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THE IMPACT OF CHEMICAL FERTILIZER CONSUMPTION ON AGRICULTURAL CARBON EMISSIONS IN AZERBAIJAN

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Abstract. The main purpose of this research is to examine the impact of chemical fertilizer consumption on environmental pollution regarding Azerbaijan. In the study, annual data obtained from the FAOSTAT database for the time span from 1992 to 2018 were utilized. All data used were included in the model by taking the natural logarithm. The Augmented Dickey-Fuller, Philips-Perron, Kwiatkowski-Phillips-Schmidt-Shin, FMOLS, DOLS, and CCR tests have been applied for the statistical part of the paper. According to the results of the empirical tests there was a positive and statistically significant relationship between chemical fertilizer consumption and CO_2 emissions.

Keywords: *environment, pollution, CO2 emissions, chemical fertilizer consumption.*

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1. Introduction

Soils that are useful for agriculture become poor after a while as a result of both the consumption of nutrients by plants and other factors such as washing and erosion. Therefore, it is aimed to increase productivity through agricultural processes such as fertilization, pest control and correct irrigation methods, which are indispensable factors for agriculture. Reinforcing the nutrients consumed by the plants is very important in order to maintain the fertility of the soil. Thus, it requires fertilization. For this reason, fertilization maintains its importance for agricultural production for years. In agricultural production, chemical fertilizers can cause many negativities as well as increasing the yield. The amount and time of fertilizer applied to the soil are seen as important factors at the beginning of these negativities. Recent studies in the 21st century we live in show that the mistakes that occur as a result of fertilizer applications seriously harm the environment (Sönmez *et al.*, 2008).

Fertilizer is one of the most important inputs in agricultural production. When it is not applied in sufficient amount, there are significant losses in yield and quality. It has been observed that when it is applied excessively, it causes pollution of ground and surface waters by washing the manure, and air pollution with nitrous oxide (N_2O) emission. Nitrogen and phosphorus fertilizers are examples of such pollution. It is very important to choose the right application method, as it is not possible to completely use chemical fertilizers. The excessive use of chemical fertilizers in agriculture and the heavy metal content of some fertilizers (eg, cadmium and chromium) cause many environmental problems (Atılgan *et al*., 2007).

Today, people are aware of the harmful effects of the use of chemical fertilizers on the environment, but sometimes issues such as environmental pollution are ignored in order to meet the food needs of the increasing world population. This need may lead to the uncontrolled use of fertilizers and pesticides in developing and less developed countries with less opportunities (Atılgan *et al*., 2007).

According to 2006 data of the Intergovernmental Panel on Climate Change (IPCC), 1% of the nitrogen fertilizers applied to agricultural soils is released into the atmosphere as N_2O. This release factor determined for N_2O may increase when nitrogen fertilizer is applied more than the uptake capacity of the soil and the plant (Halvorson *et al*., 2008).

A graphical representation of nitrogen, phosphorus and potassium fertilizers used in agriculture worldwide between 1961 and 2018 is presented in Figure 1.

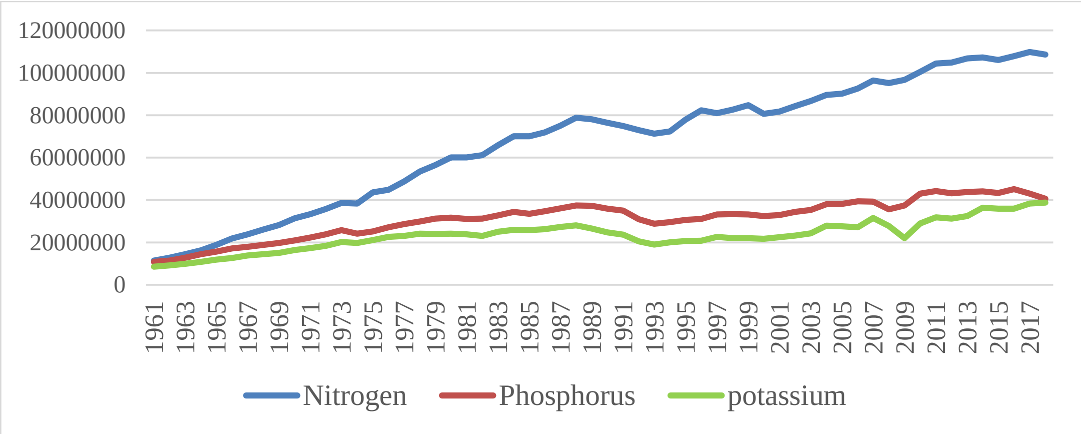

Figure 1. Chemical fertilizer consumption used in agriculture worldwide, 1961-2018
Source: FAOSTAT

As can be seen from the results of Figure 1, nitrogen fertilizer comes first among the three most commonly used chemical fertilizer types in agriculture. Nitrogen fertilizer is the most preferred fertilizer type in plant cultivation worldwide. Nitrogen fertilizers increased significantly (853%) from 1961 to 2018. This increase was 275% in phosphorus fertilizer and 351% in potassium fertilizer (Faostat, 2021).

