sustainability

Article

Analyzing EU's Agricultural Sector and Public Spending under Climate Change

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Abstract: Climate change not only affects weather conditions, patterns, and the frequency and severity of extreme weather events but also changes the structure of government spending. Agriculture is an important sector of the European Union (EU). However, by 2050, the industry will most likely decrease by 16%. One-third of the EU's budget has been spent on agricultural funding, adaptation, and climate action. The effect of climate change on agriculture is mixed and dependent on the location of the region. The southern EU is adversely affected, while the northern EU is positively affected by the changes in weather patterns. The main goal of this paper is to gain insight regarding the effect climate change has on public spending in relation to the agricultural sector of the EU, using the pooled Ordinary Least Squares (OLS) and Generalized Method of Moments (GMM) methodology. The study concludes that public spending is influenced by government expenditure and government support in agricultural research and development in the EU region. In the southern EU region, the variables impacting public spending are greenhouse gases from the agricultural sector, temperature, and GDP, while in the northern region, no variable has a significant impact on public spending proxied by agricultural subsidies. The policy recommendations include a better allocation of agricultural subsidies, reconsideration of the efficiency of Common Agricultural Policy (CAP), and a focus on expanding investment in research and development in the agricultural sector.

Keywords: economic growth; climate change; global warming; public budget; Generalized Method of Moments (GMM)

Citation: Dincă, G.; Netcu, I.-C.; El-Naser, A. Analyzing EU's Agricultural Sector and Public Spending under Climate Change. *Sustainability* **2024**, *16*, 72. https://doi.org/10.3390/su16010072

Academic Editors: Hossein Azadi and Bin Xu

Received: 27 October 2023
Revised: 13 December 2023
Accepted: 18 December 2023
Published: 20 December 2023

1. Introduction

Climate change is defined by the National Aeronautics and Space Administration as "a long-term change in average weather patterns that have come to define Earth's local, regional, and global climate" [1]. Climate change is associated with an increase in ozone level, air pollutants, temperature, rainfall, and snowfall in certain areas, while in other areas, there is an increase in droughts and water scarcity. An additional repercussion attributable to climate change involves the elevation of sea and ocean levels and increase in the intensity, frequency, and severity of hurricanes and wildfires [2]. To limit climate change and global warming, the Paris Agreement was adopted in 2015. The Paris Agreement is an international legal binding treaty between 193 parties that has the role of limiting global warming to 1.50–2.0 °C compared to the pre-industrial levels and eliminating greenhouse gases [3]. According to the Intergovernmental Panel on Climate Change (IPCC) Report, the global temperature is forecasted to increase from 1.3 to 2.4 °C in 2020–2060 and from 1.9 to 5.7 °C in 2061–2100 if pollution control policies and emissions control processes are not implemented [4]. The National Centers for Environmental Information reported that, in 2021, the global warming temperature was situated at 1.04 °C higher compared to the pre-industrial levels [5].

Climate change affects fiscal sustainability and increases financial risk. The fiscal impact of climate change is due to the allocation function, which is split into mitigation, allocation policies, redistribution, and stabilization function. All functions have a direct impact that increases the expenditure side of the public budget and decreases the revenue side [6]. The direct costs associated with climate change for a 3 °C increase scenario is estimated to be EUR 122 billion, mortality due to extreme heat, a median of EUR 234 billion due to sea-level rise, EUR 2.4 trillion in a high-emission scenario, and EUR 21 billion due to river floods in a moderate scenario. The loss from extreme weather events is projected to range between EUR 4 and 8 billion, while the loss associated with the agricultural sector is projected to be EUR 831 million [7]. Climate change has a direct mixed effect on agriculture, depending on the country and its location. On one hand, in the Southern European countries, with an established warmer weather, climate change negatively impacts harvested agricultural output level, the consistency of it, and the level of production quality due to an increase in droughts, heat stress, and lack of precipitation. In addition to the negative effects on crops, the land exhibits a downgrade in quality and productivity [8]. On the other hand, in the Northern European countries, where the climate is colder, climate change has a positive effect on agriculture due to an increase in average temperature and a decrease of the cold and frost, extending the growing period [9].

The main component of the EU's agricultural policy is the Common Agricultural Policy (CAP). In the EU, EUR 54 billion of public funds have been spent yearly under the CAP since 2006. Globally, approximately EUR 640 billion are spent as agricultural subsidies. During the period 2014–2020, 38% of the EU's budget was allocated to the CAP, which equaled a total of EUR 362.8 billion [10]. An audit regarding the efficiency of CAP shows that the funds are misallocated, increase income disparity, and increase the land value which only benefits landowners, not farmers. A considerable proportion of funding is directed to countries that would be well off in the absence of the payments. According to the report of the European Court of Auditors issued in 2022, during the years 2014–2020, climate spending was overstated by EUR 72 billion, 80% of which was allocated to agricultural funding. The results show that only 13% of the budget was spent on climate action [11]. As of 2021, in the EU, the estimated gross value added from the agricultural industry was EUR 189.4 billion and contributed 1.3% to EU's GDP [12]. Osberghaus and Reif [13] stated that although the costs of agricultural adaptation due to climate change are high and most of them are private, by 2050, the agricultural sector of the European Union will decrease by 16%. Overall, 40% of the EU's land is categorized as agricultural land, and it provides 22 million jobs within the agricultural sector and another 22 million jobs outside of the sector.

Due to climate change, governments need to increase public spending due to disaster relief payments and infrastructure rebuilding. Climate change impacts other economic sectors too, such as labor and tourism [14,15]; therefore, climate change reduces the tax base and adversely affects fiscal balance. Droughts, rising temperatures, and extreme weather conditions have a negative effect on the agricultural and tourism sector, which implicitly lowers the GDP. As a result, the countries' fiscal budgets will fall due to a decrease in the amount of income generated by the government and an increase in government expenditures due to adaptation costs. There are also indirect consequences that consist in devaluation of other sectors due to job and income loss [15].

Europe experiences weak precipitations and higher temperatures. Such conditions do not only impact the agricultural sector by decreasing the crop quality and yield, but also the energetic sector that experiences lower generation of hydropower and challenges associated with maintaining the cooling systems in power plants. According to the GDO Analytical Report created by the European Commission titled "Drought in Europe", the August 2022 edition, the Combined Drought Indicator states that 17% of Europe is in alert conditions, while 47% is under warning conditions (as shown in Figure 1).

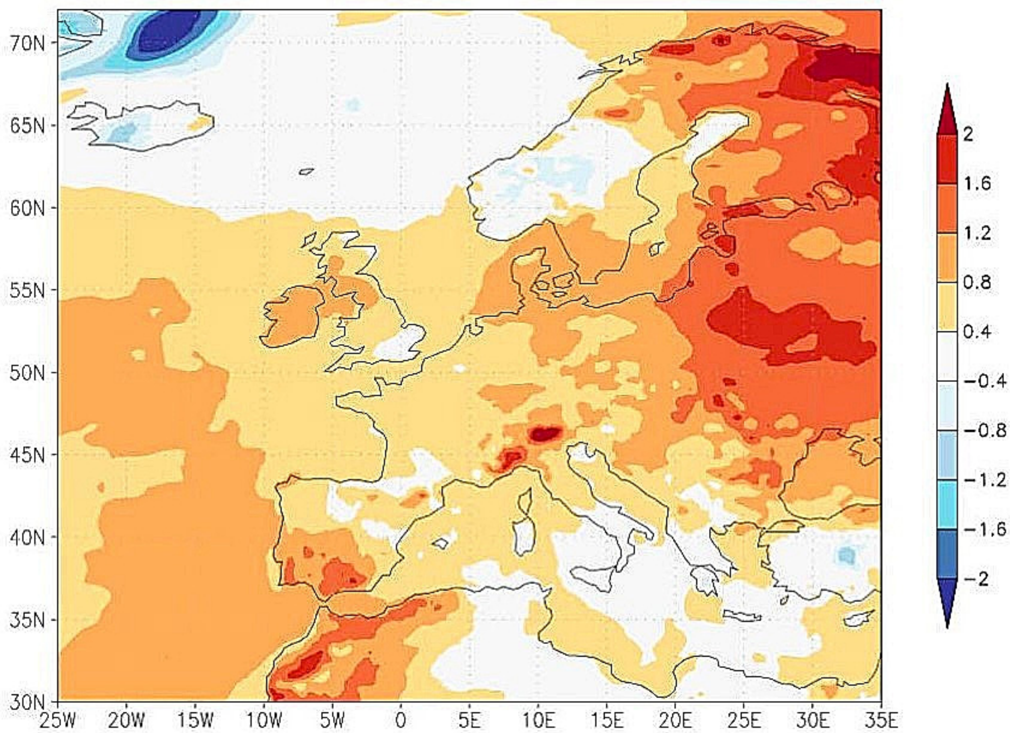

Figure 1. Average temperature anomaly during January–May 2023. Source: The KNMI Climate Explorer.

Although the drought hazard has increased in Italy, Spain, Portugal, France, Germany, the Netherlands, Belgium, Luxembourg, Romania, Hungary, Serbia, Ukraine, Moldova, Ireland, and the United Kingdom, the countries experiencing severe conditions are Italy, France, Hungary, and Romania. According to the Standardized Precipitation Index, a severe to extreme drought is experienced in Italy, France, and Eastern Europe [16]. The countries that are under severe weather conditions are still experiencing cold temperatures and snow in the winter [17].

This paper stands out for its original contribution in elucidating the nuanced relationship between public spending and climate change. It diverges from conventional approaches by introducing innovative variables, particularly within the domain of agriculture. In contrast to prior literature, the following paper uses subsidies from agriculture as a proxy for public spending and temperature, rain, and greenhouse gases from the agricultural sector to better assess climate change. The aim and goal of this paper is to clearly answer the following research questions:

Q1: Is there a relationship between public spending and climate change looking at evidence from the EU's agricultural sector?
Q2: Is there a relationship between public spending and climate change looking at evidence from the Southern EU's agricultural sector?
Q3: Is there a relationship between public spending and climate change looking at evidence from Northern EU's agricultural sector?

An increase in temperature due to global warming will decrease the agricultural sector, which will cause public spending to increase and affect the public budget by creating a deficit. Also, an increase in agricultural subsidies should support economic development as well as the agricultural sector, indirectly increasing the GDP. The GMM methodology is applied to exhibit the implications of climate change on public spending in all EU countries, northern as well as southern EU countries, using the variables of agricultural subsidies as a proxy for public spending, real GDP growth, inflation, debt-to-GDP ratio, greenhouse gas from agriculture, labor in the agricultural sector, temperature, rain, and government support to agricultural research and development and government expenditure during the 2000–2020 period.

The study is structured in six sections, including an introduction. Section 2 presents the literature review, Section 3 presents the methodology and data, while Section 4 details the results, and Section 5 presents the discussion and limitations. Section 6, finally, presents the conclusion and policy implications.

