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AGRICULTURAL PRODUCTIVITY, INFLATION AND FARMERS INCOME: A GRANGER CAUSALITY ANALYSIS

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Abstract
Aim: This study aims to explore the relationships among agricultural productivity, inflation, and farmers' income in Greece over a period of 33 years.
Data: The analysis utilizes annual time-series data sourced from the Food and Agriculture Data Network, focusing on Gross Value Added (GVA) in agricultural production, the Producer Price Index (PPI) for agricultural products, and annual average farm household income (AFI).
Results: The Granger causality analysis reveals a bidirectional causal relationship between agricultural productivity and farmers' income. Additionally, a significant impact of productivity on inflation and inflation on income is observed, indicating that changes in agricultural production value precede variations in producer prices.
Conclusions: These findings highlight the complex interactions within the agricultural sector, suggesting that enhancing productivity can improve farmers' income while mitigating inflationary pressures. The study emphasizes the importance of targeted policies to foster sustainable agricultural growth and economic stability in rural communities.
Keywords: Agricultural productivity, Producer Price Index, farm income, causality
JEL: Q11, Q13

Introduction

Agricultural productivity is a cornerstone of economic development, particularly in countries with substantial rural populations and agrarian economies. Advancements in agricultural practices, technology, and efficiency can profoundly impact broader economic indicators, notably inflation and farmers' income, which directly influence economic stability and quality of life in rural areas. Understanding the dynamic interplay between agricultural productivity, inflation, and farmers' income is crucial for formulating effective economic policies.

Inflation, defined as the rate at which the general level of prices for goods and services rises, erodes purchasing power and can create economic uncertainty. For farmers, who often operate on thin margins, even small fluctuations in inflation can

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significantly impact income stability and overall economic well-being. Conversely, farmers' income, which directly affects their living standards and ability to invest in better agricultural practices, is a critical factor in the agricultural productivity equation.

The rise in agricultural prices in 2022, termed as “greed inflation” by the International Monetary Fund (Vinod, 2022), highlights how businesses increased product prices to protect profits amid rising production costs. However, when costs began to decrease, product prices did not decline, worsening the economic pressure on consumers and further distorting inflation patterns. This phenomenon has emerged as a significant threat to both the European and Greek economies, particularly in the domestic food market, as unprecedented increases in consumer prices for basic foods have been observed (Matthews, 2023). Despite the fact that a significant portion of these products is imported, Greek farmers have been unfairly blamed for profiteering, although they are also victims of this inflationary trend.

In 2022, the agricultural sector of the European Union underwent substantial transformations, as reported by Eurostat (2023). The total value of agricultural production reached €537.5 billion at basic prices, representing a noteworthy 19% surge from the previous year. This increase in value was predominantly driven by a significant uptick in nominal prices of agricultural products and services, which escalated by 22.8%. Interestingly, despite a slight decline of 3.1% in production volume, the overall value of agricultural output surged across all EU member states. Particularly notable were France, Germany, Italy, Spain, Poland, the Netherlands, and Romania, which collectively contributed three-quarters of the EU's agricultural production value. Moreover, countries like Estonia, Poland, and Lithuania experienced the highest growth rates, with increases of 44%, 43%, and 42% respectively compared to 2021.

The economic viability of agricultural holdings will be further positively affected by increased productivity due to mechanization and automation. According to the European Commission, this will help the EU's agricultural sector cope with the ongoing labor force outflow and create more opportunities for skilled labor, thereby enhancing the economic attractiveness of the sector (Krings, 2024). By improving productivity, the agricultural sector can better address production costs, ensuring more sustainable income growth for farmers.

In Greece, domestic producer prices for various agricultural products have fluctuated significantly over recent years. For instance, according to Hellenic Statistics Authority (ELSTAT) the price of Greek-produced eggs increased by 8.7% over twelve months, while cow's milk prices decreased by 2.6%. During the same period, consumer prices for dairy and eggs rose by 18%, and the price of raw milk increased by 18.8%. Similarly, the price of soft wheat for baking decreased by 25% for producers, while consumer prices for bread and cereals increased by 11.1% and 14.8%, respectively, while the price of veal for producers saw a modest increase of 3.1%, whereas consumer prices for meat rose by 11.9%. Notably, the producer price for olive oil increased by 62.9%, while consumer prices for olive oil rose by 24.6%. The burden of rising production costs, however, falls heavily on Greek farmers, as from April 2022 to April 2023, the price index for fertilizers increased by 8.2%, continuing a trend of significant price hikes from the previous year. Animal feed prices also rose by 6.2% during the same period, and these rising costs contribute to higher production expenses for farmers, who fight to keep up with the minimal or even declining increases in producer prices.

