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Climate change impacts on EU agriculture: A regionalized perspective taking into account market-driven adjustments

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ABSTRACT

The biophysical and economic consequences of climate change for agriculture are surrounded by uncertainties. The evaluation of climate change impacts on global and regional agriculture has been studied at length. In most cases, however, global and regional impacts are examined separately. Here we present a regionalized assessment – for the 2030 time horizon – covering the whole European Union while accounting for market feedback through international markets. To account for uncertainty on climate effects, we defined several simulation scenarios that differ as to climate projections and assumptions on the degree of carbon fertilization. Biophysical simulations show that crop productivity effects are largely determined by the degree of carbon fertilization, leading to decreased productivity in the absence of carbon fertilization and increased productivity otherwise. The magnitude of those effects differs across regions and crops, with maize being one of the most negatively affected in the EU. Economic simulations show that, while, on the whole, crop price effects attenuate the global impacts of climate change, aggregate results conceal significant regional disparities and their related trade adjustment. These results suggest that a multi-scale perspective is helpful for assessing climate change impacts on agriculture, as it will improve understanding of how regional and global agrifood markets respond to climate change and how these responses interact with each other.

1. Introduction

Recent developments in agricultural and food prices are leading to growing concerns about the evolution of agricultural markets in the coming years (Baffes and Haniotis, 2016). Looking forward, a number of studies project price developments above pre-2007 trends (OECD-FAO, 2015). The key drivers of change that explain the medium-term evolution of agrifood systems can be split into socio-economic drivers (i.e. population growth, income growth, dietary patterns) and environmental drivers (i.e. climate change, pressure on natural resources). Socio-economic drivers have been studied at length (Araujo-Enciso et al., 2016; Chavas et al., 2014; Swinnen and Squicciarini, 2012). Among environmental drivers, climate change is recognized as one of the most influential factors of agrifood market developments in the medium and long run (Godfray et al., 2010; Nelson et al., 2014a; Von Lampe et al., 2014). Understanding how climate change will shape future agrifood markets is crucial to address future food security challenges.

There is a growing body of evidence about the effects of climate change on agriculture, with a clear predominance of studies on biophysical effects (IPCC, 2014), which show that the size and direction of climate impacts on crop yields differ across regions depending on both natural and anthropogenic conditions (Parry et al., 2004; Rosenzweig et al., 2014; Tubiello and Fischer, 2007). Nonetheless, an assessment of the impacts of climate change on agriculture requires not only the identification of regional yield changes but also the analysis of induced impacts on crop production and prices (Baldos and Hertel, 2013; Fernández and Blanco, 2015). Efforts to anticipate how climate change will affect future food production and prices include the seminal works of Tobey et al. (1992) and Reilly et al. (1994). They showed that yield changes would be counterbalanced by interregional adjustments in production and consumption and corresponding trade flows. Many global assessments corroborate these early findings that market effects constitute an important adjustment mechanism for the impacts of

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climate change on agriculture (Baldos and Hertel, 2015; Fischer et al., 2005; Hertel et al., 2010; Nelson et al., 2014a).

Results from these global studies are not easily comparable, often contradictory and show that there is a wide range of uncertainties linked to climate projections, crop productivity effects and market adjustments (Fernández and Blanco, 2015). Even so, there is general agreement about the fact that, through its effects on crop productivity, climate change is very likely to add to agrifood market pressures in the years to come.

In recent years, the number of studies on the effects of climate change at the global or regional level has increased considerably. While some authors argue that the assessment of socioeconomic effects requires global coverage in order to account for market feedback (Nelson et al., 2014b), other authors (Reidsma et al., 2015; Wolf et al., 2015) state that a subnational analysis is crucial because biophysical effects and farm level responses are highly heterogeneous. While the latter studies focused on selected regions or countries, the aim of this study is to move forward in this area and to assess regional impacts within the whole EU while accounting for global market feedback.

From a regionalized perspective, particularly for EU agriculture, evidence from the peer-reviewed literature of economic assessments at the EU regional level was sparse before the mid-2000s and became more prevalent as from the 2010s. The studies from Ciscar et al. (2011, 2014) represented a landmark in the regional assessment of the economic impacts of climate change on agriculture in the EU. However, their disaggregation level was scarce, since they focused on five European regions (Central, Northern, Southern, Western and Eastern Europe). Shrestha et al. (2013) analysed the economic impact of climate change at a higher disaggregation level (subnational level, NUTS-2), but they assumed unchanged climate outside the EU.

