Accounting for externalities in cross-sectional economic models of climate change impacts

Michele Moretti [1, *]; Janka Vanschoenwinkel [2]; Steven Van Passel [1]

[1] *Department Engineering Management, University of Antwerp, Prinsstraat 13, Antwerp, Belgium*
[2] *VITO NV, Boeretang 200, Mol, Belgium*

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*Corresponding author: Dr. Michele Moretti, Prinsstraat 13, 2000 Antwerp, Belgium, michele.moretti@uantwerpen.be

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Abstract

Environmental effects and natural resources depletion associated with agriculture production affect the agriculture response to climate change. Traditional cross-sectional climate response models ignore this requirement. This research estimates the impact of climate on European agriculture using a continental scale Ricardian analysis. We correct farm income by accounting for resources (energy, fertilizers, pesticides and water) use intensity by calculating the sustainable value for a sample of 9,497 specialized field crop farms across Europe. The results show that a uniform increase in temperature (+1°C) across all four seasons lead to significant and negative effects on farmland values, net revenue and farms' sustainable value, while additional precipitation (+1 cm) across the all seasons increases farms' land values and sustainable values, and harms farms' net revenue. Compared with the traditional Ricardian method, the marginal effect of 1° C increase in temperature shift from positive to negative in Northern countries, while it leads to less damages in Southern countries when net revenue and farms' sustainable values are used as dependent variables. We demonstrate that accounting for the environmental effects and depletion of natural capital by agriculture significantly improves the ability of the Ricardian method to estimate agriculture climate response functions in the long run.

Keywords: Ricardian analysis, Sustainable value, Climate change, Cross-sectional models, Resources depletion

JEL code: General Q10, Micro Analysis of Farm Firms, Farm Households, and Farm Input Markets Q12, Climate; Natural Disasters and Their Management; Global Warming Q54, Environment and Development; Environment and Trade; Sustainability; Environmental Accounts and Accounting; Environmental Equity; Population Growth Q56,

1. Introduction

Cross-sectional Ricardian study have proved to be good and robust in predicting climate change impacts (Mendelsohn and Massetti, 2017). The Ricardian method implicitly accounts for climate change adaptation, by assuming that farmers in one location behave the same as farmers in a second location if that second location was subjected to the same exogenous conditions than the first one (Lippert et al., 2009; Timmins, 2006; Vanschoenwinkel et al., 2016). This implies that in its original form, the Ricardian method takes into account adaptation without revealing the exact nature of the farm adaptation choice (Seo and Mendelsohn, 2008). However, as showed by Vanschoenwinkel et al. (2016) regarding the instantaneous adaptation assumptions and Vanschoenwinkel et al. (2019) on the need to account for country's adaptive capacity, there are still rooms for improvements in the ability of the Ricardian model to estimate robust agriculture climate response functions. Moreover, the externalities (cultural heritage, land preservations, pollution, etc) associated with agriculture production such as pollution and resource depletion are not fully reflected in farmland values (Hrubovcak et al., 2000; Peeters et al., 2015).

To account for land market biases and neglected agriculture externalities in the Ricardian models, we measure the effects of the changing climate on sustainable farm value compared to the land value. The sustainable value is a relative measure where resources are used to produce value added (Van Passel, Nevens, Mathijs and Van Huylenbroeck, 2007). A low resource use (environmental and economic resources) compared with other farms with the same added value, results in a higher sustainable value. The sustainable value is intended as a proxy which corrects the farm income by accounting for the intermediate consumptions which have a detrimental effect on the environment (pollution and depletion of scarce resource) (Moretti et al., 2016). Correcting farm income by accounting for energy, fertilizers, pesticides and water use allows to correct for some of the externalities generated by farm production activities.

2. Materials and methods

Cross-sectional Ricardian analyses measure the sensitivity of comparable farm revenues to climate and other factors by using historical data about different farms that faced different climatic, soil conditions and socio-economic factors (Mendelsohn, Nordhaus and Shaw, 1994). The underlining assumption of the Ricardian method is that the competition for scarce land will drive farms revenues or rents to be equal to the productivity of farmland (Ricardo, 1817). This insight suggests the equivalence between farmland value and expected farm economic productivity in the long-run (Mendelsohn and Massetti, 2017). The Ricardian method regresses farmland value or net revenue on climate assuming each farmer to be a profit-maximising agents (Mendelsohn, Nordhaus and Shaw, 1994). The net revenue (NRi) of the farm can be described as follows (Mendelsohn and Dinar, 2003).