2. Literature Review

According to Aaheim et al. [14], climate change has a direct impact on the agricultural sector due to the high dependence between agriculture and climatic factors. In Europe, agriculture contributes to GDP differently according to the region. While in the Baltics and Central and Eastern Europe, the value added is more than 15%, in other regions, it is less than 10%. According to Yadav et. al. [18], climate change affects the agricultural sector in six diverse ways: soil, crop production, water, temperature, CO_2, pests, and diseases. Due to the increases in temperature and extreme weather conditions caused by climate change, the soil loses its moisture, starts to erode, and, over time, exhibits infertility, which negatively affects the quality and quantity of crops. An increase of 10 °C decreases agricultural harvest output by 1.7%, while a decrease of 100 mm in rainfall reduces agricultural growth by 0.35%. An increase in temperature of 1 °C reduces the mean yield of cereal crops by 21% in a low-gas-emission scenario and by 28% in a medium-high-emission scenario [19]. Although climate change has a direct impact on the agricultural sector, the agricultural sector also influences climate change through the emission of greenhouse gases. According to OECD [6], the agricultural sector emits greenhouse gases that contribute to climate change. The increase of greenhouse gasses impacts temperature and changes the pattern of precipitations. The constant change in environmental conditions has an adverse effect on the amount of output and quality generated from the agricultural sector and environment.

Lis and Nickel [20] looked at evidence taken from the occurrence of extreme weather events. Their results show that depending on the economic development level of the country, an extreme weather event decreases the budget balance by 0.23% and GDP by 1.4%. The budget balance of developing countries is worse off after an extreme weather event compared to the budget balance of advanced economies. Parker [21] showed that the impact that extreme weather events have on countries are dependent on the level of economic development and the type of disaster. Boneva and Ferrucci [22] revealed that extreme weather events caused by climate change led to higher prices and monetary policy shocks that increase inflation. Also, financial tools used to off-set the negative effects of climate change, such as carbon tax, have a direct impact on inflation. According to Batten et al. [23], events caused by climate change led to a decrease in GDP, decrease in financial gain and the supply of global commodities. As per [24], climatic-induced natural disasters have the potential to engender a reduction in the GDP of countries not predisposed to such disasters by approximately 1%. In contrast, nations susceptible to these calamities may experience a notably more pronounced decline, with natural disasters contributing to a GDP reduction exceeding 5%. Parrado et al. [25] underscored the imperative for undertaking adaptive measures in response to climatic events, which, if left unaddressed, are predicted to escalate public expenditures and impose fiscal strains. Failure to implement adaptation strategies is expected to exacerbate the impacts of climate change, amplifying fiscal deficits and heightening the demand for government borrowing. A detailed analysis was conducted by Cannone [26] stating that, globally, there will be a short to medium-term inflation caused by the effect of climate change in the agricultural sector, which will increase the prices on food and from mitigating actions. The impact that extreme weather events have on public spending and budget balance was further explained by Bachner and Bednar-Friedl [27] using an analysis based on Austria. Due to the necessity of frequent relief payments and reconstruction of infrastructure, public spending increases, creating an exacerbating imbalance in the public budget. In addition to the effect on the expenditure side, revenue is also negatively affected through the reduction of the sectoral tax base and lower revenues earned from taxes. Such simultaneous actions exacerbate the imbalance in the public budget. The exacerbated imbalance indirectly affects other sectors due to the low availability of funds that can be distributed to other sectors. The results show that without a counterbalancing method, the effect that climate change has on public budget is −0.3% compared to the baseline. The revenue side is decreased by low labor tax revenue (−0.4%) and low production revenue (−0.8%), and the expenditure side increases due to disaster relief (+184%) and unemployment benefits (+10%). GDP and welfare are also lower compared to the baseline by −0.2% and −0.6%, respectively, while unemployment is higher compared to the baseline by 0.4%. The prevailing challenge concerning public expenditure in the context of climate change resides in the inherent difficulty associated with accurately appraising the requisite financial allocations mandated for climate spending and policy implementation by governments. Consequently, governments encounter impediments in delineating the precise quantum of their financial resources earmarked for such purposes. Moreover, a further complication ensues from the arduous task of effectively monitoring expenditures associated with climate activities. Public spending addressing climate change and climate policy is directed toward the agricultural, energy, and environmental sectors [28].

Looking at the impact that climate change, proxied by temperature and rain, has on public spending and budget balance, the results do not reach a consensus regarding the impact each variable has on public spending. Giovanis and Ozdamar [29] revealed that temperature has a negative effect on the government's budget, and it increases debt. The average temperature reduces the budget balance by 0.3% and expands the debt by 1.87%. The study has forecasted temperature and rain patterns for a period of 79 years and concluded that upholding present conditions will adversely affect the budget balance by 7.3% and increase the levels of debt by 16% in 2060–2079 and 18% in 2080–2099. Previous forecasts have been projected under a scenario of prominent level of greenhouse gases. Changing the forecasts to a scenario that is based on low level of greenhouse gases, budget balance decreases by 1.7% in 2020–2039 and 2.2% in 2080–2099, while the levels of debt increase by 5% in 2020–2039 and 6.3% in 2080–2099. In the incipient phase, emissions contribute to the advancement of economic growth until a state of equilibrium is attained, surpassing the equilibrium threshold; however, results in a detrimental impact on economic growth [30]. Kahn et al. [31] showed that increase in temperature decreases GDP growth in the short and medium run, which implicitly reduces the budget of governments. The impact of temperature depends on the level of economic development of each country, with low-income countries being more affected compared to emerging economies. An increase of 1 °C compared to the median temperature of the emerging economies decreases growth by 0.9%, while an increase of 1 °C from the average temperature of low-income countries decreases growth by 1.2%. Kahn et al. [31] concluded that continuous changes in temperature, above and below the historical benchmark, adversely affect per capita growth. Another conclusion that was reached in the same study is that the changes in the pattern of precipitation do not have any effect on capita growth. The research shows that the impact of increasing temperature is different according to geographic regions and income level. The analysis shows that an increase in temperature of 0.04 °C per year will decrease GDP by more than 7% by the year 2100, unless adaptation policies are put in place. Yahaya [32]'s analysis, based on ECOWAS countries, contradicts previous studies and concludes that the only variable that negatively affects budget balance by creating a deficit is rainfall. The extreme changes in rainfall pattern reduce the amount of revenue generated and increase expenses. The following scenario will force countries to borrow more money and exacerbate public spending. Conversely, Abbas et al. [33] demonstrated that, with respect to agriculture, short-term implications reveal a positive correlation between the temperature, rainfall, and agricultural value added, whereas over the long term, this relationship becomes negative. Additionally, the analysis of carbon dioxide (CO_2) emissions indicates a positive impact on the agricultural value added, persisting in both short and long temporal contexts.

Although previous studies are showing that temperature increases debt and spending and decreases GDP growth, Leppänen et al. [34], showed that in the cold climate of Russia, an increase in temperature decreased public spending by a small amount. The authors suggested that Russia could have saved up to USD 3–4 billion, during a period of 20 years, from 2000 to 2020, under an increase in temperature of 1–2 °C. If the increase in temperature is higher than 1–2 °C, there could be possible environmental consequences that are harder to predict due to data limitation. Therefore, the impact that temperature has on public spending could be dependent on the climate of the region. Equivalent results have been reached by Nawaz [30] that the increase in temperature caused by climate change has a positive effect on economic growth.

Climate change also causes inflation, which implicitly affects public spending. According to a study conducted by Ezirim et al. [35], there is an interdependence between inflation and public expenditure in the short run as well as in the long run. An increase in inflation will result in an increase in public spending and vice versa. Different results were obtained by George-Anokwuru and Ekpenyong [36], who found that the relationship between public expenditure and inflation is positive and insignificant in the short run and negative and significant in the long run. Due to an analysis conducted by Adediran et al. [37], we can confirm that at a global level, climate change has an inflationary effect on the global economy due to the extreme weather events that disrupt supply chain which directly increases prices of food, by its effect on the labor efficiency and effectiveness, and its increase in fuel prices and production costs. In accordance with Odongo et al. [38], it is posited that not solely the extremities of extreme weather conditions exert an inflationary influence but also the fluctuations in temperature and precipitation levels. The variability in temperature is implicated in its repercussions on food production, resultant effects on food prices, and implications for energy pricing and generation capacity. Likewise, the variability in precipitation levels is indicated to impact both overall inflation and food production. According to Kunawotor et al. [39], climatic occurrences exerting the most pronounced influence on inflation and significantly impacting monetary policy are extreme weather conditions, with floods and droughts being the climatic phenomena most substantially affecting inflation in the realm of food production. In addition to its ramifications on public spending and climate change, inflation exerts a noteworthy adverse influence on the value added within the agricultural sector. The inflationary environment disrupts the equilibrium between supply and demand dynamics. Escalation in the prices of resources, production costs, and final goods and services, induced by inflation, may precipitate a crisis in food pricing. Furthermore, inflation impairs investment in the agricultural sector, as delineated in prior research [40].

Public spending on subsidies has a direct and relative impact on agricultural growth. Gautam [41] illustrated that in countries where subsidies are a major contributor to public spending, the effect on agricultural growth is negative. The study conducted by Zafar and Tarique [42] showed that public investment is a better alternative for agricultural development compared to subsidies. The analysis by Baig et al. [43] on the effect of agricultural subsidies on agricultural productivity stated that the governmental focus should be on technological innovations in the agricultural sector to promote growth and development. Also, subsidies have an adverse effect on food grain yield. Agricultural subsidies fail to achieve the intended goal. More often, the results of subsidies are inefficient farming, inequality, and environmental degradation. Although, subsidies do have a direct effect on the end price of goods [44]. Balough [45] examined the influence of subsidies under CAP on the mitigation of agricultural greenhouse gases. Their results concluded that the direct payments received under CAP are facilitating greenhouse gases from the agricultural sector. Therefore, CAP fails to mitigate GHG emissions. Secondly, organic farming and the increase in rural development spending has an adverse effect on GHG emissions. However, subsidies seem to have a negative effect on agriculture and increase GHG emissions. Scown et al. [9] supported the inefficient allocation of funds through CAP and the environmental degradation caused by it. CAP supports the production of unhealthy products and increases unsustainable agricultural practices. The monitoring indicators of CAP are not implemented; therefore, the implications of CAP cannot be accurately assessed. Although CAP has a detrimental impact on agriculture, public investment in agricultural research and development (R&D) is positively associated with agricultural productivity [46]. R&D and technological advances are considered key instruments in solving current climate change issues and mitigate externalities. Pop [47]'s analysis focuses on government subsidies used for climate-friendly R&D. The result of the study shows that R&D subsidies have a positive impact on the research and development of environmentally friendly projects but do not have a significant impact on climate. Subsidies are not incentivizing the development and adoption of technological innovations and limit the potential of R&D projects due to high opportunity costs. Pardley et al. [48] stated that agricultural R&D is a key indicator of agricultural productivity and production. Although public investment in agricultural R&D is economically underdeveloped, it does offer substantial return on the investment. The agricultural investment in agricultural R&D is dependent on the level of economic development of each country. While the volatility of public investment in agricultural R&D is high in low-income countries, in high-income countries, the volatility is increasing at a steady rate. The result of the high fluctuations in volatility present in low-income countries have a negative effect on agricultural productivity. On the other hand, Stoian et al. [49] stated that governmental expenditure on R&D in the agricultural sector is considered an explanatory variable for the growth in farming income.

