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Analysis

Climate-induced Land Use Change in France: Impacts of Agricultural Adaptation and Climate Change Mitigation

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ABSTRACT

Interaction between mitigation and adaptation is a key question for the design of climate policies. In this paper, we study how land use adaptation to climate change impacts land use competition in the agriculture, forest and other land use (AFOLU) sector and how a mitigation policy in agriculture might affect this competition. We use for this purpose two sector-specific bio-economic models of agriculture and forest combined with an econometric land use shares model to simulate the impacts of two climate change scenarios (A2 and B1, 2100 horizon), and a greenhouse gas emissions from agriculture policy consisting of a tax of between 0 and 200 €/tCO_2 equivalent. Our results show that both climate change scenarios lead to an increase in the area devoted to agriculture at the expense of forest which could have a negative impact on reducing greenhouse gas emissions responsible for climate change. The mitigation policy would curtail agricultural expansion, and thus could counteract the effects of land use adaptation to climate change. In other words, accounting for land use competition results in a reduction of the abatement costs of the mitigation policy in the agricultural sector.

1. Introduction

According to the International Panel on Climate Change (IPCC) (2013), the average global temperature has increased by about 0.85 °C during the period between 1880 and 2012. In order to avoid the worst impacts of climate change (CC), requires global greenhouse gas (GHG) emissions to be cut substantially (EEA, 2017). In March 2015, the European Union (EU) announced its intended contribution to the CC mitigation effort by promising a 40% cut (compared to 1990 levels) in Europe's GHG emissions by 2030. A few months later, during the 2015 United Nations Climate Change Conference (COP 21) held in Paris, France pledged a 75% emissions reduction by 2050. These ambitious commitments contributed greatly to the adoption of the first universal, legally-binding global climate agreement. The EU's effort is split between member states with each one defining its own mitigation strategy. Thus, the French government announced a national low-carbon strategy (Ministère de l'écologie, du dèveloppement durable et de l'ènergie, 2015) which establishes carbon budgets for the 2015–2018, 2019–2023, and 2024–2028 periods. In order to achieve these national goals, the strategy involves carbon pricing for the energy sector of 22 €/tCO_2 in 2016, 56 €/tCO_2 in 2020, and 100 €/tCO_2 in 2030.

In France, around 70% of national GHG emissions come from energy use (in production, transport, residential, etc.) and 16%–18%[1] from agriculture. In the case of the latter sector, the goal (compared to 2013) is a reduction of some 12% for the third carbon budget (2024–2028), and a cut of 50% (compared to 1990) of GHG emissions by 2050 (Ministère de l'écologie, du dèveloppement durable et de l'ènergie, 2015). However, no economic incentive policy has been announced for agriculture. Grosjean et al. (2016) discuss the barriers to GHG pricing (cap and trade schemes, taxation) in agriculture, and categorize them into: i) transaction costs; ii) leakages; and iii) distribution effects. Their article proposes a framework for analyzing potential solutions to these issues through policy design. However, the policies currently being considered propose emissions reductions by the agriculture sector through the implementation of agroecological measures such as maintenance of meadows, development of agro-forestry, and optimization of input use.

An exemplary measure which was proposed during COP 22 held in Marrakech in autumn 2016, is the "4 per 1000" increase in carbon stock in soils which would reduce atmospheric concentrations. This solution would be associated with gains in terms of soil fertility and supply of other ecosystem services. In this paper, we show how an incentive policy such as GHG taxation in agriculture, could encourage farmers to

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[1] Cited figures are from UNFCC data for France up to 2013. Emissions include LULUCF and indirect CO_2.

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adopt GHG mitigation means in the direction of the proposed agroecological measures. Such a policy might have an additional indirect effect in the form of land use change (LUC) from agriculture to forestry which could further reduce the costs of GHG emissions abatement.

CC has been ongoing for the last several decades (IPCC, 2014), and a policy evaluation in the light of these changes is necessary. For this reason, we investigate the effects of CC on land use in France at the 2100 horizon, in the context of a CC mitigation policy based on taxing agricultural GHG emissions. We exploit the results from previous work on the impact of CC on the profitability of agriculture and forestry, and estimate a spatial econometric land use share model which captures the changes in land rents for different land use classes. In addition, we study the impact of a mitigation policy (tax on GHG emissions) on land use and on overall agricultural emissions. When accounting for the land use effects of the mitigation policy, we find that private abatement costs are lower, and this difference is amplified in different CC scenarios. We build on three branches of the literature on agriculture and CC adaptation and mitigation: i) impact of CC on the agricultural sector; ii) impact of CC on land use; and iii) abatement costs related to GHG emissions from agriculture.