$$NR_i = \sum P_{q,i}\, Q_i\big(X_i, L_{i,}K_i, C, Z, G\big) - \sum P_x X_i - \sum P_L L_i - \sum P_k K_i \qquad (1)$$

where $P_{q,i}$ is the market price of each output i, Q_i is the quantity of each output i, X_i is a vector of purchased inputs for the output i, L_i is a vector of labour for the output i, K_i is the vector of capital, C is the vector of climate variables, Z is the vector of geo-biophysical factors (e.g., altitude, and soil characteristics), G is a vector of socio-economic variables (e.g., distance from markets, population density), P_x, P_L, and P_k are the vectors for prices of annual inputs, labour and capital respectively. The profit-maximization assumption implies that farmers choose the optimal amount of all the endogenous variables $(X_i, L_{i,}K_i)$ which are within their control. Farmers' choices are therefore only affected by market prices (P_x, P_L, and P_k) and other exogenous conditions (C, Z, G) outside their control (Van Passel, Massetti and Mendelsohn, 2017). Farmland value (Vi) is therefore equal to:

$$V_i = \int_t^{\infty} NR_t e^{-\varphi t} \, dt \quad (2)$$

where $-\varphi$ is the interest rate and V_i is therefore function of only the exogenous factors:

$$V_i = f(C, Z, G) \quad (3)$$

By assuming farmers profit-maximising behaviour, the Ricardian method accounts for all the human, agronomic and socio-economic mechanisms already happened because farmers had the time to optimise their choices (to adapt) to the climate in which they live (Mendelsohn, Arellano-Gonzales and Christensen, 2009). The method assumes that farmers in one location behave the same as farmers in a second location if that second location was subjected to the same exogenous conditions than the first one (Lippert, Krimly and Aurbacher, 2009, Timmins, 2006). This means that if there are sufficient farm details in the dataset, the economic model, which correspond to the idea of Hedonic Pricing of environmental attributes (Vanschoenwinkel, Mendelsohn and Van Passel, 2016), accounts for all the possible adaptation options adopted by the farmers represented in the dataset (Lippert, Krimly and Aurbacher, 2009). However, this means that the Ricardian method often ignores individual farm level conditions which might influence farmers' choices.

We used data on farmland value and net revenue per hectare (Vi and NRi) and the sustainable value indicator (SVi) from the FADN (Farm Accountancy Data Network) database (Fadn, 2014). The FADN consists of an annual survey collecting accountancy data from about 80.000 commercial agricultural holdings in the EU27 with the objective of collecting farm level data for evaluating the impacts of the Common Agricultural Policy (CAP). Farmland values are measured as the replacement value of agricultural land in owner occupation, while farm household net revenues are calculated from the sum of total output and balance of subsidies and taxes on current operations, deducting total intermediate consumption. Temperature and precipitation of each location (30 years average for the period 1981-2010) were used to describe the climate. Although Massetti, Mendelsohn and Chonabayashi (2016) show that the growing degree-days variable offers a compact alternative compared to seasonal variables, regressing farmland values (or SVi or NRi) on monthly or growing season climate data will have generated correlation issues (Vanschoenwinkel, Mendelsohn and Van Passel, 2016) Therefore, climate data were averaged into four seasons since agronomic and Ricardian studies acknowledged that seasonal temperature and precipitation have a significant impact on farm productivity (see Mendelsohn and Dinar (2009)). Moreover, in at the European continental scale, the use of growing degree-days variable as implemented by Vaitkeviciute, Chakir and Van Passel (2019) brought to the similar conclusions as founded by Van Passel, Massetti and Mendelsohn (2017) where seasonal climate variables were used. Linear and quadratic terms were introduced for both temperature and precipitation since previous studies demonstrated the non-linear relationship between climate and land values (Mendelsohn and Dinar, 2003, Mendelsohn, Nordhaus and Shaw, 1994). We therefore estimated the following model:

$$V_i = \alpha + \beta_T T + \gamma_T T^2 + \beta_P P + \gamma_P P^2 + \eta E_i + \xi D_i + \mu_i \quad (4)$$

where T and P were vectors reflecting seasonal temperature and precipitation; E was a set of exogenous variables; D was a set of country fixed effects; and μ was a random error term which was assumed not to be correlated with the climate variables. The quadratic specification implied that the marginal impact of temperature (or precipitation) on farmland values (or SVi or NRi), depends upon the level of temperature Ti (or precipitation Pi) registered in the specific farm location (Mendelsohn, Arellano-Gonzales and Christensen, 2009). Therefore, the temperature (or precipitation) coefficients should be interpreted by looking at the marginal effect of temperature for season i, which is calculated as follow:

$$ME_i = \frac{\delta V}{\delta T_i} = \beta_{T,i} + 2\gamma_{T,i} T_i \quad (5)$$