3. Materials and Methods

This paper demonstrates the effect of climate change on public spending by looking at evidence from the agricultural sector. The GMM methodology was applied to establish climate change effects on public spending from the period 2000–2021, in all 27 EU countries, which are Belgium, Bulgaria, Czechia, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, the Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, and Sweden. The paper also analyzes the effect of climate change on public spending in the northern and southern countries of Europe. The countries were grouped into northern and southern according to the United Nations classification. The northern countries are Ireland, Denmark, Lithuania, Estonia, Finland, Sweden, and Latvia, while the southern countries are Spain, Italy, Greece, Croatia, Malta, Portugal, and Slovenia. The reason for dividing the countries according to the region is because climate change affects the northern and southern part differently; while the conditions in the southern part of the EU are worsening for the agriculture sector, the conditions in the northern countries of the EU are facilitating the agricultural sector. Also, the northern and southern parts of the EU have different climate conditions.

The research design of this paper follows the GMM model proposed by Yahaya [32], which concludes that the only variables that have an impact on public spending are the rainfall and previous years' deficit. In addition to the variables used in the previously stated study such as GDP growth, inflation, temperature, debt-to-GDP ratio, and rainfall, this study adds new variables. The new variables added to this study are subsidies for agricultural output, government support to agricultural research and development, greenhouse gas emitted by the agricultural sector, and employment in the agricultural sector. Agricultural subsidies are used as a proxy to assess the public spending allocated to the agricultural sector. Data regarding greenhouse gas emissions from the agricultural sector are used to assess climate change and the impact that greenhouse gases have on public spending. Compared to the study conducted by Yahaya [32], the new variables added to the study are meant to provide evidence on the impact that climate change has on public spending by looking at the agricultural sector of the EU, as well as northern EU countries, and southern EU countries. The model uses agricultural subsidies as an independent variable and GDP growth rate, inflation rate, debt-to-GDP ratio, greenhouse gas from agriculture, agricultural labor, mean temperature deviation and rainfall as dependent variables and government support to agricultural research and development.

Table 1 presents the variables used in the model, abbreviations, unit, and data source used to gain insight about the relation between public spending, climate change, and agriculture.

Table 1. Variables, abbreviations, unit, and source.

Variables Name	Abbreviation	Unit	Source
Dependent Variables			
Agriculture subsidies	AGR_SUB	Millions	Eurostat 2000–2020 [50]
Independent Variables			
GDP growth rate	GDP_GR	%Annual	World Bank 2000–2020 [51]
Government expenditure	GOVE	%GDP	Eurostat 2000–2020 [50]
Inflation Rate	INF	% Average Consumer Price	Eurostat 2000–2020 [50]
Debt-to-GDP ratio	DTG	% GDP	Eurostat 2000–2020 [50]
Greenhouse Gas from Agriculture	GHG	% Agriculture	Eurostat 2009–2020 [50]
Agricultural labor input statistics	LAB	Absolute figures	Eurostat 2000–2020 [50]
Mean temperature deviation	TEMP	Absolute figures	Climate Change Knowledge Portal 2000–2020 [52]
Rainfall	RAIN	Absolute figures	Climate Change Knowledge Portal 2000–2020 [52]
Government support to agricultural research and development	GSARD	Millions	Eurostat 2000–2020 [52]

Source: Adapted from Yahaya et al. [32].

The effect that climate change has on public spending by looking at the agricultural sector has been analyzed using the following model:

$$AGR\_SUBi, t = \beta 0 \pm \beta 1\ GOVEi\ i, t \pm \beta 2\ GHGi, t \pm \beta 3\ \Delta DTGit \pm \beta 4\ GDP\_GRi, t \pm \beta 5\ INF, t \pm \beta 6\ LABi, t \pm \beta 7\ TEMPi, t \pm \beta 8\ RAINi, t \pm \beta 9\ GSARDi, t \pm \delta t \pm \gamma t \pm \mu i, t \quad (1)$$

In the regression equation, AGR_SUB is the dependent variable followed by the independent variables, GHG*i*, *t*, INF*i*, *t*, DTG*i*, *t*, GDP_GR*i*, *t*, LAB*i*, *t*, TEMP*i*, *t*, RAIN*i*, *t*, GOVE*i*, *t*; GSARD*i*, and *t* represent each country within the dataset, while *t* represents different time periods. β are each variable's coefficients, while δ, γ, and μ represent error terms.

The reason for choosing subsidies in the agricultural sector is because in the EU, CAP represents 38% of public spending [10]. Agriculture has a direct effect on the GDP because it provides direct and indirect job opportunities and facilitates economic development, which is the reason for choosing labor in the agricultural sector. The GDP growth rate is the annual average increase in GDP based on the market prices using the local currencies. To assess the fiscal policy of each country, the debt-to-GDP ratio variable was used, which provides a better perspective about each country's ability to pay its debt created by public spending. While a lower debt-to-GDP ratio shows a better budget balance, a higher rate increases interest payments, unbalancing the public budget. Public spending is how governments manage to achieve their objectives and differs according to the size of the country [53]. The greenhouse gases variable from the agricultural sector was chosen as a way of assessing climate change. The reason for using temperature and rain as variables was to gain a better perspective of the change in environmental conditions, and because the agricultural sector is dependent on these two factors. The reason for choosing governmental support in research and development in the agricultural sector was due to its high impact on environmental production, productivity, and economic development [48,49].

To scrutinize the interdependencies among variables in the dataset, the analysis employs a correlation matrix. This statistical tool proves valuable in the analysis as it succinctly synthesizes extensive datasets, offering insights into the strength and direction of relationships between variables. This research adopts panel data analysis techniques because it is the best fit for the data. The study uses a blend of time cross-sections section data collected from multiple time periods. The model used in this statistical analysis takes into consideration unobservable heterogeneity within the dataset that accounts for bias and unobserved variables providing accurate results. The analysis uses instrumental variables to account for endogeneity issues [54]. Thus, the paper adopts a system estimator that uses adjusted standard errors to account for possible heteroskedasticity issues within the dataset. The following method accounts for unobserved effects by using GMM's instrumental variables to fix any issues related to endogeneity [55]. The next section presents the empirical results of this study and what the effects the independent variables have on the dependent variable.

From a statistical perspective, Table 2 below lists the key descriptors of the variables employed in all the EU27 countries.

Table 2. Descriptive statistics: EU27 countries.

Variable	Observations	Mean	Std. dev	Min	Max
AGR_SUB	498	3237	13.9	0	115.5
GOVE	567	44.9	6.6	24.3	64.9
GDP	567	2.2	3.8	−14.8	25.2
INF	567	2.5	3.3	−1.7	45.7
DTG	567	58.8	34.9	3.8	206.3
GHG	324	10.8	6.0	2.5	35.2
LAB	562	405.9	578.6	3.34	3645
TEMP	567	10.6	3.8	.91	20.35
RAIN	567	781.7	242.0	278.4	1780.0
GSARD	446	100.7	173.9	.002	1028.5

Source: processed by authors.

From Table 2, one can notice that the highest standard deviation is for the variable labor in the agricultural sector (578.6) which shows that heterogeneity is present within the dataset. The large standard deviation shows that the values within the dataset are farther from the mean (405.9), which can pose a problem to the analysis due to the high frequency of extreme values. The second largest standard deviation is for the variable rain (242.0) with a mean of (781.7). The smallest standard deviation is for the variable inflation, which has a value of 3.3, showing that the values within the variables are closer to the mean (2.5), and the dataset does not present high variability. The second smallest standard deviation is for the variables GDP (3.8) and TEMP (3.8). It is noticeable that the variables RAIN, TEMP, DTG, INF, GDP, and GOVE have 567 observations, the variable LAB has 562 observations, the variable AGR_SUB has 498 observations, and the variable CSAR has 446 observations. Looking at the scatterplot in Appendix A, Figure A1 provides insight regarding the relationship between public spending and the other variables in all of the EU.

Table 3 below lists the key descriptors of the variables employed in southern EU countries.

Table 3 shows the descriptive statistics from the southern and northern region of the EU. The variables that had the highest standard deviation in the southern part of the EU were LAB (431.6), RAIN (328.1), and CSARD (191.1). The variables that had the highest standard deviation in the northern region of the EU were AGR_SUB (1.246) and RAIN (496). The significant differences in standard deviation and mean could pose a problem to the analysis due to the high variability within the dataset and lack of consistency. Looking at the scatter plot in Appendix A, Figures A2 and A3 show insight about the relationship between public spending and the other variables in the northern and southern part of the EU.

Table 3. Descriptive statistics of southern and northern EU countries.

	Southern EU Countries					Northern EU Countries				
Variable	**Obs.**	**Mean**	**Std.dev**	**Min**	**Max**	**Obs.**	**Mean**	**Std.dev**	**Min**	**Max**
AGR_SUB	129	0.619	0.946	0.0026	4.027	147	0.6020	1264	0.69	5.961
GOVE	147	46.4	4.7	34.4	62.8	147	43.5	8.7	24.3	64.9
GDP	147	1.3	4.0	−10.8	19.7	147	2.9	4.7	−14.8	25.2
INF	147	2.0	1.7	−1.4	9	147	2.1	2.3	−1.7	15.3
DTG	147	85.9	41.4	21.8	206.3	147	37.6	21.9	3.8	119.9
GHG	84	8.3	2.6	2.5	13.7	84	17.3	7.6	5.9	35.2
LAB	142	474.4	431.6	4.0	1408.5	147	94.1	47.3	17.2	186.7
TEMP	147	14.2	2.9	8.7	20.2	147	6.5	2.5	0.91	10.2
RAIN	147	858.1	328.1	355.3	1780.0	147	753.4	209.2	496.4	1451.2
GSARD	114	127.1	191.2	0.099	717.8	118	48.72	38.20	1.867	109.6

Source: processed by authors.

4. Results

Tables 4–6 show the correlation matrixes of the whole EU region, the southern part, and the northern part of EU, respectively. In the whole EU region, the variables that had the largest positive correlation were the debt to-GDP and GOVE, TEMP and debt-to-GDP, and RAIN and GHG, while the variables that had the largest negative correlation were the GDP and GOVE, TEMP and GHG, and DTG and GDP. In the southern region of the EU, the variables that exhibited the largest positive correlation were the LAB and AGR_SUB, DTG and GOVE, and RAIN and GHG, while the variables exhibiting the largest negative correlation were the GDP and GOVE, DTG and INF, and TEMP and GHG. In the northern region of Europe, the RAIN, TEMP, and GHG and GSARD and DRG had the highest positive correlation, while the LAB, TEMP and GOVE and DTG and INF had the highest negative correlation.

Table 4 below shows the correlation matrix for all the European Union countries.

Table 5 presents the correlation matrix of the countries in the southern region of the European Union.