Nitrogen is the most widely used fertilizer type in agriculture in Azerbaijan, as in the rest of the world. Almost all nitrogen, phosphorus and potassium fertilizers are imported to Azerbaijan from abroad. When the greenhouse gas emissions caused by the use of chemical fertilizers in Azerbaijan are analyzed by years, it is seen that the amount of emissions is high in the first years of independence. This is a result of the overuse of chemical fertilizers per hectare of arable land during the Soviet Union (Figure 2). It is observed that there is a decrease in greenhouse gas emissions from chemical fertilizers starting from the first years of independence until 2000. Since 2000, greenhouse gas emissions due to the use of chemical fertilizers have been on the rise in Azerbaijan, and this rise has gained a sharp upward momentum after 2013.

It is seen that there is a high increase of 137% in nitrogen fertilizer used in agriculture between 1992-2018 in Azerbaijan, but there is a decrease in the use of other fertilizer types. This decrease was 93% in phosphorus fertilizer and 24% in potassium fertilizer. This decrease in the use of phosphorus fertilizer was very high compared to potassium fertilizer. While the total phosphorus fertilizer used in agriculture in Azerbaijan was 20 thousand tons in 1992, this figure decreased to 1329 tons in 2017 (Faostat, 2021).

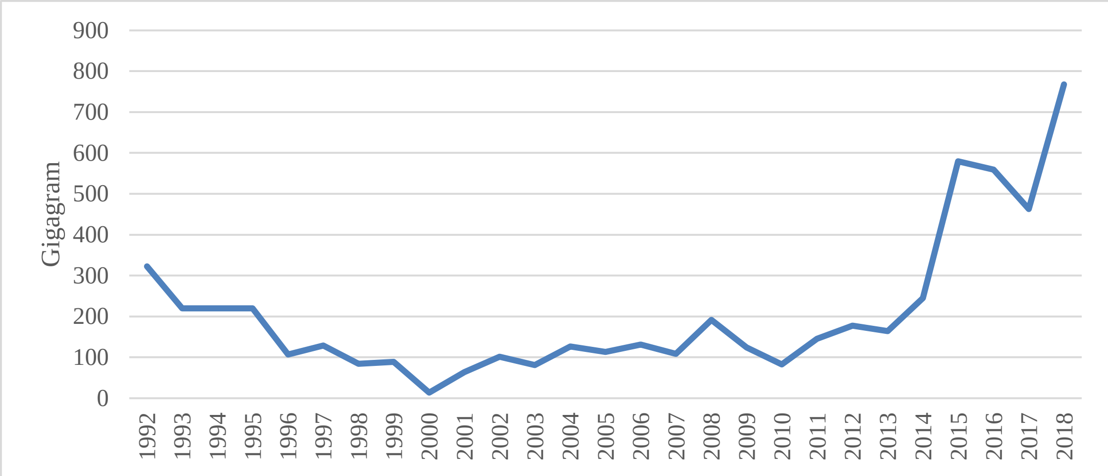

Figure 2. Greenhouse gas emissions (CO_2 equivalent) from the use of chemical fertilizers in Azerbaijan, 1992-2018. Source: FAOSTAT

2. Material

The main purpose of this study is to analyze the effect of chemical fertilizer consumption on environmental pollution for Azerbaijan. In the study, annual data obtained from the FAOSTAT database for the years 1992-2018 for Azerbaijan were used. All data used were included in the model by taking the natural logarithm. The availability of data on the variables used in the study for Azerbaijan in the FAOSTAT database was considered, and therefore the period 1992-2018 was chosen as the time interval. The study consists of one dependent and one independent variable and there are twenty-seven observations for each variable. Total agricultural greenhouse gas emissions (CO_2 equivalent) were chosen as the dependent variable in the study. Table 1 includes explanations of the variables used in the analysis of the study.