2.1. Data description

The FADN database provides farm-specific measures of approximately 80,000 farm holdings in the EU-27, which represent about 14 million farms, covering the total utilized agricultural area of about 216 million hectares. Within its field of observation, FADN provides data which are representative in terms of region, economic size and type of farming. Each Member State conducts the survey using uniform and consistent instruments, which is important in order to compare correctly different regions. Different farm types generate both economic outcomes by using different production technologies and diverse combination of human, financial and natural capitals. Moreover, previous studies have shown that different farm types respond differently to climate (Bozzola, Massetti, Mendelsohn and Capitanio, 2018, Chatzopoulos and Lippert, 2015, Van Passel, Massetti and Mendelsohn, 2017) In this analysis, we followed this literature and focused on specialized field crop agricultural holdings (General Type of Farming (TF8) = 1) according to the European classification of agricultural holdings typologies. Such classification provides an homogenous classification of the agricultural holdings by type of farming and economic size, which are determined based on the "standard output criterion"[1] (European Commission, 2008). Agricultural holdings are assigned to TF8 when the relative contribution of field crops (cereals, oilseeds, protein crops and other field crops) contribute for more than 2/3 to the total standard output of the holding (European Commission, 2009).

Average data form three years period (2011-2013) have been considered suitable to reduce the variability derived from yearly changes in management, land use, owned land, and farms' input/output. We have modified the FADN sample by selecting only the farms replicated for the three consecutive years (from 2011 to 2013). The sample of 10,445 specialised FC farms is designed to be representative of the underlying population of 517,118 farms across Europe (EU-27) and includes population weights for each farm (EC 2009). We removed greenhouses, farm with less than a hectare of owned land, inconsistent farms with irrigate land and no water purchases, farms with no fertilisers but crop protection use (and vice versa), farms with crop protection and fertilisers use but no energy costs, and outliers, leaving a final sample of 9,497 farms. The following farms are removed: 10 farms with less than one-hectare land in ownership, 52 farms under glass, 158 inconsistent farms and 728 outliers (e.g. farms with a high output with (nearly) no farmland, farms with low farmland with high level of assets or labour force). Besides the country levels, the FADN data set divides the European Union into a set of territorial units called NUTS2 (Nomenclature of Territorial Units for Statistics) regions. In our dataset, 212 out of 251 NUTS2 regions[2] are represented in the sample accounting for an average of 43 agricultural holdings sampled for each NUTS2 region.

The observed climate data for each NUTS2 region was derived from the Climatic Research Unit (CRU) CL 2.0 dataset (New, 2002). This study uses the 30-year normal period for temperature from 1981 to 2010. These long-run climate estimates are stable and representative for the recent average climate and encompass a range of climatic variations in the study region (Carter, La Rovere, Lorenzoni, Jordan and et al., 2001). Because of the high correlation between climate data of neighbouring months, monthly temperature and precipitation are aggregated into seasons (Mendelsohn, Dinar and Sanghi, 2001). Market condition are accounted for by controlling for distance from cities and ports and population density. We control also for soil type and elevation as these might influence land values. Farm socio-economic characteristics are also accounted for by controlling for farm subsidies and percentage of rented land. Finally, we include country-fixed effects to control for other country-

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[1] Standard value of gross production European Commission (2008). COMMISSION REGULATION (EC) No 1242/2008 of 8 December 2008 establishing a Community typology for agricultural holdings. In E. Commission (ed). Official Journal of the European Union..

[2] No specialised FC are sampled in 39 NUTS2 regions and 9 NUTS2 regions have been delated because they counted only one observation.

specific characteristics. Soil data come from the Harmonized World Soil Database, a partnership of Food and Agriculture Organization (FAO), the European Soil Bureau Network, and the Institute of Soil Science (Fao/Iiasa/Isric/Iss, 2009). Additional socioeconomic and geographic variables (population density, distance from urban areas, distance from ports, mean elevation, elevation range and GDP per capita) were obtained from EuroGeographics, Natural Earth Data, the World Port Index, ESRI and Eurostat, respectively (Esri, 2014, EuroGeographics, 2014, Eurostat, 2016, National Geospatial Inteligence Agency, 2014, Natural Earth, 2014). Table A1 in "Appendix A" provide a detailed description of all models' variables and sources.