This study focuses on Greece utilizing econometric techniques and time-series data to explore the relationship of agricultural productivity, inflation and farmers' income. By employing Granger causality analysis, we aim to uncover whether changes in agricultural productivity, variations in inflation rates and fluctuation on farmers' income levels are associated. Granger causality is a statistical hypothesis test for determining whether one time series can predict another, making it an ideal tool for our research.

Methodology

The study utilizes a dataset of annual time-series data of 33 years for Greece, from 1990 to 2022, sourced from the Food and Agriculture Data Network (FAND). Data include three variables:

The study employs three key variables: Gross Value Added (GVA) in agricultural production, the Producer Price Index (PPI) for agricultural products, and the Annual Average Farm Household Income (AFI). The GVA serves as a critical metric, quantifying the economic value generated by the agricultural sector while excluding the costs of inputs and raw materials, thus reflecting the sector's productivity and its contribution to the national economy. The PPI captures the average changes over time in the selling prices received by domestic producers for their agricultural output, providing insights into the inflationary pressures within the sector. Finally, the AFI is employed as an indicator of the financial health and living standards of the agricultural population, making it essential for understanding the interrelationships among agricultural productivity, inflation, and income.

To meet the study’s objective, we implement the Granger causality test (Granger, 1969), an effective method for assessing whether one time series can predict another. Granger causality is preferred than regression analysis as the second can reveal statistical relationships between variables, but it does not establish causality (Lütkepohl, 2005). In contrast, the Granger causality test provides insights into the directionality of these relationships, showing whether changes in one variable precede and potentially influence changes in another.

The models used for the analysis are specified as follows:

$$Y_t = \sum_{i=1}^{m} a_i Y_{t-i} + \sum_{i=1}^{m} \beta_i X_{t-i} + u_t \quad (1)$$

$$X_t = \sum_{i=1}^{m} \gamma_i Y_{t-i} + \sum_{i=1}^{m} \delta_i X_{t-i} + \varepsilon_t \quad (2)$$

Based on these, several scenarios can be identified (Gujarati, 2021). If the coefficients of the X_{t-i} variables in equation (1) are statistically significant while the coefficients of the Y_{t-i} variables in equation (2) are not, it indicates unidirectional Granger causality from X to Y. Conversely, if the coefficients of the X_{t-i} variables in equation (1) are not significant but the coefficients of the Y_{t-i} variables in equation (2) are, it indicates unidirectional Granger causality from Y to X. Bidirectional Granger causality occurs if both sets of coefficients are statistically different from zero and finally if neither set of coefficients is significant, it indicates no Granger causality between the variables.

The validity of the Granger causality tests relies on several critical assumptions. First, the time series data must exhibit stationarity, meaning that its statistical properties – such as mean and variance – remain constant over time. This requirement is confirmed through unit root tests, including the Augmented Dickey-Fuller (ADF) test, Phillips-Perron test, and the DF-GLS test, with the study employing the first differences of the variables when necessary. Additionally, the appropriate lag length is paramount for accurate Granger causality testing. The study meticulously determines the optimal number of lags using AIC, SC, and HQ criteria to effectively capture the temporal relationships among the variables. Another fundamental assumption is the linearity of the relationships being examined, as Granger causality analysis presupposes linear interactions among the time series. Furthermore, the tests assume no simultaneity in the relationships, meaning that the causal influences should not occur within the same time period being analyzed. The independence of errors is another vital assumption, where the residuals of the regression models must be independent and identically distributed (i.i.d.), as violations could lead to biased estimates of causal relationships. Lastly, homoscedasticity is assumed, indicating that the variance of the errors remains constant across all levels of the independent variables; heteroscedasticity can undermine the reliability of the findings. Finally, all statistical hypothesis tests are conducted at a 5% significance level.

Results

Based on the Pearson correlation matrix presented in Table 1, Gross Value Added exhibits a positive correlation with both Producer Price Index ($r = 0.335$, $p = 0.018$) and annual average farm household income ($r = 0.300$, $p = 0.040$), with the results indicating that higher levels of GVA are associated with higher values of PPI and AFI and vice versa. In contrast, the correlation between PPI and AFI is weaker, with a correlation coefficient of -0.101, and not statistically significant (p = 0.451), suggesting suggests that changes in producer prices are not related to variations in farm household incomes.

