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Combined effects of climate change and policy uncertainty on the agricultural sector in Norway

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ABSTRACT

Farmers are exposed to climate change and uncertainty about how that change will develop. As farm incomes, in Norway and elsewhere, greatly depend on government subsidies, the risk of a policy change constitutes an additional uncertainty source. Hence, climate and policy uncertainty could substantially impact agricultural production and farm income. However, these sources of uncertainty have, so far, rarely been combined in food production analyses. The aim of this study was to determine the effects of a combination of policy and climate uncertainty on agricultural production, land use, and social welfare in Norway.

Output yield distributions of spring wheat and timothy, a major forage grass, from simulations with the weather-driven crop models, CSM-CERES-Wheat and, LINGRA, were processed in the a stochastic version Jordmod, a price-endogenous spatial economic sector model of the Norwegian agriculture. To account for potential effects of climate uncertainty within a given future greenhouse gas emission scenario on farm profitability, effects on conditions that represented the projected climate for 2050 under the emission scenario A1B from the 4th assessment report of the Intergovernmental Panel on Climate Change and four Global Climate Models (GCM) was investigated. The uncertainty about the level of payment rates at the time farmers make their management decisions was handled by varying the distribution of payment rates applied in the Jordmod model. These changes were based on the change in the overall level of agricultural support in the past. Three uncertainty scenarios were developed and tested: one with climate change uncertainty, another with payment rate uncertainty, and a third where both types of uncertainty were combined. The three scenarios were compared with results from a deterministic scenario where crop yields and payment rates were constant. Climate change resulted in on average 9% lower cereal production, unchanged grass production and more volatile crop yield as well as 4% higher farm incomes on average compared to the deterministic scenario.

The scenario with a combination of climate change and policy uncertainty increased the mean farm income more than a scenario with only one source of uncertainty. On the other hand, land use and farm labour were negatively affected under these conditions compared to the deterministic case. Highlighting the potential influence of climate change and policy uncertainty on the performance of the farm sector our results underline the potential error in neglecting either of these two uncertainties in studies of agricultural production, land use and welfare.

1. Introduction

Current research on climate change has led to a renewed interest in uncertainty as an increasingly important factor in any study that attempts to assess the effects of climate change on agricultural production (Olesen et al., 2007; Lobell and Burke, 2008; Asseng et al., 2013). This is because the impacts of climate change, notably those related to higher variance of weather distributions are not yet fully understood (Thornton et al., 2014). Such an increased variability in the weather distributions could entail increased risks of losses in the agricultural production sector due to increased frequency and intensity of heat waves and dry spells, especially in regions which already today experience warm and dry conditions (Bindi and Olesen, 2011; Teixeira et al., 2013). For the agricultural sector in northern Europe, positive effects including a prolonged growing season and increased crop yields from projected climate change have been projected (Bindi and Olesen, 2011; Rötter et al., 2012) although the range in climate projections also allow for negative yield effects (Rötter et al., 2012). However, potential effects of the projected climate change with increased weather variability on the agricultural sector in this region, including effects on farm profits and welfare, have been given little attention so far.

Farm income in many countries depends to a large extent on various types of farm subsidies (OECD, 2014). Hence, farmers are exposed to uncertainties regarding the design and extension of these subsidies. That policies themselves constitute a source of risk to farmers is commonly

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underemphasized in research (Gardner, 2002). While some studies focus on farmers' perceptions and responses to policy risk (Flaten et al., 2005; Niles et al., 2013), we are not aware of any study that explicitly compares the effects of the two different sources of uncertainty on the agricultural sector: climate change and policies. Previous analyses of impacts of climate change on farm productivity have assumed present day prices also under projected future climate conditions (Leclère et al., 2013). The farming sector in Norway, which is dominated by forage grass based dairy, beef and sheep production, and primarily in the southern regions, to some extent also include spring and winter cereals for bread or animal feed, is heavily dependent on governmental subsidies. Currently, at the farm sectoral level about two-thirds of farm income in Norway is related to policy interventions in form of market price support and subsidies, which is a high proportion compared to other countries (OECD, 2014). The significant dependence of subsidies on farm-income in Norway constitutes a potentially important source of uncertainty as policies, in principle, can shift frequently. Subsidies have remained fairly stable over the last decades, however, because there has been broad parliamentary support for the need of agricultural policies to achieve agricultural policy goals such as a high level of self-sufficiency (Ministry of Agriculture and Food, 2011).

While decision-making under risk at the farm level has been widely analysed (Hardaker et al., 2004), studies taking into account uncertainty at the sectoral level are less common as many agricultural models at that level are deterministic (Van Tongeren et al., 2001). Moreover, the analysis of the combined effects of uncertainty due to projected climate change and due to potential shifts in agricultural policies that farmers are facing could help better understand the prospects of agricultural production until the mid-21st century and the need for adjusting agricultural policies. Accordingly, the results from such an analysis could help to develop new strategies to handle the uncertainty that such climate and policy changes are associated with on farm and national levels. The relatively high dependency of the profitability of the farm sector in Norway on farm subsidies makes this country a suitable object for a study of the combined effects of climate and farm policy uncertainty on farm profit, production, land use and other performance indicators of the agricultural sector. Such a study could help clarify the effect various sources of uncertainty have on the agricultural sector and hence help guiding research needs, policy focus and farm management towards the source with the largest adverse impact.