2.2. Models specifications

In our analysis, we use an extensive sample of European specialized field crop farms. Firstly, we apply the Sustainable Value Approach method developed by Figge and Hahn (2005). In this study, the sustainable value (SV) is used as indicators to analyse farm's contribution to sustainability. Furthermore, three cross-sectional Ricardian models are constructed to analyse the effects of different farm performance metric on the long-term climate change impacts estimation.

As reported by Van Passel, Van Huylenbroeck, Lauwers and Mathijs (2009), the choice of the benchmark determined the explanatory power of the analysis. Since our goal is to understand how the resources are distributed among field crop farms across Europe, we adopt the financial economics (Ang and Van Passel, 2010). Among the several benchmarks forms could have been chosen, without affecting the firm's ranking (Moretti, De Boni, Roma, Fracchiolla and Van Passel, 2016, Van Passel, Nevens, Mathijs and Van Huylenbroeck, 2007), we use the minimum benchmark alternative. This benchmark is constructed by creating a 'virtual' worse performing farm which generates the lowest economic return using the maximum amount of each capital form. We use total revenue (TR) to illustrate the economic performance of each farm in the sample. Four resources categories are considered: (i) used land in ownership, (ii) capital assets (excluding land capital), (iii) labour, and (iv) natural resources. For each farm, the annual expenses for energy (electricity, heat, and machine fuels), fertilisers, crop protection materials (hereinafter simply pesticides) and water are deemed proxies for the natural resources used. Thus, the SV is expressed as function of used land, farm assets, labour, energy, fertilisers, pesticides and water:

$$SV_i \int (land\ used_i, farm\ assets_i, labor_i, energy_i, fertilizers_i, pesticides_i, water_i) \quad (6)$$

To account for farm size, we follow the approach of Van Passel, Van Huylenbroeck, Lauwers and Mathijs (2009) and calculate the Return to Cost Ratio (RTCi) according to Eq. (7).

$$RTC_i = \frac{TR_i}{(TR_i - SV_i)} \quad (7)$$

In the Ricardian analysis, we estimate the climate sensitivity of European field crop farms through OLS regression models applied to the entire sample. Three different models have been estimated using farmland value per hectare, net revenue per hectare, and the sustainable value per hectare as dependent variable in Eq.4. We correct for non-normality by taking the log transformation of the dependent variables as suggested by Massetti and Mendelsohn (2011) and Schlenker, Hanemann and Fischer (2006) for land values. Additionally, each farm is weighted using the total amount of owned agricultural land to control for heterogeneity (Vanschoenwinkel, Mendelsohn and Van Passel, 2016). The regressions also include country fixed effects to capture national influences that cannot be captured by the other control variables. The annual average marginal effect (ME) is derived from Eq.5 by summing up the average seasonal marginal effects. ME were presented by weighing the average results by the total amount of farmland that each sampled farm represents in its region (Figure 1).