Table 6 presents the correlation matrix of the countries in the northern region of the European Union.

Four modeling approaches have been employed in this study's statistical analysis: pooled OLS, random effects model (REM), fixed effects model (FEM), and GMM. These approaches are most frequently used in the related analysis of this kind of panel data [19,30,40]. Taking into consideration that each model had its own limitations, the least squares model (FGLS) and panel-corrected standard errors model (PCSE) have been used in the case of all 27 EU countries, 7 northern countries of the EU, and 7 southern countries of the EU.

For all the 27 European countries, the analysis started with a pooled OLS regression using the data from the 2000–2020 period. On the sampled data, the Breusch–Pagan/Cook–Weinsberg and White test were used, which resulted in p-values of 0.0000, and 0.0003, respectively. Therefore, the OLS model was not suitable, but the data showed signs of heteroskedasticity. The multicollinearity test using the variance inflation factors averaged all variables at 1.62 with no values above 5; therefore, there was no multicollinearity within the dataset. Using the Breusch–Pagan Lagrangian test to assess the random effects within the panel showed a p-value of 0.0000, which means that it was appropriate to use REM over OLS within the sample. REM proved a random variation within countries, and the unobserved variables were uncorrelated with the independent ones. The Hausman test was used on the data set to assess the better fit between REM and FEM. The p-value concluded that FEM was better fitted due to $0.0000 < 0.05$. The data was also tested using the Wooldridge and Pesaran test, which both resulted in a p-value of 0.0000 < 0.05;therefore, within the panel data, there were signs of autocorrelation and cross-dependence. The Ramsey RESET test for robustness shows a value of 0.0008 < 0.05. To correct the previous issues, the panel-corrected standard errors (PCSE) were used as they had a higher number of observations compared to periods of time. We noticed that in the OLS model, the significant variables that had an impact on public spending proxied by agricultural subsidies were GOVE and GSARD. In the REM model, no variable had a significant effect on public spending. In the FEM model, the variable that moderately affected public spending was the DTG. In the PCSE model, the variables that have a moderate impact on public spending were the GOVE, GHG, TEMP, and GSARD. In the GMM model, all the variables had a significant impact on public spending.

The same analysis was used on the southern and northern parts of the European Union. Looking at the southern part of the European Union, multicollinearity was found within the dataset; therefore, the variables labor in agriculture and temperature were dropped. The Breusch–Pagan/Cook–Weinsberg test and White test had p- values of 0.0000 < 0.05; therefore, the OLS model was not suitable. The White test had a value of 0.0703 > 0.05 for the analysis, and there was no sign of heteroskedasticity. Using the Breusch–Pagan Lagrangian test to assess the random effects within the panel showed a p-value of 1.0000, which means that it was appropriate to use OLS over REM within the sample. The results of the Hausman test were 0.0000, which means that FEM was suitable for the analysis. The Wooldridge test for autocorrelation resulted in a value of 0.0000, showing that there was autocorrelation within the variables. However, the Pesaran test had a value of 0.0000 < 0.05 which showed that cross-dependence was present. The Ramsey RESET test for robustness showed a value of 0.0002 < 0.05. The results of the pooled OLS model showed that the variables that had the highest impact on public spending proxied by agricultural subsidies are GHG and GSARD. The variable LAB was dropped due to multicollinearity. In the REM model, the variables that had the highest effect on public spending were GHG and GSARD, while in the FEM model, only the variables GSARD had a significant impact. In the FGLS model, only the variables GHG and GSARD had a significant impact on public spending. The GMM model showed that only the variable TEMP had a significant impact, while the GDP had a moderate impact.

In the northern part of EU, the Breusch–Pagan and White test resulted in a p-value of 0.0000, and White test resulted in a value of 0.1285 > 0.05; therefore, the OLS model was not suitable, and the data showed no signs of heteroskedasticity. The VIF test used for multicollinearity identified that there was multicollinearity for the greenhouse variable; therefore, the variable was dropped, and the new mean is 2.41. Using the Breusch–Pagan Lagrangian test to assess the random effects within the panel showed a p-value of 1.000, which showed that the OLS model was suitable for the analysis. The Hausman test resulted in a p-value of 0.000, which means that FEM was suitable for this analysis. The Breusch–Pagan LM showed 0.0000, Wald showed 0.0000, Wooldridge had a p-value of 0.0000, and the Pesaran test gad a value of 0.383, meaning that the data presented signs of autocorrelation, cross-sectional dependence, and heteroskedasticity. To correct these data, the fit-panel data model (FGLS) was used for more time periods than the number of observations. The Ramsey RESET test for robustness showed 0.1721 > 0.05. For the pooled OLS analysis, no variables had a significant impact on public spending. The variable GHG was dropped due to multicollinearity. For the REM model, no variable had a significant impact on public spending. The results were identical for the FEM model. For the PCSE model, no variable was significant. In the GMM model, the only variable that has a moderate significant impact on AGR_SUB was GMM.

Table 7 represents the pooled OLS, REM, and FEM analysis of the statistical significance that the variables GDP, inflation, debt-to-GDP, government support in agricultural research and development, greenhouse gases from the agricultural sector, labor in the agricultural sector, temperature, government expenditures, and rain have on public spending, while Table 8 represents the PCSE and GMM analysis of the variables.

Table 4. Correlation matrix: EU27.

	AGR_SUB	GOVE	GDP	INF	DTG	GHG	LAB	TEMP	RAIN	GSARD
AGR_SUB	1.0000									
GOVE	0.1086 ***	1.0000								
GDP	0.0290 *	−0.5058 ***	1.0000							
INF	0.0513 *	−0.2208 ***	0.1620 ***	1.0000						
DTG	0.0478 *	0.5136 ***	−0.3363 ***	−0.2743 ***	1.0000					
GHG	−0.0165 *	−0.1372 ***	0.1112 **	−0.1267 **	−0.0812 *	1.0000				
LAB	0.0521 *	−0.0663 *	0.0308 *	0.3798 ***	0.0834 **	−0.0016 *	1.0000			
TEMP	0.0657 *	−0.1041 ***	−0.0665 *	−0.0476 *	0.4418 ***	−0.3069 ***	0.0843 **	1.0000		
RAIN	−0.1365 ***	0.1556 ***	−0.0549 *	−0.1095 ***	0.0749 *	0.2392 ***	−0.1851 ***	−0.1485 ***	1.0000	
GSARD	−0.0486 *	0.1718 ***	−0.1212 ***	−0.1116 ***	0.2190 ***	−0.0476 *	0.2957 ***	0.0562 *	−0.0847 *	1.0000

Note: ***, ** and * denote $p < 0.01$, $p < 0.05$, $p < 0.1$. Source: processed by authors.

Table 5. Correlation matrix: southern EU.

	AGR_SUB	GOVE	GDP	INF	DTG	GHG	LAB	TEMP	RAIN	GSARD
AGR_SUB	1.0000									
GOVE	−0.3157 ***	1.0000								
GDP	0.1158 *	−0.6222 ***	1.0000							
INF	0.1622 *	−0.2144 ***	0.2602 ***	1.0000						
DTG	−0.0897 *	0.5153 ***	−0.4216 ***	−0.5111 ***	1.0000					
GHG	0.3998 ***	0.3764 ***	−0.3108 ***	−0.2336 **	0.1435 *	1.0000				
LAB	0.6091 ***	0.0976 *	−0.1594 *	−0.0328 *	0.3475 ***	0.1295 *	1.0000			
TEMP	−0.1286 *	−0.4411 ***	0.1191 *	−0.1786 **	0.1443 *	−0.6833 ***	−0.1757 **	1.0000		
RAIN	−0.2189 **	0.3542 ***	−0.0605 *	0.0562 *	−0.2440 **	0.4827 ***	−0.2570 ***	−0.7640 ***	1.0000	
GSARD	0.5456 ***	−0.1107 *	−0.0901 *	0.0363 *	0.0178 *	0.1860 *	0.8427 ***	−0.1041 *	0.2926 ***	1.0000

Note: ***, ** and * denote $p < 0.01$, $p < 0.05$, $p < 0.1$. Source: processed by authors.

Table 6. Correlation matrix: northern EU.

	AGR_SUB	GOVE	GDP	INF	DTG	GHG	LAB	TEMP	RAIN	GSARD
AGR_SUB	1.0000									
GOVE	0.3665 ***	1.0000								
GDP	−0.0590 *	−0.5019 ***	1.0000							
INF	−0.0524 *	−0.2710 ***	0.1157 *	1.0000						

Table 6. *Cont.*

	AGR_SUB	GOVE	GDP	INF	DTG	GHG	LAB	TEMP	RAIN	GSARD
DTG	0.1728 **	0.3715 ***	−0.1612 **	−0.4514 ***	1.0000					
GHG	−0.2459 **	−0.3846 ***	0.2295 **	−0.3701 ***	0.6077 ***	1.0000				
LAB	−0.1179 *	−0.4770 ***	0.2810 ***	0.0094 *	0.2750 ***	0.7871 ***	1.0000			
TEMP	−0.1518 *	−0.4463 ***	0.1257 *	0.0368 *	−0.0106 *	0.7499 ***	0.3389 ***	1.0000		
RAIN	−0.0939 *	−0.3441 ***	0.1336 *	−0.0703 *	0.3749 *	0.7556 ***	0.4691 ***	0.5817 ***	1.0000	
GSARD	0.1620 *	0.4303 ***	−0.0220 *	−0.3632 *	0.5799 *	0.3501 ***	0.1382 *	0.0131 *	0.4177 ***	1.0000

Note: ***, ** and * denote $p < 0.01$, $p < 0.05$, $p < 0.1$. Source: processed by authors.

Table 7. *p*-values showing the statistical significance of the considered variables, pooled OLS, REM, and FEM.

