	61.00	134.00	195.00
		% of total	19.81	43.51	63.31
Total		Number of cases	106.00	202.00	308.00
		% of total	34.42	65.58	100.00

Data source: own processing of Eurostat data.

Regarding the type of connection between the remuneration rate of borrowed capital in GVA and the efficiency of R&D expenditure in relation to GVA, the analysis based on the Pearson correlation coefficient ($r = 0.598$) outlines that they vary in the same direction. Thus, the increase in R&D spending to 1,000 euros GVA is accompanied by an increase in the relative importance of interest and related financial expenditures in agricultural gross value added. In other words, attracting borrowed capital and increasing indebtedness can intensify innovation processes in agriculture.

Across the 28 EU countries, in 49.35% of cases values under the EU-28 were registered for the rate of remuneration of borrowed capital from GVA and efficiency of R&D expenditure in relation to gross value added (Table 6).

Table 6. The association between the "remuneration rate of borrowed capital in GVA" and "efficiency of R&D expenditure in relation to GVA" at EU-28 level

Indicator			Efficiency of R&D expenditure in relation to GVA: above the EU-28 average	Efficiency of R&D expenditure in relation to GVA: below the EU-28 average	Total
Rate of remuneration of borrowed capital from GVA	above the EU-28 average	Number of cases	75.00	25.00	100.00
		% of total	24.35	8.12	32.47
	below the EU-28 average	Number of cases	56.00	152.00	208.00
		% of total	18.18	49.35	67.53
Total		Number of cases	131.00	177.00	308.00
		% of total	42.53	57.47	100.00

Data source: own processing of Eurostat data.

From the analysis of the links created between the efficiency of the R&D expenditure in relation to the GVA and the environmental performance indicators, we found that an increase of the R&D expenditure to 1,000 euro GVA was associated with an increase of the energy consumption in the agricultural activities, respectively with the decrease of the environmental performance.

*Table 7***.** The association between the "energy intensity of agricultural activities" and "efficiency of R&D expenditure in relation to GVA" at EU-28 level

Indicator			Efficiency of R&D expenditure in relation to GVA: above the EU-28 average	Efficiency of R&D expenditure in relation to GVA: below the EU-28 average	Total
Energy intensity of agricultural activities	above the EU-28 average	Number of cases	77.00	34.00	111.00
		% of total	25.00	11.04	36.04
	below the EU-28 average	Number of cases	54.00	143.00	197.00
		% of total	17.53	46.43	63.96
Total		Number of cases	131.00	177.00	308.00
		% of total	42.53	57.47	100.00

Data source: own processing of Eurostat data.

The energy intensity of agricultural activities was below the EU-28 average for 46.43% of the countries that allocated lower amounts for R&D activities related to GVA, indicating a good environmental and innovative performance in most of the analysed cases (Table 7).

Moreover, in 42.86% of the cases, values below the EU-28 average were registered, both at the energy intensity level and at the level of the gross technological innovation value at 1,000 euros GVA (Table 8).

Table 8. The association between "energy intensity of agricultural activities" and "gross technological innovation per 1,000 euros GVA" at EU-28 level

Indicator			Gross technological innovation per 1,000 euros GVA		Total
			above the EU-28 average	below the EU-28 average	
Energy intensity of agricultural activities	above the EU-28 average	Number of cases	72.00	39.00	111.00
		% of total	23.38	12.66	36.04
	below the EU-28 average	Number of cases	65.00	132.00	197.00
		% of total	21.10	42.86	63.96
Total		Number of cases	137.00	171.00	308.00
		% of total	44.48	55.52	100.00

Data source: own processing of Eurostat data.

According to Table 8, the efficiency of the innovation activity in agriculture was given by obtaining a gross added value of 1,000 euros with a minimum investment effort. This resulted in 55.52% of the analysed cases, which were characterized by gross technological innovations at 1,000 euros GVA, below the EU-28 average.

CONCLUSIONS

A rich economy has the financial resources to invest in research - development - innovation in the agricultural sector, which stimulates the economic performance of the involved actors, such as farmers, suppliers, consultants, etc. Also, the implementation of new agricultural technologies based on reducing resource consumption contributes to reducing the impact of agriculture on the environment.

The statistical survey conducted at the EU-28 agriculture highlighted the direct link between the general level of development of a country's economy and the innovative capacity of the strategic sector represented by agriculture.

Regarding the association between the three areas of agricultural performance, namely economic, environmental and innovative, the following aspects were outlined:

- on average, there was an inverse relationship between economic and environmental performance, namely the limited use of organic and inorganic fertilizers (a low gross balance of nutrients) and low energy consumption in agricultural activities, reduce environmental pollution, but slow down the increase in agricultural output and gross value added per agricultural production unit;
- on average, rising indebtedness can enhance the innovation processes in agriculture, by increasing the financial allocations for R&D in gross agricultural value added, with a positive impact on attracting technical progress and innovation to agricultural farms;
- the innovative activities are hazardous and involve assuming high risks that should be financially spread among investors, creditors and governments;
- increasing the economic performance of agriculture in the EU-28 was positively correlated with the intensive use of agricultural land (a high balance of nutrient substances).

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