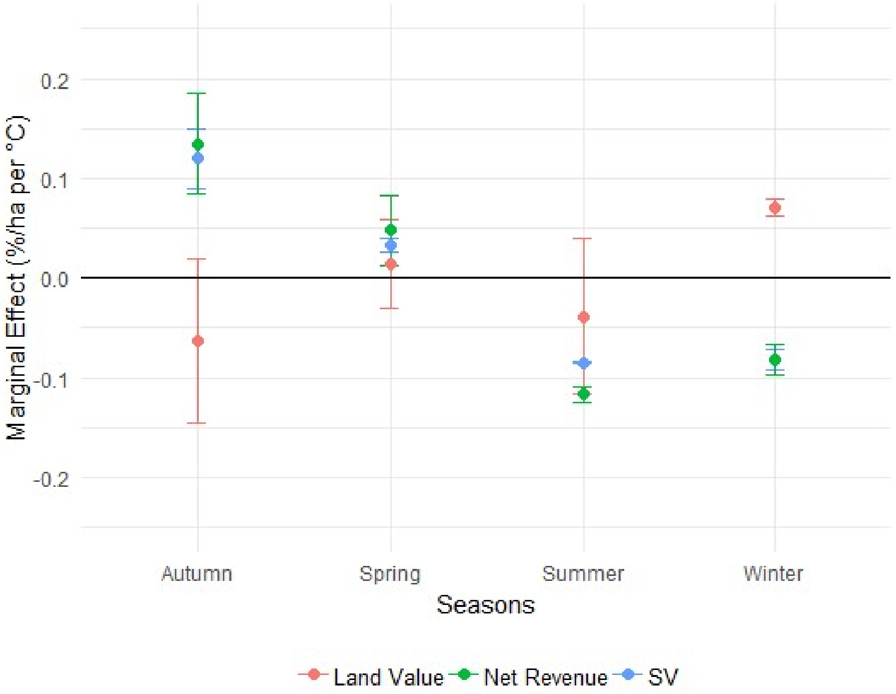
3. Results

This section presents the three regressions that have been modelled in this paper using land value, net revenue and the sustainable value as dependent variable. For simplicity, we will refer to these model as: the land value, the net revenue and the SV models, respectively. For all models, most of the control variables have the expected signs: higher population density, level of subsidies and elevation range have a positive impact on the values of all the dependent variables. Higher elevation is detrimental. Decreased accessibility, higher day-night temperature variance and increased slope might explain the negative effects of higher elevation. Overall, higher distances from markets have a positive impact on farmland value, farm net revenue and sustainable value. With respect to the share of rented land, it has a positive impact on farmland value, while it negatively affects farms' net revenue and sustainable value. It is common to assume that agricultural landowners are more willing to invest and improve their land value or to resort to rental markets to turns economically productive their un-used land. These conditions could explain the positive signs of the rented land coefficient for the farmland value. These results suggest that marginal lands are more often rented, which determine a decrease in the marginal output per unit of land used at the farm level. Therefore, decreasing the economic performances and sustainable value of farms which use more land to produce lower yield than expected. Furthermore, soil chemical and physical properties (pH and topsoil composition) significantly affect farmland values, net revenue and the sustainable value, suggesting these farm performance indicators are sensitive to the quality of farmed land.

In all three models, at least ten of the sixteen climate coefficients are statistically significant, revealing that climate has a significant impact on land value, net revenue and the sustainable value of field crop farms in Europe. Also, the squared coefficients are statistically significant, supporting the non-linearity assumption between climate and farmland value, net revenue and the sustainable value. Some of the squared terms are negative, implying that there is an optimal range of temperature and precipitation from which the value function decreases in both directions. Country fixed effects are generally significant in all three models, implying higher farmland values, net revenues and sustainable value for field crop farms in Belgium, Denmark and The Netherlands, while lower values for all three performance indicators are recorded in Latvia, Lithuania and Estonia compared to Austria (omitted variable). To interpret the climate coefficient estimates, we analyse the impact of marginal changes from current temperatures in line with the farmland, net revenue, and the sustainable value. The marginal effects of temperature (MEt) must be interpreted as the percentage change in one-hectare land value, unit of net revenue or sustainable value of a certain farm associated with a 1 °C increase in temperature. The OLS regressions of the entire sample of farms reveal that a uniform marginal increase of temperature across Europe decreases farmland values (-1.7%), net revenue (-1.6%) and farms' sustainability performance (-1.3%).

The marginal effects of +1 °C increase in temperature is significantly different for land value and the SV (and/or the net revenue) models only in winter and autumn, while the temperature increase in spring and summer does not result in significant differences among the models. A 1 °C increase in temperature during autumn decreases farmland value (-6.3%), while it increases net revenue (+13.4%) and farm sustainable value (+11.9%). Smaller differences can be observed in spring. Farmland value, net revenue and the farms' sustainable values all increase by +1.4%, +4.8%, and +3.3%, respectively, for a marginal increase in the temperature regime. Negative effects on all farms are disclose in summer, when higher temperature (+1°C) decreases farmland value (-3.8%), net revenue (-11.6%) and sustainable values (-8.4%). A marginal increase in winter temperature increases farmland value (+7.1%), while it has negative effects on both net revenue and farm sustainability performance (around -8%).

Figure 1: Marginal impact of temperature increase in percentage of land, net revenue and sustainable values



Van Passel, Massetti and Mendelsohn (2017) found similar outcomes for 1°C increase in spring and summer temperature, while their estimations disclose opposite directions for autumn and winter. However, the large variance of the MEt on farmland values in autumn suggests some EU regions benefit from a marginal increase in temperature (Figure 1). Moreover, the magnitude of the MEt estimated in this study are lower compared to previous estimations of climate impacts on crop farms in Western Europe (Van Passel, Massetti and Mendelsohn, 2017). It must be noted that Eastern European countries are included in our sample. As demonstrated by Vanschoenwinkel, Mendelsohn and Van Passel (2016), these countries (especially the northern ones) are penalised by the use of a 'single' climate response model for both Western and Eastern European countries.