Dependent Variable AGR_SUB									
Independent Variable	**Pooled OLS**			**REM**			**FEM**		
	EU27	**Southern EU**	**Northern EU**	**EU 27**	**Southern EU**	**Northern EU**	**EU27**	**Southern EU**	**Northern EU**
GOVE	0.543 *** (0.187)	−0.0018 * (0.0087)	0.0262 * (0.0155)	0.1443 * (0.1920)	−0.0018 * (0.0087)	0.0262 * (0.0155)	0.1607 * 0.2047	−0.0107 * (0.0063)	0.0038 * (0.018)
GDP	0.492 ** (0.245)	−0.0054 * (0.0073)	0.0215 * (0.0165)	0.2060 * (0.1673)	−0.0054 * (0.0073)	0.0215 * (0.016)	.2216 * 0.1725	−0.0060 * (0.0056)	0.0051 * (0.016)
INF	1.373 ** (0.682)	−0.0035 * (0.0169)	−0.0275 * (0.0330)	−0.5125 * (0.4429)	−0.0035 * (0.0169)	−0.0275 * (0.033)	−0.6094 * 0.4620	−0.0208 * (0.0131)	−0.0229 * (0.033)
DTG	−0.0289 * (0.0349)	−0.0003 * (0.0007)	−0.0039 * (0.005)	−0.0695 * (0.0487)	−0.0003 * (0.0007)	−0.0039 * (0.005)	−0.1276 ** (0.0635)	−0.0020 * (0.0015)	0.0011 * (0.005)
GHG	0.351 ** (0.171)	0.0445 *** (0.0106)	Dropped	0.4925 * (0.3423)	0.0445 *** (0.0106)	Dropped	1.145 * (0.6376)	0.0106 * (0.0307)	Dropped
LAB	0.0046 * (0.0026)	Dropped	0.0019 * (0.002)	−0.0020 * (0.0048)	Dropped	0.0019 * (0.002)	−0.0211 * (0.0118)	Dropped	0.0120 * (0.007)
TEMP	0.736 ** (0.3196)	0.0129 * (0.0158)	−0.0477 * (0.035)	0.7555 * (0.5900)	0.0129 * (0.0158)	−0.0477 * (0.035)	−0.1493 * (1.101)	−0.0594 * (0.0410)	0.03334 * (0.0111)
RAIN	−0.0101 ** (0.0045)	−0.0001 * (0.0001)	−0.0000 * (0.0005)	−0.0031 * (0.0048)	−0.0001 * (0.0001)	−0.0000 * (0.0005)	−0.0035 * (0.0053)	−0.0001 * (0.0001)	−0.0000 * (0.0008)
GSARD	−0.02555 *** (0.0095)	0.0010 *** (0.0001)	0.0013 * (0.002)	0.0025 * (13.75)	0.0010 *** (0.0001)	0.0013 * (0.002)	0.0006 * (0.0223)	0.0022 *** (0.0004)	0.0036 * (0.008)
_CONS	−25.42 ** (10.75)	−0.1533 * (0.6129)	−0.5097 * (0.911)	−9.0734 * (13.75)	−0.1533 * (0.6129)	−0.5097 * (0.911)	3.089 * (17.48)	1.667 ** (0.7252)	−1.21 * (1.86)
OBS	274	71	118	274	71	118	274	71	118
PROP	0.0047	0.0000	0.0572	0.4680	0.0000	0.0462	0.0934	0.0000	0.8836
R-SQUARED	0.0850	0.7156	0.1262	0.0014	0.8376	0.1262	0.0026	0.5798	0.0017
F- STATISTIC	2.72	19.50	1.97	8.67	309.56	15.74	1.68	8.04	0.46
Sargan test							0.002	0.969	0.000
Hansen test							0.380	1.000	1.000

Note: ***, ** and * denote $p < 0.01$, $p < 0.05$, $p < 0.1$. Source: processed by authors.

Tables 7 and 8 show that the variable that the highest impact on public spending proxied by agricultural subsidies is dependent on the country, and there are no variables consensually affect public spending.

Table 8. *p*-values showing the statistical significance of the considered variables, PCSE, and GMM. Dependent variable: AGR_SUB.

Independent Variables	**PCSE**	**FGLS**		**GMM**		
	EU 27	**Southern EU**	**Northern EU**	**EU 27**	**Southern EU**	**Northern EU**
GOVE	0.2836 ** (0.1221)	0.0003 * (0.0041)	0.0019 * (0.006)	3.145 *** (0.1520)	−0.2072 * (0.1128)	0 (omitted)
GDP	0.1523 * (0.1354)	0.0002 * (0.0027)	−0.0001 * (0.003)	1.614 *** (0.1659)	−0.1248 ** (0.0640)	0.2100 ** (0.108)
INF	0.5352 * (0.5826)	0.0031 * (0.0089)	−0.0015 * (0.005)	−1.663 *** (0.1647)	0.0489 * (0.0757)	0.3253 * (0.342)
DTG	−0.0125 * (0.0160)	0.0000 * (0.0006)	0.0001 * (0.002)	−0.4209 *** (0.1161)	0.0069 * (0.0105)	0.0305 * (0.038)
GHG	0.1826 ** (0.0835)	0.0287 *** (0.0106)	Dropped	−1.604 ** (0.7267)	0 (omitted)	0 (omitted)

Table 8. *Cont.*

Independent Variables	PCSE	FGLS		GMM		
	EU 27	Southern EU	Northern EU	EU 27	Southern EU	Northern EU
LAB	0.0031 * (0.0017)	Dropped	0.0014 * (0.000)	0.0284 *** (0.0083)	dropped	−0.0207 * (0.029)
TEMP	0.4334 ** (0.2059)	0.0071 * (0.0110)	−0.0124 * (0.018)	8.781 *** (0.7547)	0.4872 *** (0.1919)	0 (omitted)
RAIN	−0.0048 * (0.0031)	−0.0000 * (0.0000)	−0.0001 * (0.000)	0.0095 *** (0.0010)	0.0023 * (0.0018)	−0.0010 * (0.002)
GSARD	−0.0170 ** (0.0075)	0.0010 *** (0.0002)	0.0021 * (0.001)	0.1951 *** (0.0202)	0.0023 * (0.0017)	0.0030 * (0.021)
_CONS	−12.34 * (6.44)	−0.2172 * (0.3249)	0.881 * (0.369)	−212.2 *** (18.60)	0 (omitted)	0 (omitted)
OBS	274	71	118	271	71	118
PROP	0.5606	0.0000	0.0834	0.000	0.000	0.000
R-SQUARED	0.0341					
F- STATISTIC	7.74	38.74	13.94	3.04	344.20	29,988.72

Note: ***, ** and * denote $p < 0.01$, $p < 0.05$, $p < 0.1$. Source: processed by authors.

5. Discussion

The results of this study illustrate that greenhouse gasses emissions from the agricultural sector, debt-to-GDP, government support for agricultural research and development, temperature, and GDP are affected by public spending proxied by agricultural subsidies. The results also show that public spending is affected by different variables according to regions.

In all the EU, looking at the GMM model, it illustrates that all variables have a significant impact on public spending. Due to climate change, debt-to-GDP has a positive effect on public spending. This result is supported by a few research papers [25,29,31]. Therefore, the increase in public spending due to subsidies in agriculture will implicitly cause an imbalance in the public budget, increasing debt. The results show that the GDP has a positive effect on public spending. The conclusion supports the study conducted by Lepanen et al. [34] that shows that due to climate change and the increase in temperature, public spending will decrease, and public revenue will increase. Rain has a positive effect on public spending. The results are supportive of the study conducted by Yahaya et al. [32] that shows the adverse effect that precipitations have on budget balance, causing a budget deficit by exacerbating the imbalance between the spending and revenue portion of the budget. Inflation has a negative effect on public spending. The conclusion does not support the study conducted by Ezirim et al. [35] that illustrates the interdepended between public spending and inflation. This analysis states that the increase in inflation decreases public spending. Temperature has a positive effect on public spending. The results do not support the conclusion of Yahaya et al. [32] that analyzed the implications of rain and temperature on budget balance and concluded that only rain has a significant effect on budget balance. The positive effect between public spending and agricultural subsidies that are used as a proxy for public spending is also in accordance with the study conducted by Scown [9].

In the southern region of the EU, temperature has a positive impact on public spending. The results are supportive of the research conducted by Kahn et al. [31] that states that changes caused by difference in temperature have a detrimental effect on the GDP. The costs associated with the adaptation policies put in place to mitigate the detrimental effect of temperature variability increase public spending. The positive relation between greenhouse gases and public spending is in accordance with the study conducted by Balough [45] showing the adverse effect of agricultural subsidies on the environment by supporting contaminating agricultural practices; furthermore, the investment in research and development in the agricultural sector contributes to the reduction of greenhouse gasses. Governmental support investment in research and development has a positive impact on agricultural subsidies. The following results do not support the analysis conducted by Scown et al. [9]. Compared to this analysis, the authors' conclusion shows that subsidies do not stimulate investment and research development in the agricultural sector due to opportunity cost. Governmental support investment in research and development are considered pivotal in climate change adaptation policies and mitigating efforts. Another recent research by Zlati et al. [56] showed that inconsistencies in national policies and strategies in the field of natural disasters and climate changes' risk management are the main sources of vulnerabilities for Romanian agriculture, amplified by factors such as the low technology level, low resources for research and agricultural development, and limited access to diversified financial products.

In the northern region of the EU, no variables show any sign of significance. Due to the cold climate conditions, agriculture is not considered an important sector [9]. Because the conditions are unfavorable for crop growth, there is no need for public spending proxied by agricultural subsidies due to the lack of agriculture. Therefore, our study contributes to novelty by showing that in the northern region of EU, no variable has a significant impact on agricultural subsidies. The only variable that has a moderate impact on agricultural subsidies in GDP. Acknowledging the constraints inherent in the study, we underscore the limitations imposed by the availability of greenhouse gas data spanning 2009–2020, concerns of misrepresentation stemming from the Gaussian assumption in the Generalized Method of Moments (GMM) model, and the exigency of excluding certain variables due to multicollinearity. The temporal ambit of the study, encompassing two decades from 2000 to 2020, is acknowledged as a constraint, eliciting a recommendation for future research endeavors to explore an extended temporal framework or alternative econometric models. This would facilitate a more nuanced and comprehensive comprehension of the impact of climate change on public spending across EU countries.

6. Conclusions and Policy Implications

This study seeks to enhance the understanding of the intricate relationships between climate change, the agricultural sector, and public spending within the EU. Utilizing advanced econometric methods, including pooled Ordinary Least Squares (OLS) and the Generalized Method of Moments (GMM), the research introduces agriculture as a refined indicator, surpassing traditional climate change proxies. With a specific focus on the EU, the study investigates the differential impacts of climate change on agriculture, particularly in the southern and northern regions. By identifying the significant influence of agriculture on public spending, the research aims to offer nuanced insights for policymakers, emphasizing the importance of maintaining controlled inflation through adept fiscal and monetary policies in the face of climate-induced challenges.

Climate change stands as a paramount challenge of the era, imperiling not only the agricultural domain, weather patterns, and economic landscapes but the very existence. Investigating the ramifications of climate change on public spending through evidence drawn from the agricultural sector, existing research centers are needed for underdeveloped nations like Nigeria, Mexico, Ethiopia, Ghana, Uganda, and Tanzania. Notably, there is a conspicuous dearth of studies examining developed countries in this context.

The principal findings of the study underscore that inflation significantly shapes public spending across the European Union, impacting both its northern and southern regions. The influence of agriculture on public spending is most pronounced in regions where it holds substantial sway over the GDP, as evident in the southern countries of the EU. Conversely, in areas where agriculture assumes a secondary role, such as the northern part, there is no variable that holds a substantial impact on public spending.

The southern EU confronts more severe conditions compared to its northern counterpart. Increasing droughts in the south jeopardize soil fertility and quality, leading to harsh agricultural conditions and desertification. Meanwhile, the northern EU anticipates an expanding role for the agricultural sector. Migration is an inevitable consequence in such circumstances, posing a potential future challenge.