Table 1. Explanatory information about the variables used in econometric analysis

Variables	Acronym	Unit of measure	Source
Agricultural greenhouse gas emissions (CO_2 equivalent)	CO_2	Gigagrams	FAOSTAT
Chemical fertilizer consumption	CFC	Tonne	FAOSTAT

Source: Authors` own invention

3. Econometric model

In order to determine the effect of chemical fertilizer consumption on environmental pollution, studies in the literature were taken as a basis and a model was created as in equation 1 in this direction.

$$CO_2 = f(CFC) \quad (1)$$

The model number 1 was rewritten and transformed into a linear-logarithmic model.

$$lnCO_{2t} = \beta_0 + \beta_1 CFC_t + \varepsilon_t \quad (2)$$

In the model, ln represents the natural logarithm, and the coefficient β represents the effect ratio of the independent variables on the dependent variable. In this model; $lnCO_2$ represents total agricultural greenhouse gas emissions (CO_2 equivalent) (gigagrams), lnCFC represents chemical fertilizer consumption (tonnes), and εt represents the error term.

4. Method

Time series approach was used as econometric method in the study. In the research, firstly, logarithms of the series were taken in order to avoid small fluctuations in the time series. Then, unit root tests were performed to test the stationarity of the time series. For this, Augmented Dickey-Fuller (ADF-1981), Philips-Perron (PP-1988), Kwiatkowski-Phillips-Schmidt-Shin (KPSS-1992) unit root tests were used. After testing the stationarity, FMOLS, DOLS, CCR tests, which are long-term estimators, were conducted to investigate the existence and direction of the relationship between the series.

FMOLS, DOLS and CCR long-term estimators

FMOLS, DOLS and CCR estimators are frequently used in research and support each other because of their advantages such as determining the long-term relationships between the variables and facilitating the interpretation of their coefficients, eliminating the internality problem and giving reliable results in small samples. Although these three methods support each other, they contain different steps in calculating the long-term cointegration coefficients (Adom *et al.*, 2015).

The FMOLS method, developed by Phillips and Hansen in 1990, is an improvement of the least squares (OLS) method and eliminates the diagnostic problems that arise in standard estimators. On the other hand, with the help of FMOLS method, accurate and unbiased results are obtained in series with a small number of observations (Phillips & Hansen, 1990).

The DOLS estimator was first applied by Stock and Watson (1993) and developed by Pedroni (2000, 2001). With the help of the DOLS estimator, the long-term coefficients of the independent variables can be estimated and the deviations caused by the internality problem between the error term and the independent variables can be eliminated (Nazlıoğlu, 2010).

The CCR method developed by Park (1992) is closely related to the FMOLS method. However, unlike the FMOLS method, the stationary values of the variables are used, not the level values, in order to eliminate the long-term dependence between stochastic shocks and the cointegration equation in CCR. In the CCR method, as in the FMOLS method, firstly error terms and covariance matrices are obtained (Küçükaksoy *et al.*, 2015).

5. Results

Unit Root Test Results

Before analyzing whether there is any cointegration relationship between the variables, the stationarity of the series should be investigated. The problem of spurious regression arises in studies with non-stationary time series. For this reason, firstly, the stationarity test was carried out with the help of ADF, PP and KPSS unit root tests. The results of the stationarity test are presented in Table 2, respectively.

Table 2. Unit root test for agricultural input variables

		At level		At first difference	
	Series	**CO_2**	**CFC**	**ΔCO_2**	**ΔCFC**
ADF	Constant	0,254	-1,634	-4,166**	-6,658***
		(0,971)	(0,452)	(0,004)	(0,000)
	Constant+Trend	-3,468	-2,428	-3,956**	-7,116***
		(0,064)	(0,358)	(0,024)	(0,000)
PP	Constant	0,006	-1,634	-4,504***	-6,804***
		(0,951)	(0,452)	(0,002)	(0,000)
	Constant+Trend	-3,399	-2,225	-4,271***	-13,832***
		(0,073)	(0,457)	(0,013)	(0,000)
KPSS	Constant	0,201	0,328	0,731**	0,376
	Constant+Trend	0,106	0,170**	0,170**	0,501***

Note: In the ADF, PP and KPSS test, the appropriate lag length was determined according to the Schwarz information criterion (SIC). In the PP test, the kernel method was determined according to the "Barlett kernel" and the bandwidth (bandwith) was determined according to the "Newey West bandwith" method. Values in parentheses represent one-way p (probability) values of MacKinnon (1996). **, *** symbols represent 5% and 1% statistical significance levels, respectively, in unit root tests.