Models aimed at understanding the impact of various exogenous variables on agricultural systems have been developed during the last decades. These models include, among other models, agricultural sector models (Takayama and Judge, 1971; Van Tongeren et al., 2001), and dynamic crop simulation models (Jones et al., 2003; Keating et al., 2003; Stöckle et al., 2003). The former models simulate the response of farmers and other economic agents to changes in the model's exogenous variables like world market prices, technological progress and population growth. Such changes (or 'policy shocks') can be related to changes in agricultural or trade policies, in input or output prices or technologies. The objective of these models is to determine equilibrium prices and quantities in markets that are endogenous to the model (Van Tongeren et al., 2001). Crop models simulate the effect of exogenous physical variables, such as the weather, soil characteristics and crop management practices, on the growth, development and yield of agricultural and horticultural crops during the growing season (Jones et al., 2003; Keating et al., 2003; Stöckle et al., 2003). The latter type of models has previously been applied to assess crop potential under different geophysical conditions including those representing climate change (Soussana et al., 2010).

Linking models of different scope and scale, such as economic and biogeophysical agricultural models, is a complex task (Ewert et al., 2011). There are nevertheless a few notable examples of such linkages. Briner et al. (2012) studied the impact of climate change on agricultural ecosystems using a modular framework including an economic land allocation model and a crop model. Their approach was dynamic, but did not involve uncertainty. Lehmann et al. (2013) studied the impact of climate and price risk in Swiss agriculture by combining a whole-farm bioeconomic model and a crop growth model. Although accounting for climate and price uncertainty, their approach was related to the farm rather than the agricultural sector.

The use of crop model output yields resulting from simulations under current and projected future climate conditions as input to a farm sector model, which, in turn, is run under contrasting policy scenarios would be one adequate approach to determine and compare the effects of climate and policy uncertainty on farm profits and welfare. Even though there are crop simulation studies, which include climate change conditions published for most regions of the world (White et al., 2011), the data are usually not suitable for direct use in economic models. Mostly, only average yield data, which are not sufficiently detailed to account for the variability that is relevant to include in an analysis of climate change impact on the profitability and welfare of the agricultural sector, are available from previous studies. In addition, the crops included in such simulations usually do not represent the mix of crops which is typical for production systems in a region, but are rather chosen to evaluate climate change effects on a specific crop. Therefore, crop simulations with the aim of generating yield data that would be further processed in economic models should be tailored to the framework and the aim of the simulations with the economic models. A study with such an approach would also extend previous work on risk handling at farm level by including a stochastic model in which farmers make management decisions in the presence of uncertainty about yields and payment rates of agricultural subsidies.

The aim of this study was to determine the effects of a combination of policy and climate uncertainty on agricultural production, land use, and social welfare in Norway. Those characteristics are important in order to measure to which extent agricultural objectives in Norway are achieved and thus to identify and implement possible measures to alleviate negative consequences of policy and climate uncertainty. The remainder of the paper is outlined as follows. A description of the crop models and the economic model is given in the next section. Section 3 introduces the modelling framework, while scenarios are presented in Section 4. The main results of the study can be found in Section 5. The final section discusses the results and concludes the paper.

2. Model description

In this study, we applied two crop simulation models, the CSM-CERES-Wheat model (Ritchie et al., 1998) as included in the Decision Support System for Agrotechnology (DSSAT) v 4.5 software (Hoogenboom et al., 2010) and timothy grass version of the LINGRA model (Höglind et al., 2001), and the Jordmod farm sector model (Brunstad et al., 2005) to evaluate the combined effect of climate change and related uncertainty, and policy related uncertainty on key characteristics of the agricultural sector in Norway until 2050. These characteristics included crop, milk and beef production and farm profitability.

2.1. Crop simulation models

The CSM-CERES-Wheat and the LINGRA model dynamically simulate growth, development and yield of wheat and timothy grass, respectively, as a function of weather, soil, and crop management practices over the growing season with a time step of one day. Parameters, which regulate growth and development functions in these models, are calibrated to represent cultivar specific traits. Both models are based on the source-sink concept, where photosynthesis and mobilization of reserves represents sources, and sinks constitute growth and respiration of plant tissues. LINGRA is able to simulate the removal of the above-ground biomass in the form of cutting and harvesting in production systems with multiple seasonal cuts. The partitioning of biomass between plant organs are modified by stresses in form of sub-optimal temperatures, water deficit, and, for the CERES-wheat model, also