First, we draw on the numerous studies assessing the direct effects of CC on agriculture (Adams et al., 1990; Rosenzweig and Parry, 1994). According to Mendelsohn and Dinar (2009), the literature proposes five approaches to the impacts of CC on agriculture: i) crop simulation models (Ciscar et al., 2011); ii) cross-sectional or intertemporal analyses of yields (Lobell et al., 2011); iii) panel (intertemporal) analysis of net revenues across weather (Deschenes and Greenstone, 2007); iv) cross-sectional analyses of net revenues or land values per hectare (Mendelsohn et al., 1994, 2004); and v) computable general equilibrium (CGE) models (Nelson et al., 2014). Each has limitations and advantages; however, most models do not allow for adaptations to farmer behavior, or possible land use changes outside the agricultural sector. Mendelsohn et al. (1994) address these issues in part, and propose a method that relies on Ricardian theory of differential land rents. The Ricardian method assumes that the land price is the net present value of future land rents. However, future land rents can be driven by factors other than agricultural use (Capozza and Helsley, 1990; Plantinga et al., 2002). Schlenker et al. (2005) in their assessment of CC impacts on US agriculture, account for urban pressure on agricultural land prices. Adams et al. (1995) combine an economic and a crop simulation model to account for some adaptations to crop choice, while Leclère et al. (2013) go a step further and explore some agronomic adaptations (sowing dates, crop varieties). We build on this body of work and estimate an econometric land use model that allows for LUC among two land based sectors namely agriculture and forestry.

Second, there are some recent studies (Ay et al., 2014 and Haim et al., 2011, for instance) that investigate the effects of CC on land use. To estimate future land rents for their land use model, Ay et al. (2014) use the same principle as Mendelsohn et al. (1994). While Mendelsohn et al. (1994) focus solely on agriculture adaptations related to crops and practices, Ay et al. (2014) evaluate the impact of CC in terms of LUCs among annual crops, perennial crops, pastures, forests, and urban areas. Haim et al. (2011) investigate LUC by approximating future agricultural and forestry productivity by ecosystem net primary productivity. Fezzi et al. (2015) build on an agricultural land use model (Fezzi and Bateman, 2011) to investigate the effect of CC on water quality. However, their model does not consider other land-demanding economic sectors or their future evolution. In contrast, our methodology allows for LUC not only among sectors but also within the agricultural and forestry sectors (choice of crops and/or pasture, and choice of tree species). This aspect is fundamental when considering CC adaptations.

Third, the marginal abatement costs of GHG for agriculture have been studied using different modeling techniques. In a meta-analysis, Vermont and De Cara (2010) classify the different approaches according to three groups: i) supply-side models specialized in agriculture (e.g. De Cara and Jayet, 2000; De Cara et al., 2005; Garnache et al., 2017); ii) general equilibrium models (e.g. McCarl and Schneider, 2001; Schneider and McCarl, 2006); and iii) engineering studies (e.g. Beach et al., 2008). Vermont and De Cara (2010) argue that the results of the first model types generally are closer to the microeconomic definition of marginal costs, while general equilibrium models integrate the commodity price responses to pollution abatement. Nevertheless, supply-side models provide a better representation of the heterogeneity in farming systems. The level of detail in descriptions of the production function is even higher in engineering studies but this is at the expense of the geographical extent of these studies.[2]

With the exception of general equilibrium models, the responses of farmers to GHG taxation in terms of land use is ignored in previous work. Since land use feedback effects have been shown to be important in the context of GHG mitigation policies such as incentives for using biofuels (Searchinger et al., 2008), in our simulations we account explicitly for LUC. Finally, Lubowski et al. (2006) estimate an econometric land use model for the USA and simulate landowner responses to sequestration policies. They examine a two-part policy involving a subsidy for converting land to forest, and a tax on converting land from forest. They then estimate the carbon sequestration supply function of these policies by computing the corresponding flows of carbon in terrestrial sinks. However, unlike our study, they do not simulate the impacts of climate change on land use.

The present paper addresses three main questions:

1. What are the impacts of CC on agricultural and forest rents in France?
2. What are the impacts of a mitigation policy (tax on GHG emissions from agriculture) on farms emissions and on LUC in France?
3. What are the impacts of CC on agriculture and LUC in France?

To investigate these questions we exploit the results from two mathematical programming models (AROPAj for agriculture and FFSM ++ for forestry) to study the impacts of CC on agricultural and forest rents. We use the supply model AROPAj to study the impacts of a mitigation policy (tax on GHG) on agriculture, and we use a spatial econometric model to study the impacts of CC and a mitigation policy on LUC. Our econometric model allows for the allocation of land among four land uses, namely: i) agriculture (crops and pasture); ii) forest; iii) urban; and iv) other. We estimate a spatial econometric land use share model which accounts explicitly for spatial autocorrelation between land uses in neighboring grid cells. Most previous work assumes spatial independence of land use choices between neighboring areas, although some recent exceptions include Ay et al. (2017), Chakir and Le Gallo (2013), Li et al. (2013), Sidharthan and Bhat (2012), Ferdous and Bhat (2013), and Chakir and Parent (2009). Incorporating spatial autocorrelation into land use models allows for more precise estimation, and improves prediction accuracy (Chakir and Lungarska, 2017).

The article is organized as follows. In Section 2, we describe the models used to assess GHG emissions from agriculture, and Section 3 presents the data. Section 4 presents and discusses the results of our simulations.

2. Methodology

The study methodology is based on two mathematical programming models (AROPAj for agriculture, and FFSM ++ for forestry), coupled to bio-ecological models, and a spatial econometric land use model that allows us to combine the results of the sector-specific models. Fig. 1 describes the modeling scheme adopted. The bio-ecological components of the sector specific models account for the direct impact of CC on agriculture and forestry in terms of crop and forest yields. These

[2] For more details on the methodologies and the results of these studies, see Vermont and De Cara (2010).