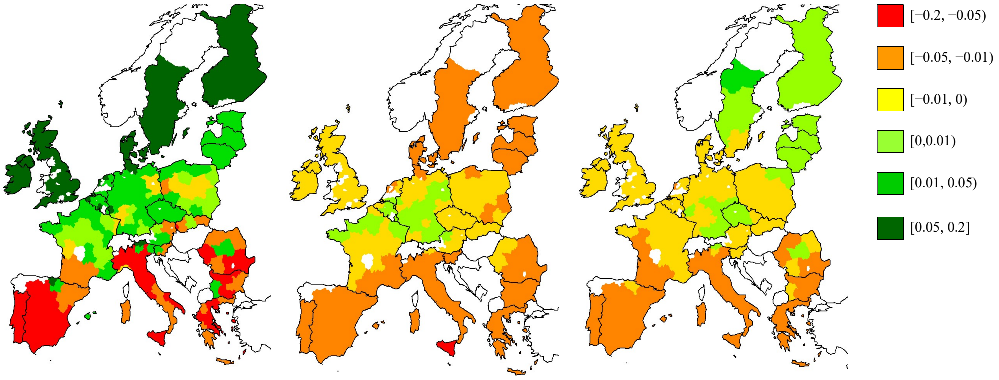
The marginal effects of temperature differ a great deal across the EU-25 member counties because each country has a different initial climate regime. Figure 2 visualises the marginal effect of temperature for the land value (Figure 2A), the net revenue (Figure 2B) and the sustainable value (Figure 2C) models for each NUTS2 region. With respect to land values, North European countries benefit from a marginal increase in temperature no matter their longitude (MEt around +10%). While Southern countries both in West and Eastern Europe are damaged by a 1 °C increase in temperature (MEt around -15%). In Western Europe, the highest benefits, are estimated for Denmark, United Kingdom, Ireland, Finland, and Sweden. The Netherlands, Belgium, Germany and Luxembourg also benefit from a marginal increase in temperature. The estimated marginal effects for these countries range from +2.3% in Germany to +4.6% in The Netherlands.

In Southern Europe, the highest negative effects are estimated in Portugal and Greece, while the estimated marginal effects are around the 20% lower for Italy and Spain. In Eastern Europe, the Baltic states (Latvia, Lithuania and Estonia) reveal the highest benefit from a marginal increase in the temperature regimes among Eastern EU countries. The 17% to the 30% lower positive effects are estimated for Poland and Czech Republic. All other Eastern European countries are damaged by the marginal increase in temperatures, with higher damages estimated for Bulgaria and Romania. Other large-scale cross-sectional Ricardian studies, in the US (Massetti and Mendelsohn, 2011), Latin America (Seo and Mendelsohn, 2008), India (Sanghi and Mendelsohn, 2008) and Europe (Van Passel, Massetti and Mendelsohn, 2017, Vanschoenwinkel, Mendelsohn and Van Passel, 2016) showed that the marginal increase in temperature are beneficial in cold climate (high latitude or altitude) and harmful in low latitude climates. The outcomes of these studies endorse the presence of some NUTS2 regions in the north of Spain, centre of Romania and west of Bulgaria that benefit from a marginal increase in temperature. These NUTS2 regions are characterized by high elevation (above 600 m mean elevation) and the long-run (30-year normal period) temperature estimated for these NUTS2 regions is below (around 2° C) the estimates for neighbourhood regions (data available on request). Similarly, high elevation NUTS2 regions in Austria, Slovenia and Slovakia benefit from increasing temperature regimes, while negative climate responses are estimated for low elevation regions. However, this variability results in a decrease in farmland values at the country level.

Farms' net revenues in Northern countries are damaged by a marginal increase in temperature. The marginal effects for these countries range from -3.7% in Finland to -0.04% in The Netherlands. Benefits from an increase in the temperature regime are estimated only in Belgium and Luxembourg (+0.02% and +0.2%, respectively). On average, German field crop farm revenues decrease of about -0.02% in response to a marginal increase in temperature (around +1 °C). However, positive effects are estimated for field crop farms located in the central and southern NUTS2 regions of the country. Different climate responses are estimated among French field crop farms. At the country level, the impact of a marginal increase in temperature on farms income is negative (-0.3%, see Table 6 in 'Appendix 1'). However, the northern and eastern NUTS2 regions will benefit from a +1 °C increase in temperature (< +0.1%). Similar negative climate response is estimated for Sweden and Denmark (around -1.8%) Negative effects of a marginal increase in temperature are also registered in Ireland and the United Kingdom. Field crop farmers in Ireland and the United Kingdom decrease their net revenue of about -0.5% for a 1° C increase in temperature. While, the estimated effects of +1°C increase in temperature on Austrian field crop farms is about -0.2%, but within country large variability is observed as for the land value model estimates.