From a policy perspective, the recommendations advocate for governments to deploy fiscal measures to regulate inflation, implicitly controlling public spending. An effective strategy involves crafting monetary and fiscal policies focused on inflation reduction. Monetary policies could entail increasing interest rates to curtail the money supply and diminish demand, consequently lowering inflation. Additionally, enhancing each country's production efficiency could exert downward pressure on prices, implicitly reducing inflation. Fiscal tools, such as raising tax rates and implementing price caps for goods and wages, can further mitigate inflation by curbing demand and spending.

The study's implications for policy are significant, emphasizing the need for a comprehensive approach to address the economic repercussions of climate change on public spending in the EU's agricultural sector. Policymakers must implement measures to control inflation through apt monetary policies, fortifying public spending and price stability. Targeted support for the agricultural sector, especially in regions pivotal to GDP, demands a focus on sustainable practices and climate resilience. Investments in irrigation systems and the encouragement of crop diversification are imperative to counter the adverse impacts on agriculture and public spending. Striking a balance between public spending and budget revenues, along with fostering fiscal discipline, remains crucial. Policymakers must adopt a long-term perspective, accounting for regional disparities and potential migration challenges, ensuring sustainable development, and effectively addressing climate changes' impact on public spending. Furthermore, policymakers must address the unique needs and vulnerabilities of small countries grappling with climate change. A tailored policy framework, recognizing limited resources and capacity constraints, is essential. Equitable resource distribution requires increased funding and support for poorer countries compared to their wealthier counterparts. By prioritizing assistance to vulnerable nations and promoting inclusive, sustainable development, policymakers can foster resilience, reduce inequality, and formulate a more balanced and equitable response to climate changes' impacts across diverse countries and regions. The European Union also should reconsider the financial mechanisms of CAP and the usage of it. From previous research, it is noticeable that CAP has an adverse impact on economic growth and environmental sustainability and contributes to income and gender inequality. Also, monitoring controls and policies are encouraged to be implemented to provide insightful information regarding the efficiency of the program. Governmental efforts should also focus on providing more assistance with investment in research and development within the agricultural sector, instead of subsidies, due to the beneficial effects of it.

Building on the insights garnered from this study, avenues for further research beckon. Future investigations could delve deeper into the intricate mechanisms through which fiscal policies influence public spending in the context of climate change. A comparative analysis across developed and underdeveloped countries within the EU could illuminate how economic structures and climate vulnerability shape the relationship between climate change, public spending, and policy effectiveness. The refinement of methodological approaches, considering data availability and the use of econometric models, is vital. This may involve extending the analysis's timeframe or exploring alternative econometric models for enhanced robustness. A dedicated exploration of tailored policy frameworks for small countries, considering their unique challenges, could significantly contribute. Longitudinal studies tracking the implementation and impact of climate change adaptation policies in the agricultural sector would provide valuable insights into the long-term effectiveness of these measures, assessing the success of adaptive strategies over time.

Author Contributions: Conceptualization, G.D.; methodology, I.-C.N. and A.E.-N.; software, I.-C.N. and A.E.-N.; validation, G.D., I.-C.N. and A. E-N.; formal analysis, G.D. and I.-C.N.; investigation, I.-C.N.; resources, I.-C.N. and A.E.-N.; data curation, A.E.-N.; writing—original draft preparation, I.-C.N. and A.E.-N.; writing—review and editing, G.D. and I.-C.N.; visualization, G.D.; supervision,

G.D.; project administration, G.D. and I.-C.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data used in the research article can be provided by authors on request.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

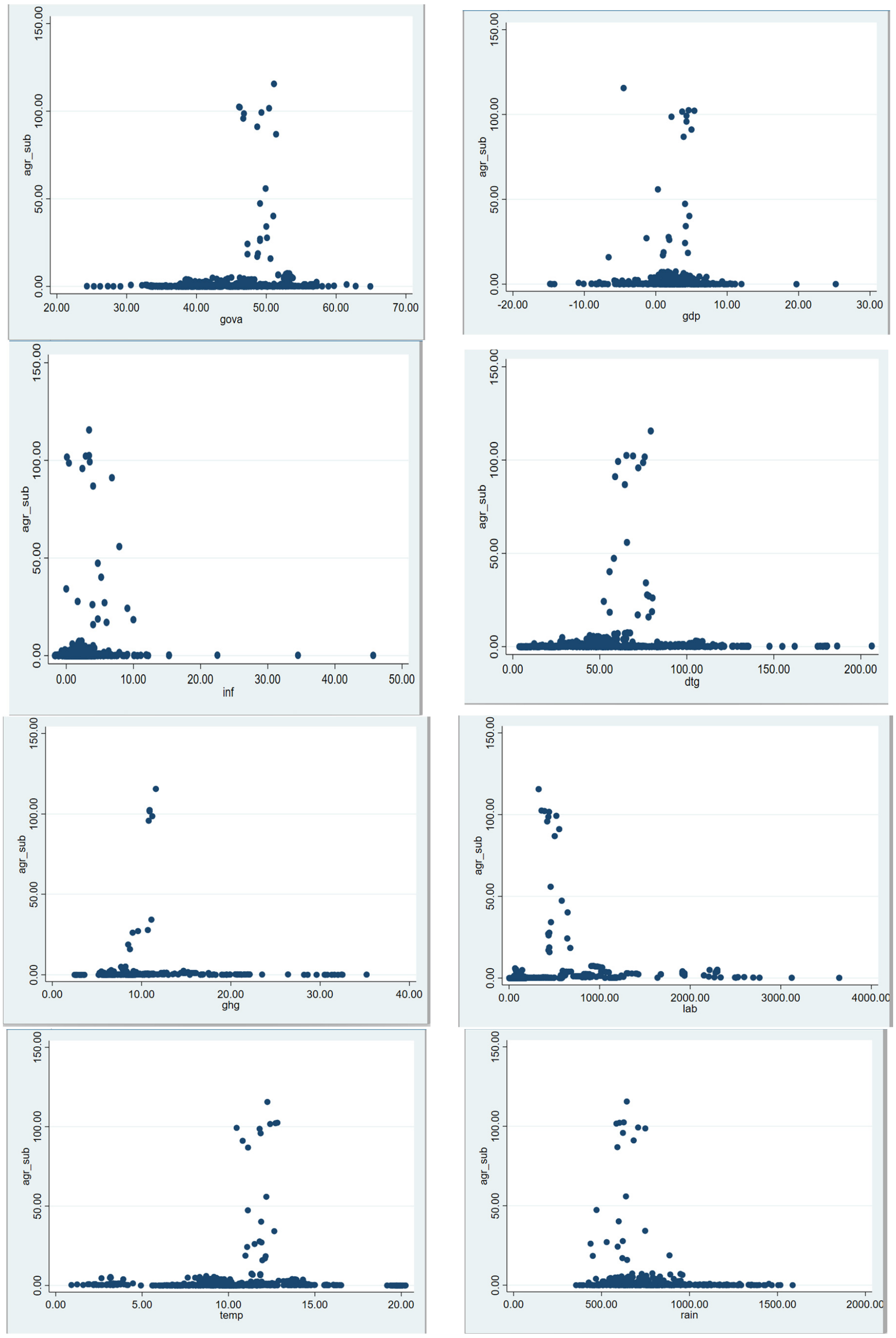

Figure A1. *Cont*.

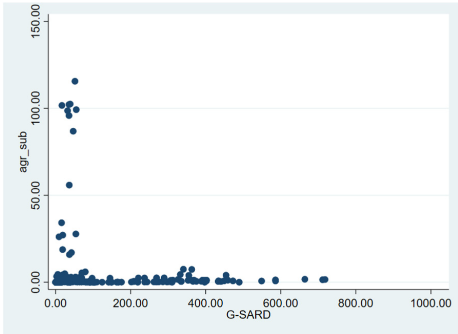

Figure A1. Scatter plot of AGR_SUB and each variable; all EU.

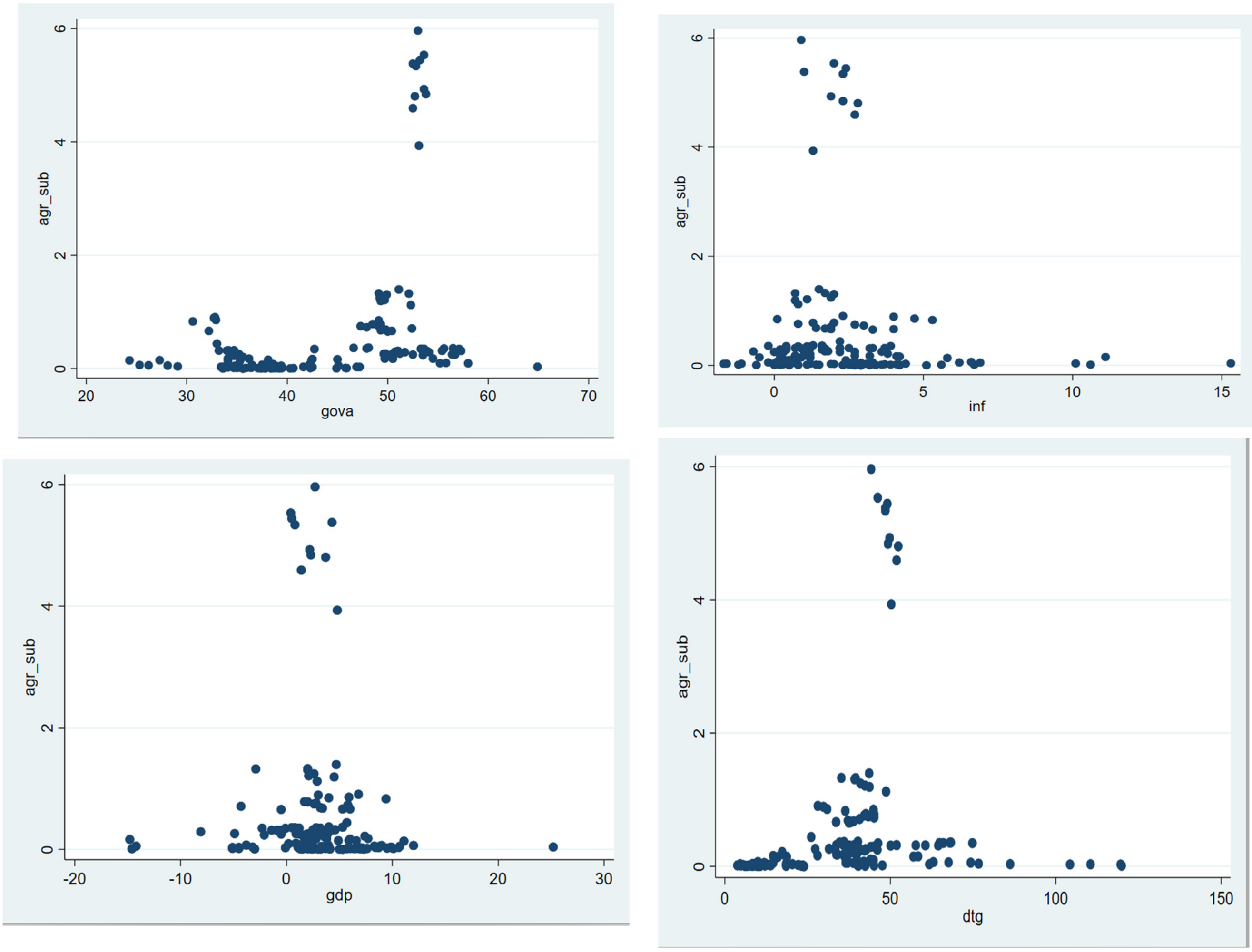

Figure A2. *Cont*.