The objective of this paper is to assess the biophysical and economic impacts of climate change at subnational level within the EU, while taking into account market feedback from international markets as well as the uncertainty regarding the degree of carbon fertilization. This study contributes to the current literature as we jointly assess regional and global effects of climate change, as well as their interplay, in the medium term horizon of 2030. Moreover, we extend the assessment of socioeconomic impacts of climate change in terms of the uncertainty related to the degree of carbon fertilization effects.

In our study we use the set of climate scenarios selected by the IPCC for the Fifth Assessment Report (IPCC, 2014). This scenario framework has been developed by the climate change research community to increase consistency and comparability across climate impact studies (Kriegler et al., 2012; Van Vuuren et al., 2012) and consists of a two-dimensional matrix representing key environmental and socioeconomic drivers of uncertainty in future outcomes. Each scenario results from the plausible combination of a Representative Concentration Pathway (RCP) with a Shared Socio-economic Pathway (SSP). The RCPs comprise four trajectories according to different levels of anthropogenic radiative forcing in the year 2100 (2.6, 4.5, 6 and 8.5 W/m^2) (Van Vuuren et al., 2011). The SSPs are based on five narratives describing alternative socio-economic developments, built on socio-economic drivers consistent with different challenges to adaptation and mitigation: SSP 1 (sustainability), SSP 2 (middle of the road), SSP 3 (fragmentation), SSP 4 (inequality) and SSP 5 (conventional development) (O'Neill et al., 2015).

The paper is structured as follows. In Section 2, we present the modelling approach as well as the scenario definition. In Section 3, we present the results of the biophysical and economic simulations. Finally, in Section 4 we discuss the results of this study and highlight the main conclusions.

2. Methodology

2.1. Bio-economic modelling approach

A general approach to the joint analysis of the biophysical and socio-economic impacts of climate change is to use biophysical models to project the crop yield effects of climate change and incorporate the resulting yield effects into agro-economic models in order to evaluate impacts on production and prices (e.g. Adams et al., 1998).

The bio-economic modelling approach used in this study is capable of analysing the impacts of climate change on agriculture at a regionalized level within the EU while taking into account market feedback through international markets. To do this, results from biophysical simulations were incorporated into the agro-economic model CAPRI (Britz and Witzke, 2014), which provides results simultaneously at the global level (around 40 trade blocks all around the globe) and at more disaggregated level within Europe (around 270 NUTS 2 regions). For this purpose, the crop yield simulations for non-EU regions were obtained from the LPJmL agro-ecosystem model (Bondeau et al., 2007) while more detailed crop yield analysis was performed for the EU regions, where the WOFOST crop model (Van Diepen et al., 1989) was run to provide NUTS 2 level simulations for nine of the most grown crops in Europe (MARS, 2014). The same source of meteorological data, consisting of bias corrected global climate model simulations from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP), was used for global and European assessments (Hempel et al., 2013).

In terms of assumptions of this study, it is important to highlight that, while biophysical simulations assume no climate-induced changes in farming practices, economic simulations account for farmers' adaptation strategies. As the available global crop yield simulations assume no change in management practices over time (Hempel et al., 2013), the WOFOST simulations for the EU were carried out under the same conditions (for consistency), meaning that our approach does not account for changes in farming practices due to climate change (i.e. changes in sowing dates). Nevertheless, the economic model allows for endogenous adaptation strategies, that is, changes in relative crop yields will induce – through market effects – changes in cropland allocation (extensive margin adjustments), changes in production intensity (intensive margin adjustments, as crop yields respond to crop prices) and changes in interregional trade flows (trade adjustments).

Given that we focus on the influence of climate change on agrifood market developments, the time horizon chosen for this study is 2030, in view of the high degree of uncertainty surrounding macroeconomic projections over longer periods. Accordingly, we selected the middle-of-the-road socio-economic pathway (SSP2) as a representation of a moderate capacity to face future mitigation and adaptation challenges in the medium term (O'Neill et al., 2015). Therefore, the baseline scenario until 2030 (1) reflects agricultural market developments and land use up to 2030 based on socio-economic drivers from SSP2[1]; and (2) assumes no climate effects on crop productivity between 2010 and 2030.

The simulation scenarios are based on the RCP 8.5, which has the highest radiative forcing among the four RCPs (rising radiative forcing pathway leading to 8.5 W/m^2 in 2100). Although this may be regarded as an extreme scenario, the choice of RCP 8.5 is justified as we wanted to consider the upper end of the climate effects. Moreover, the omission of other negative factors that will likely depress yields, such as the increase of troposphere ozone, changes of pest incidence or increasing variability in weather, suggest that this scenario might not be as extreme as it first seems.

Based on SSP 2 and RCP 8.5, we defined several simulation scenarios for 2030, in order to account for the uncertainty about future

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[1] The SSP data is available from IIASA (https://secure.iiasa.ac.at/web-apps/ene/SspDb).