Among Southern European countries, Spain and Portugal have similar climate response (around -2.3%), while the highest damages are estimated in Greece and Italy (-3.3%). A marginal increase in temperature regimes lead to a decrease in farmers income in Eastern Europe. However, this negative climate response is higher in the Baltic region (Estonia, Latvia and Lithuania), Bulgaria and Romania, whit income reductions ranging from -1.4% to -2.5%. Lower damages are estimated in Central Eastern European countries. The income of specialized field crop farms in Poland and Slovakia is expected to decrease of about -0.5%, while Slovenian farmers are likely to face higher damages (-1.2%). With respect to farm sustainability, the field crop farms response to a marginal increase in temperature is negative across all Europe (-1.3%). The climate response of farms' sustainable value follows a similar North-South path compared with farmland values. The sustainable value of specialized field crop farms is expected to increase in Finland (0.3%), Sweden (0.2%) and the Baltic region (average: +0.2%). The climate responses of Western European countries are negative for all countries. The sustainability performances of specialized field crop farms decrease of about the -0.6% in The Netherlands, Belgium, Ireland and the United Kingdom. Less harmful is the impact of a marginal increase in temperature in Denmark (-0.4%). While the expected decrease in farm sustainability performances is about -0.1% in Germany and -0.8% in France. However, as for the farmland value model, regional variability can be observed in Germany. The decrease in the sustainable value of field crop farms located in Southern European countries is below the –2% for all countries. Framers in Greece, Italy, and Portugal are the most affected. The sustainable values decrease by the -2.7% in Spain, the -3% in Italy and Greece, and the -3.4% in Portugal. The sustainable value is expected to decrease by a range between -1.9% in Bulgaria and -0.2% in Poland. While farms in Czech Republic are likely to have positive effects on their sustainable values (<+0.1%) from a marginal increase in temperatures.

Figure 3: Percentage change in farmland value (A), Net Revenue (B), and sustainable value (C) per ha of land used at the NUTS2 regions


A) Marginal Effect of Temperature on Farmland Value

B) Marginal Effect of Temperature on Net Revenue

C) Marginal Effect of Temperature on Sustainable Value

Legend

4. Discussion and Conclusion

A uniform increase in temperature (+1°C) across all four seasons lead to significant and negative effects on farmland values, net revenue and farms' sustainability performances. However, the range of marginal impacts varies greatly across Europe and according to the model chosen. Compared with the traditional Ricardian method (the land value model), the marginal effects of 1° C increase in temperature remain positive (but less positive) in Northern countries, while they lead to less damages in Southern countries when net revenue and farms' sustainability performances are used as dependent variables.

Although farmland values and net revenues are considerate equal alternative in the Ricardian literature (Mendelsohn, Nordhaus and Shaw, 1994), the net revenue model in our study showed significantly different coefficients compared with the farmland values model. Similar results have been found by Basurto (2016) for a Ricardian analysis of Mexican farms. The authors argue that such difference is determined by the timing farmland values and net revenues are defined. Yet, net revenues are conditioned to the market prices which are determined at the end of the crop season, while farmland values are depending upon farmers' expectations formed at the beginning of the crop year (Basurto, 2016). Similarly, in our study, the sustainable value indicators are affected by the agriculture market prices which are subjected to higher price volatility compared with the agricultural land markets.