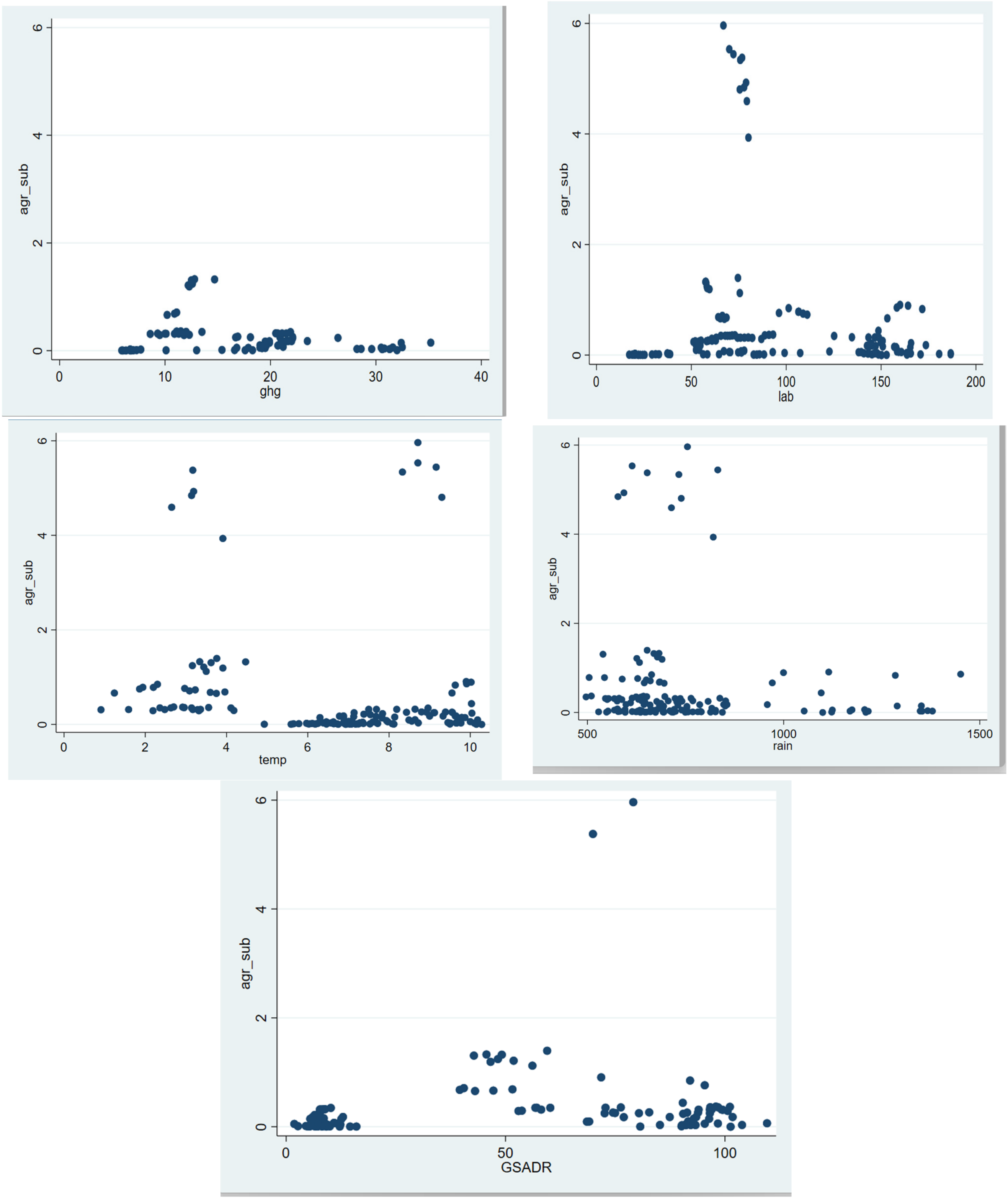

Figure A2. Scatter plot of AGR_SUB and each variable; northern EU.

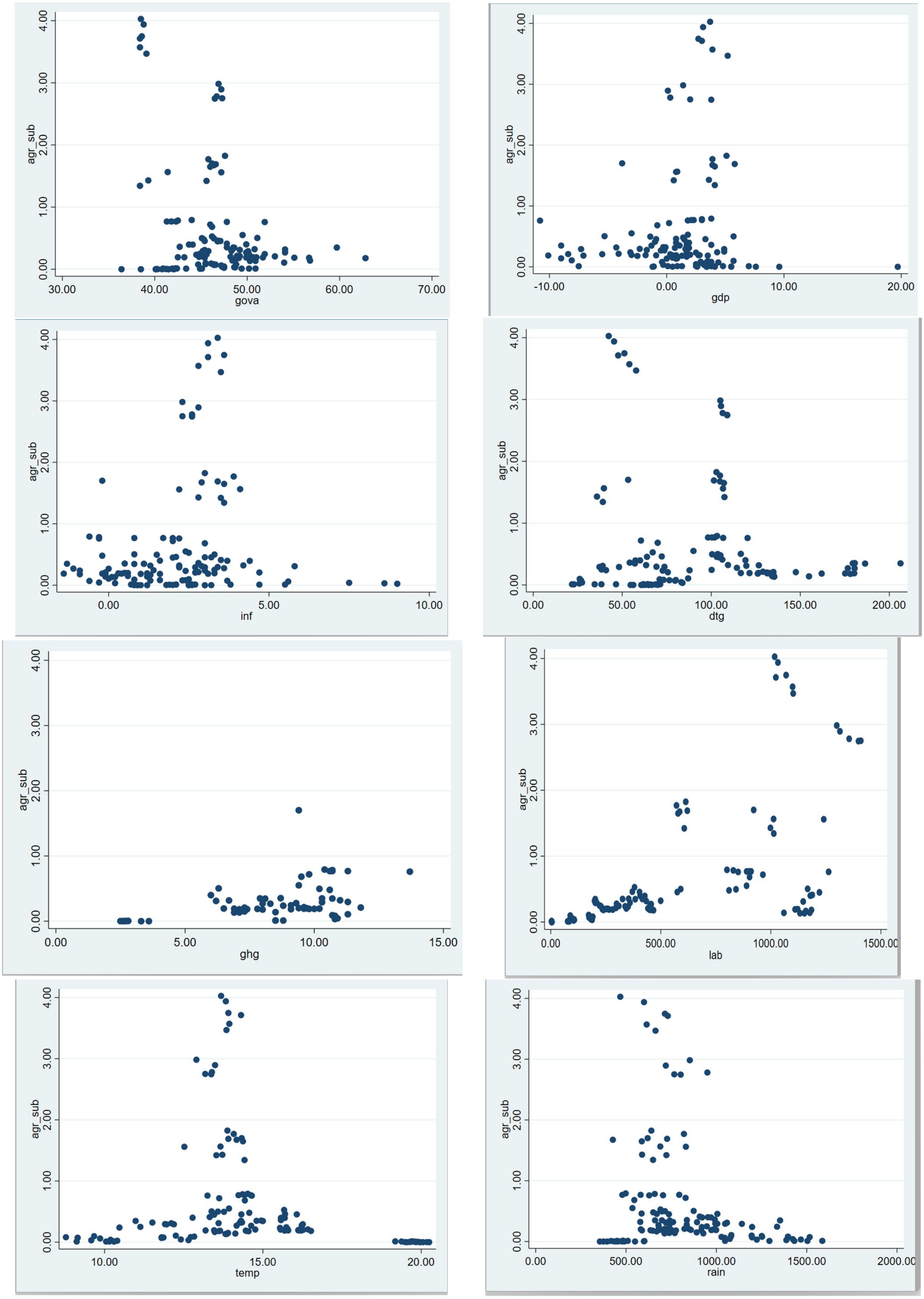

Figure A3. *Cont.*

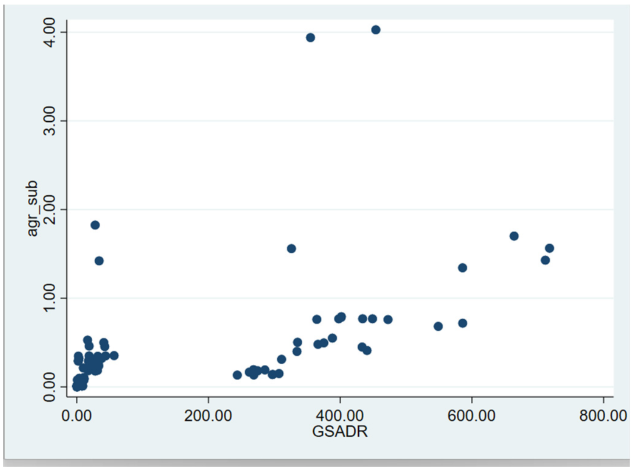

Figure A3. Scatter plot of AGR_SUB and each variable; southern EU.