When the results in Table 2 are examined, it is seen that the CO_2 series contains a unit root at the level I(0) according to the results of all three unit root tests, but when the first difference is taken, the I(1) series becomes stationary according to all unit root test results. It is seen that the CFC series is not stationary in level according to the results of the other unit root tests, except for a single KPSS test, and when the first degree difference is taken, I(1) becomes stationary according to the results of all three unit root tests.

FMOLS, DOLS and CCR Test Results

Table 3 contains the results of FMOLS, DOLS and CCR tests.

When the results of Table 3 are examined, it is seen that the consumption of chemical fertilizers has a positive and statistically significant effect on agricultural greenhouse gas emissions in all three models. It is an expected result that there is a positive and statistically significant relationship between chemical fertilizer consumption and CO_2 emissions. It has been proven by numerous studies on this subject that the consumption of chemical fertilizers has a positive effect on greenhouse gas emissions. When we examine the consumption of chemical fertilizers used in agricultural activities in Azerbaijan, it is seen that the consumption of chemical fertilizers increased by 138% during the twenty-six-year period between 1992-2018. This increase in chemical fertilizer consumption in Azerbaijan has taken a faster form since 2014. This result is consistent with Hongdou et al. (2018), Ullah et al. (2018) and Ronaghi et al. (2018) `s research results are in agreement with.

Table 3. FMOLS, DOLS, CCR cointegration test results for agricultural input variables

FMOLS cointegration test estimation results				
Variable	Coefficient	Std.Error	t-statistics	Probability
CFC	0,0421***	0,0058	7,2634	0,0000
C	-4,0252***	0,5505	-7,3119	0,0000
DOLS cointegration test estimation results				
Variable	Coefficient	Std.Error	t-statistics	Probability
CFC	0,0368***	0,0061	6,0572	0,0000
C	-4,4273***	0,5785	-7,6529	0,0000
CCR cointegration test estimation results				
Variable	Coefficient	Std.Error	t-statistics	Probability
CFC	0,0461***	0,0070	6,5602	0,0000
C	-3,7310***	0,6172	-6,0448	0,0000

Note: The symbols ** and *** denote 5% and 1% significance levels, respectively.

6. Conclusion

The relationship between agriculture and environment has become a very important issue today. The existence of a sustainable environment is very important for the welfare of individuals and societies in the world. For this reason, determining the factors that cause environmental pollution, especially greenhouse gas emissions, and taking the necessary measures against them has become a mandatory task. Agricultural activities and the agricultural sector in general are seen as one of the most important sectors affecting greenhouse gas emissions.

In this study, the effect of chemical fertilizer variable on agricultural greenhouse gas emissions was investigated for Azerbaijan.

By choosing and applying the inputs and technologies used in agricultural production in a conscious and environmentally friendly manner, it is possible to increase both agricultural production and increase the environmental performance of agriculture. Recently, environmental policies and agricultural policy objectives in the EU support each other. Agricultural environmental practices in the EU not only promote environmentally friendly agricultural production, but also increase the environmental performance of agriculture. EU's practices on this issue should be taken into account in the formation of agricultural environmental policies in Azerbaijan.

Another important point in agricultural environmental policies is the producers. It is very important for the producers to have the necessary equipment (sufficient economic and technical size, knowledge, desire, sufficient workforce, etc.) in this regard in terms of creating and maintaining agricultural environmental policies. Studies on this subject show that most of the producers have a lack of knowledge in the fight against diseases and pests. The same problem is experienced with fertilization. A large part of the producers does not fertilize according to soil analysis, but based on their past experience. Fertilization should be done according to the results of the soil analysis and the type, amount and application time of the applied fertilizer should be determined by the experts in this field. Nitrate sensitive areas should be identified in advance and implementation of fertilizer management plans for these areas should be mandatory. Training programs should also be prepared for producers on fertilization.

Animal manure and mineral fertilizers applied to the soil do not always reach the product completely. A large part of this nitrogen fertilizer that does not reach the product turns into nitrous oxide emissions (Cassman *et al.*, 2003, McSwiney & Robertson, 2005). For this reason, fertilizer applications that allow nitrogen fertilizer to reach the plants better should be preferred. As an example of such fertilizer applications;

- Use of slow-release nitrogen fertilizer,
- Application of fertilizers by dividing them during critical growth periods of plants,
- Application directly to root areas instead of sprinkling,
- Use of nitrification inhibitors etc. can be displayed.

Another important point to note about emissions from chemical fertilizers is that such emissions occur not only after fertilizer applications, but also during fertilizer production and transportation.

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