After 2020 the CAP guarantees more emphasis on environmental and climate action, but the proposed new green architecture seems weaker than in the current CAP (Pe'er, Zinngrebe, Moreira, Sirami, Schindler, Müller, Bontzorlos, Clough, Bezák, Bonn, Hansjürgens, Lomba, Möckel, Passoni, Schleyer, Schmidt and Lakner, 2019). Moreover, analysis of the implementation of the CAP revealed that Member States have not dedicated significant financial resources to adaptation and mitigation measures (European Environmental Agency, 2009). The methodology proposed in this study represents an instrument to benchmark and monitor ambitions at the Member State level for adaptation and mitigation policies. This paper illustrates some of the adjustments necessary to improve the ability of the Ricardian method to account for adaptation. By capturing the environmental effects and natural resource depletion of agricultural production, this paper proves that the adjusting the Ricardian method for the negative externalities generated by agricultural production gives more insights into actual and current adaptation capacity and impacts. Moreover, this study presents the first application of the SV approach at farm level for all EU-25 countries. Compared with the traditional Ricardian method, the marginal effect of 1° C increase in temperature shift from positive to negative in Northern countries, while it leads to less damages in Southern countries when net revenue and farms' sustainable values are used as dependent variables. Correcting the economic impact of climate change for the externalities (pollution, natural resources depletion, etc.) generated by agricultural production contributes to define European adaptation and mitigation policies targeting a more sustainable intensification of the agricultural sector.

The Ricardian approach used in this study assumes only climate will change and did not incorporate the carbon fertilization effect, the role of technological innovation or the future dynamics of agricultural products and inputs market. The integration of such Ricardian analysis with tools that analyse the wider economic context such as General or Partial Equilibrium models can omit such limitations. Key assumption for the estimation of climate change impacts on farmland values and net revenues is the farmers' profit maximising behaviour. Such assumption allows to indirectly measure adaptation in the Ricardian models. However, the sustainable value model fails to satisfy the profit maximising assumption and the resources used are not optimized, but they differ from farm-to-fam. To overcome this limitation, future studies can benchmark farm performances sustainability using a production efficient benchmark. Besides, the profit maximising behaviour assumption implies farmers have the capacity of instantaneously and autonomously adapt to the changing climate. However, taking into accounting the regional adaptive capacity has been proven to significantly affect agricultural climate response in Europe (Vanschoenwinkel, Moretti and Passel, 2019).

The outcomes of the study support the implementation adaptation and mitigation policies at the European and Member State level by defining the more affected regions and identifying what resources can be allocated and used more efficiently, at the benchmark level, for the transformational change towards a more sustainable and climate change resilient agricultural sector.

Additional information can be provided by the authors upon request.

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Appendix 1: Overview of the Variables, Descriptive Statistics

Table A1: Overview and descriptive statistics of the variable in the Ricardian Models

Variable	Description	Units	Mean	Min	Max	SD	Source
Land Value	Valued based on prices (net of acquisition costs) that apply in the region for non-rented land of similar situation and quality sold for agricultural purposes. The replacement value is divided by the amount of land owned.	€/ha	10,596.9	173.8	73,431.8	12,093.6	FADN
Net Revenue	Farm total output minus total intermediate consumptions	€/ha	912.3	16.7	62,029.8	1,532.6	FADN
Land used	Utilized agricultural area consists of land in owner occupation, rented land, land in share-cropping.	ha	137.4	1.0	3,634.0	275.5	FADN
Land owned	Land in the owner's occupation and land in share-cropping	ha	48.2	1.0	2,060.0	85.1	FADN
Share of rented land	Total leased land out of the total utilized agricultural land	ha/ha	0.4	0.0	1.0	0.3	FADN
Subsidies	Subsidies on current operations linked to production (not investments) per UAA	€/ha	19.0	0.0	6,330.3	83.6	FADN
Sustainable Value	Sustainable value generated	value/ha	1,848.3	129.7	91,775.6	2,225.5	Own elaboration
Gravel	Weight % gravel (materials in a soil larger than 2 mm) content in the topsoil	%vol	8.5	2.4	15.8	2.8	World soil database
Sand	Weight % sand content in the topsoil	%wt	46.2	20.0	82.5	10.2	World soil database
Silt	Weight % silt content in the topsoil	%wt	31.4	10.8	45.9	6.3	World soil database
Clay	Weight % clay content in the topsoil	%wt	21.8	6.6	40.0	4.9	World soil database
pH	pH measured in a soil-water solution		6.4	4.2	7.9	0.6	World soil database
Population density	Population density in 2010	cap/km^2	142.2	2.6	3,209.0	211.3	ESRI, MBR, and EuroGeographic
Distance to cities	Distance from cities with population > 500.000	1,000 km	0.1	0.0	0.4	0.1	Natural Earth Data
Distance to ports	Distance from medium and large ports	1,000 km	0.2	0.0	0.6	0.1	World port index
Elevation range	Elevation range	1,000 m	0.9	0.0	3.8	0.8	ESRI
Elevation mean	Elevation mean	1,000 m	0.3	0.0	1.7	0.3	ESRI