References

1. National Aeronautics and Space Administration. Weather, Global Warming and Climate Change. Available online: https://climate.nasa.gov/global-warming-vs-climate-change/ (accessed on 15 October 2022).
2. Congressional Budget Office. Budgetary Effects of Climate Change and of Potential Legislative Responses to It. Available online: https://www.cbo.gov/publication/57175#_idTextAnchor003 (accessed on 10 November 2022).
3. United Nations. The Paris Agreement United Nations. Available online: https://www.un.org/en/climatechange/paris-agreement#:~:text=Today,%20193%20Parties%20(192%20countries,strengthen%20their%20commitments%20over%20time (accessed on 9 November 2022).
4. IPCC. AR6 Climate Change: The Physical Science Basis. The Working Group I Contribution to the Sixth Assessment Report, Intergovernmental Panel on Climate Change. Available online: https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/ (accessed on 22 November 2022).
5. NCEI. Assessing the Global Climate. Available online: https://www.ncei.noaa.gov/news/global-climate-202112 (accessed on 22 November 2022).
6. OECD. Climate Change and Long-Term Fiscal Sustainability. Available online: https://www.oecd.org/gov/budgeting/scoping-paper-on-fiscal-sustainability-and-climate-change.pdf (accessed on 20 October 2022).
7. United Nations Office for Disaster Risk Reduction. Available online: https://www.preventionweb.net/publication/climate-change-impacts-eu-new-evidence-recent-research (accessed on 21 October 2022).
8. Agovino, M.; Casaccia, M.; Ciommi, M.; Ferrara, M.; Marchesano, K. *Agriculture, Climate Change and Sustainability: The Case of EU-28*; Elsevier: Amsterdam, The Netherlands, 2019; Volume 105, pp. 525–543.
9. Scown, M.W.; Brady, M.V.; Nicholas, K.A. Billions in misspent EU agricultural subsidies could support the Sustainable Development Goals. *One Earth* **2020**, *3*, 237–250. [CrossRef] [PubMed]
10. European Commission. Agricultural and Rural Development. The Common Agricultural Policy at a Glance. Available online: https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-glance_en (accessed on 1 November 2022).
11. European Court of Auditors. Special Report—Climate Spending in the 2014–2020 EU Budget. Available online: https://www.eca.europa.eu/Lists/ECADocuments/SR22_09/SR_Climate-mainstreaming_EN.pdf (accessed on 22 November 2022).
12. European Commission. Performance of the Agricultural Sector. Performance of Agricultural Sector—Products Eurostat News—Eurostat. Available online: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20210413-2 (accessed on 10 December 2022).
13. Osberghaus, D.; Reif, C. Total Costs and Budgetary Effects of Adaptation to Climate Change: An Assessment for the European Union. In *ZEW—Centre for European Economic Research Discussion Paper*; No. 10-046. 2010. Available online: https://ssrn.com/abstract=1649452 (accessed on 1 November 2022). [CrossRef]
14. Aaheim, A.; Amundsen, H.; Dokken., T.; Wei, T. Impacts, and adaptation to climate change in European economics. *Glob. Environ. Chang.* **2012**, *22*, 959–968. [CrossRef]
15. European Commission. Climate Impacts in Europe—The JRC PESETA II Project. Available online: https://data.europa.eu/doi/10.2791/7409 (accessed on 13 December 2022).
16. European Commission. Drought in Europe August. Available online: https://edo.jrc.ec.europa.eu/documents/news/GDO-EDODroughtNews202208_Europe.pdf (accessed on 15 December 2022).
17. Lixăndroiu, R.; Lupșa-Tătaru, D. Switzerland? The Best Choice for Accommodation in Europe for Skiing in the 2023 Season. *Sustainability* **2023**, *15*, 4032. [CrossRef]
18. Yadav, D.; Gupta, A.; Gupta, P.; Ranjan, S.; Gupta, V.; Badhai, S. Effects of Climate Change on Agriculture. Available online: https://www.researchgate.net/publication/344064949_Effects_of_Climate_Change_on_Agriculture (accessed on 1 December 2022).

19. Sarwary, M.; Samiappan, S.; Khan, G.D.; Moahid, M. Climate Change and Cereal Crops Productivity in Afghanistan: Evidence Based on Panel Regression Model. *Sustainability* **2023**, *15*, 10963. [CrossRef]
20. Lis, E.M.; Nickel, C. The impact of extreme weather events on budget balances. *Int. Tax Public Financ. J.* **2010**, *17*, 378–399. [CrossRef]
21. Parker, M. The impact of disasters on inflation. *Econ. Disasters Clim. Chang. J.* **2017**, *2*, 21–48. [CrossRef]
22. Boneva, L.; Ferrucci, G. *Inflation and Climate Change: The Role of Climate Variables in Inflation Forecasting and Macro Modelling*; Inspire; LSE: London, UK, 2022.
23. Batten, S.; Sowerbutts, R.; Tanaka, M. Climate change: Macroeconomic impact and implications for monetary policy. In *Ecological, Societal, and Technological Risks and the Financial Sector*; Springer: Berlin/Heidelberg, Germany, 2020; pp. 13–38.
24. Cantelmo, A.; Melina, G.; Papageorgiou, C. Macroeconomic outcomes in disaster-prone countries. *J. Dev. Econ.* **2023**, *161*, 103037. [CrossRef]
25. Parrado, R.; Bosello, F.; Delpiazzo, E.; Hinkel, J.; Lincke, D.; Brown, S. Fiscal effects, and the potential implications on economic growth of sea-level rise impacts and coastal zone protection. *Clim. Chang.* **2020**, *160*, 283–302. [CrossRef]
26. Cannone, E. The Role of Climate Change on Inflation Forecasting Using Time Varying Parameters Model. Master's Thesis, Luiss Guido Carli University, Roma, Italy, 26 January 2023.
27. Bachner, G.; Bednar-Friedl, B. The effects of Climate change impacts on public budget and implications of fiscal counterbalancing instruments. *Environ. Model. Assess.* **2019**, *24*, 121–142. [CrossRef]
28. Gilmore, E.; St. Clair, T. Budgeting for climate change: Obstacles and opportunities at the US state level. *Clim. Policy* **2018**, *18*, 729–741. [CrossRef]
29. Giovanis, E.; Ozdamar, O. The impact of climate change on budget balances and debt in the Middle East and North Africa (MENA) region. *Clim. Chang. J.* **2020**, *172*, 34. [CrossRef] [PubMed]
30. Nawaz, A.; Siddique, H.M.A.; Majeed, M.T. The Impact of Climate Change on Economic Growth: A Panel Data Analysis. *Bull. Energy Econ.* **2016**, *4*, 359–365.
31. Kahn, M.E.; Mohaddes, K.; Ng, R.N.; Pesaran, M.H.; Raissi, M.; Yang, J.C. Long-term macroeconomic effects of climate change: A cross-country analysis. *Energy Econ.* **2021**, *104*, 105624. [CrossRef]
32. Yahaya, B.; Nkwatoh, L.S.; Jajere, B.A. Impact of Climate Change on Budget Balance: Implications for Fiscal Policy in the ECOWAS Region. *Int. J. Econ. Financ.* **2021**, *13*, 1–25. [CrossRef]
33. Abbas, A.C.; Jiang, Y.; Rehman, A.; Rauf, A. Short and long-run impacts of climate change on agriculture: Empirical evidence from China. *Int. J. Clim. Strateg. Manag.* **2020**, *12*, 201–221.
34. Leppänen, S.; Solanko, L.; Kosanen, R. The impact of climate change on regional government expenditure: Evidence from Russia. *Environ. Resour. Econ.* **2017**, *67*, 67–92. [CrossRef]
35. Ezirim, C.; Muoghalu, M.; Elike, U. Inflation versus public expenditure growth in the U.S.: An empirical investigation. *N. Am. J. Financ. Bank. Res.* **2010**, *2*, 26–40. Available online: https://ssrn.com/abstract=1536656 (accessed on 10 November 2022).
36. George-Anokwuru, C.C.; Ekpenyong, B.I. Government expenditure and inflation in Nigeria. *J. Econ. Manag. Sci.* **2020**, *3*, 29. [CrossRef]
37. Adediran, I.A.; Isah, K.O.; Ogbonna, A.E.; Badmus, S.K. A Global Analysis of the Macroeconomic Effects of Climate Change. *Asian Econ. Lett.* **2023**, *4*. [CrossRef]
38. Odongo, M.T.; Misati, R.N.; Kamau, A.W.; Kisingu, K.N. Climate Change and Inflation in Eastern and Southern Africa. *Sustainability* **2022**, *14*, 14764. [CrossRef]
39. Kunawotor, M.E.; Bokpin, G.A.; Asuming, P.O.; Amoateng, K.A. The impacts of extreme weather events on inflation and the implications for Monetary Policy in Africa. *Prog. Dev. Stud.* **2022**, *22*, 130–148. [CrossRef]
40. Nugroho, A.; Feher, I.; Fekete-Farkas, M.; Lakner, Z. How to improve agricultural value-added in the MENA region? Implementation of Diamond Porter's theory in agriculture. *Front. Sustain. Food Syst.* **2022**, *6*, 956701. [CrossRef]
41. Gautam, M. Agricultural Subsidies: Resurging Interest in a Perennial Debate. *Indian J. Agric. Econ.* **2015**, *70*, 83–105.
42. Zafar, S.; Tarique, M. Efficacy of public spending for agricultural development in India: A disaggregate analysis contextualizing subsidies vs. investment debate. *Int. J. Soc. Econ.* **2023**, *50*, 925–940. [CrossRef]
43. Baig, I.A.; Irfan, M.; Salam, M. Addressing the effect of meteorological factors and agricultural subsidy on agricultural productivity in India: A roadmap toward environmental sustainability. *Environ. Sci. Pollut. Res.* **2023**, *30*, 15881–15898. [CrossRef] [PubMed]
44. Damania, R.; Balseca, E.; Fontaubert, C.; Gill, J.; Rentschler, J.; Russ, J.; Zaveri, E. *Detox Development: Repurposing Environmentally Harmful Subsidies*; World Bank Publications: Washington, DC, USA, 2023.
45. Balough, J.M. The impacts of agricultural subsidies of Common Agricultural Policy on agricultural emissions: The case of the European Union. *Agric. Econ.* **2023**, *4*, 140–150.
46. Gao, X.; Ji, L.; Chandio, A.A.; Gul, A.; Ankrah Twumasi, M.; Ahmad, F. Towards Sustainable Agriculture in China: Assessing the Robust Role of Green Public Investment. *Sustainability* **2022**, *14*, 3613. [CrossRef]
47. Popp, D. R&D Subsidies and Climate Policy: Is there a "Free Lunch?". *Clim. Chang.* **2006**, *77*, 311–341.
48. Pardley, P.G.; Chan-Kang, C.; Dehmer, S.; Beddow, J.M.; Hurley, T.M.; Rao, X.; Alston, J.M. *Investments in and the Economic Returns to Agricultural and Food R&D Worldwide*; Elsevier: Amsterdam, The Netherlands, 2014.
49. Stoian, M.; Ion, R.A.; Turcea, V.C.; Nica, I.C.; Zemeleaga, C.G. The Influence of Governmental Agricultural R&D Expenditure on Farmers' Income—Disparities between EU Member States. *Sustainability* **2022**, *14*, 10596. [CrossRef]

50. Database—Eurostat. Available online: https://ec.europa.eu/eurostat/data/database (accessed on 15 December 2022).
51. The World Bank. Databank. Available online: https://databank.worldbank.org/metadataglossary/world-development-indicators/series/GC.NLD.TOTL.GD.ZS (accessed on 25 November 2022).
52. World Bank Climate Change Knowledge Portal. Home. Available online: https://climateknowledgeportal.worldbank.org/ (accessed on 23 December 2022).
53. Ortiz-Ospina, E.; Roser, M. Government Spending. Our World in Data. Available online: https://ourworldindata.org/government-spending?fbclid=IwAR1AbgbCrF2wlfYZPJYFQHjSab3ougHy19Bzts4QuEWitKjs4oIi0n6ChWc (accessed on 30 November 2022).
54. Wooldridge, J.M. *Econometric Analysis of Cross Section and Panel Data*; MIT: Cambridge, UK, 2002.
55. Arellano, M.; Bond, S. Dynamic Panel Estimation Using DPD98 for GAUSS: A Guide for Users. Working Paper, Institute for Fiscal Studies. Available online: http://www.cemfi.es/~arellano/#dpd (accessed on 23 November 2022).
56. Zlati, M.L.; Florea, A.M.; Antohi, V.M.; Dinca, M.S.; Bercu, F.; Fortea, C.; Silvius, S. Financing Romanian Agricultural Cooperatives' Investments for the 2023–2027 Horizon. *Sustainability* **2023**, *15*, 2306. [CrossRef]