Table 1. Pearson correlation matrix

		GVA	PPI	AFI
GVA	r	1		
	p	-		
PPI	r	0.335	1	
	p	0.018	-	
AFI	r	0.300	–0.101	1
	p	0.040	0.451	-

All variables are set as I(1), based on the ADF test. It is observed that in each case the relevant t-statistics are below the critical values of -3.447 for a 1% significance level and -2.868 for a 5% significance level, an element that is also confirmed by the results of the Phillips-Perron test that uses the same critical values. Additionally, given the critical values of -2.570 for a 1% significance level and -1.941 for a 5% significance level for the DF – GLS test, it is also confirmed that the variables in the analysis are stationary at first differences (Table 2). Consequently, for the Granger causality testing, the first differences of the variables will be used.

Table 2. Unit root tests

	ADF		Phillips-Perron		DF-GLS	
	Level	First difference	Level	First difference	Level	First difference
GVI	–2.261	–16.422**	–2.090	–16.407**	0.080	–6.890**
PPI	–0.632	–17.324**	–1.120	–17.996**	–0.918	–2.164*
AFI	–2.481	–18.619**	-2.624	–29.341**	–1.234	–2.292*

** Denotes stationarity at 5% significance level*
*** Denotes stationarity at 1% significance level*

To test the presence of a causal relationship between agricultural productivity, inflation and farmers' income, the use of 2 lags is chosen based on the agreement of the AIC, SC and HQ criteria (Table 3).

Table 3. Lag length criteria

Lag	AIC	SC	HQ
0	0.171	0.173	0.119
1	–16.597	–15.033	–16.339
2	–16.760*	–15.736*	–16.373*
3	–16.677	–15.111	–16.079
4	–16.503	–14.566	–15.717
5	–16.593	–13.195	–15.610
6	–16.395	–13.636	–15.335
7	–16.396	–13.176	–15.139
8	–16.309	–11.517	–13.775

Based on the Granger causality tests conducted (Table 4), initially the results indicate that Gross Value Added (GVA) demonstrates a unidirectional causal effect on the Producer Price Index (PPI) (p = 0.010, suggesting that changes in agricultural production value precede and influence variations in producer prices. Conversely, PPI does not exhibit a causal effect on GVA (p = 0.417). GVA and AFI show a bidirectional causal effect highlighting the influence of agricultural productivity on farmers' income levels and vice versa (p = 0.007 and p = 0.015 respectively). Notably, PPI causes changes in AFI (p < 0.000), implying that shifts in producer prices forecast changes in farm household income.

Table 4. Granger causality tests

Null Hypothesis:	F	p
GVA does not Granger Cause PPI	4.228	0.010
PPI does not Granger Cause GVA	0.745	0.417
GVA does not Granger Cause AFI	4.982	0.007
AFI does not Granger Cause GVA	4.210	0.015
PPI does not Granger Cause AFI	5.521	0.000
AFI does not Granger Cause PPI	1.024	0.280

Conclusions

Agricultural productivity plays a pivotal role in driving economic development in rural areas. The study's identification of causal connections between changes in productivity and inflation highlights the sector's significant influence on broader economic trends, as understanding how enhancements in productivity can affect inflationary pressures by impacting producer prices enables policymakers to develop targeted strategies for maintaining price stability and bolstering economic resilience. The bidirectional causality observed between agricultural productivity and farm household income, shows that increased productivity not only enhances incomes but also empowers farmers to invest in technologies and practices that further boost productivity. Conversely, the study reveals that inflation can negatively impact farmers' incomes, emphasizing the need for adaptable policies to mitigate these effects.

Implications

To effectively implement these findings, policymakers should adopt a multifaceted approach with several strategic recommendations. Promoting technological adoption in the agricultural sector is crucial. Governments and agricultural organizations must incentivize farmers to utilize innovative technologies, such as precision agriculture and data-driven decision-making tools. These technologies enhance productivity and reduce costs, leading to improved farmer incomes. Additionally, developing training programs can help bridge the knowledge gap and foster innovation. Improving market access is also vital. Policymakers should invest in infrastructure, such as transportation networks and storage facilities, to facilitate the movement of agricultural goods. Establishing cooperative structures will empower farmers to pool resources and negotiate better prices, thus reducing vulnerability to economic fluctuations. Furthermore, enhancing financial services is essential for farmers' financial management and investment. Developing tailored financial products, including microloans and insurance schemes, and collaborating with financial institutions can improve access to credit. Addressing climate change risks is imperative. Investment in climate-resilient crops and sustainable practices can mitigate adverse effects, while creating awareness and providing necessary training will enhance farmers' adaptive capacity. Lastly, fostering inclusive growth involves empowering marginalized communities, including women and youth, through equal access to resources and training in agriculture, promoting innovation and sustainability in the sector.

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