Tackling Modelling and Policy challenges of the "GREENING" of the Common Agricultural Policy

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Tackling modelling and policy challenges of the “greening” of the Common Agricultural Policy

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AIC	Akaike Information Criteria
BIC	Bayesian Information Criteria
BS	Budget Share
CAP	Common Agricultural Policy
CAPRI	Common Agricultural Policy Regionalized Impact
CCCP	Counter Cyclical Capacity Payment
CCP	Counter Cyclical Payment
DEA	Data Envelopment Analysis
DGP	Data Generating Process
DMUs	Decision Making Units
EC	European Commission
EFA	Ecological Focus Area
EP	European Parliament
EU	European Union
FADN	Farm Accountancy Data Network
FAO	Food and Agriculture Organization of the United Nations
GAMS	General Algebraic Modelling System
IDvrs	Inverse Data Envelopment Analysis under Variable Return to Scale
IQR	Interquartile Range
LU	Livestock Unit
MAD	Mean Absolute Deviation
Max	Maximum
MD	Mean Deviation
Min	Minimum
MLE	Maximum Likelihood Estimators
MS	Member States
NLP	Non-Linear Programming
NZFARM	New Zealand Forest and Agriculture Regional Model
OECD	Organisation for Economic Co-operation and Development
PC	Profit Change
PG	Permanent Grassland
PMP	Positive Mathematical Programming
RLR	Restricted Linear Regression
SD	Standard Deviation
SFP	Single Farm Payment
SHDI	Shannon diversity index
UAA	Utilized Agricultural Area
US	United States
VCS	Voluntary Coupled Support
VRS	Variable Return to Scale
WTO	World Trade Organisation

Chapter 1. Introduction

1.1. Fifty shades of green

Green et al. (2005) revived the debate on how to reconcile farming production with nature preservation. Their study emphasises two schools of thought: wildlife-friendly farming - which aims to integrate the provision of environmental goods within the farming production process, but may reduce agricultural yield – and, land sparing - which aims to increase agricultural yield in order to reduce the demand for farmland. The wildlife-friendly approach has received support in Europe and today the rural development programs within the Common Agriculture Policy (CAP) provide payments to farmers to shift towards a more extensive mode of production and to minimize negative externalities. The land sparing approach goes beyond the farming system and argues that the former approach would require a larger area of farmland to meet food production targets. It suggests, instead, freeing farmers of any environmental requirements and increasing yield on already converted lands, thereby reducing the pressure on natural habitat and ultimately returning former farmland back to natural area. Such an approach is mostly advocated in development literature (Lee and Barrett, 2001). Nevertheless, in reality, a range of mixed approaches exist between both paradigms and choices are often driven by landscape and its biophysical properties, historical evolution and socio-economic context (Fischer et al., 2008). The present study focuses on the integration of environmental policy into the European agricultural policy and more specifically on the greening of the CAP during the last reform, but parallels are made with other country's policies where relevant.

The integration of environmental issues into international law was formally recognised in 1992, during the United Nations conference on the environment and development, in Rio. Since then, agricultural policy has integrated the management of natural resources by requiring or incentivising farmers to contribute, maintain or restore certain environmental attributes. Governments across the globe sponsor several environmental programs aimed at more environmentally friendly farming practices, or sanction farmers who fail to comply with a set of environmental rules. The current CAP reflects this dichotomy between promoting and sanctioning with its two pillar structure. Pillar I is oriented towards production and withholds payments if farmers do not comply with a set of environmental rules, while Pillar II promotes sustainable rural development. The rationale behind rural development programs is that farmers, by producing positive environmental externalities and/or reducing negative externalities, will deviate from the economically optimal decision. Consequently, governments compensate for farmers' economic losses and, in so doing, address the market failure to internalize environmental concerns (Baylis et al., 2008). However, the rationale behind the integration of environmental concerns within Pillar I of the CAP remains unclear and is discussed further on.

The integration of environmental policy into agricultural policy has been a slow process driven by historical developments, international and socio-economic contexts, leading eventually to the latest CAP reform in 2013 and the greening of the direct payment systems. The "greening" refers to the introduction of three main measures deemed beneficial for the environment and the climate, namely: crop diversification, maintenance of permanent grassland and dedicating 5% of arable land to Ecological Focus Area (EFA).

The crop diversification measure aims to tackle the issue of decreasing diversity in agricultural landscapes - in other words the presence of monocultures. Farmers are required to have a minimum of two crops if they have between 10 and 30 ha of arable land. If they have more than 30 ha, they need to have three crops. The first crop cannot cover more than 75% of the arable land, and in cases involving more than 30 ha of arable land, the first two crops are not allowed to cover more than 95% of the arable land (Council of the European Union, 2012). Regarding permanent grassland, Members States (MS) need to ensure that the ratio of permanent grassland area to total Utilized Agricultural Area (UAA) does not fall by more than 5% compared to the baseline year (2012), plus arable land converted to permanent grassland in 2015. MS could choose whether to implement this ratio at national, regional or farm level. Finally, farmers with arable areas exceeding 15 ha must ensure that at least 5% of such areas is an EFA. EFAs cover a broad range of features. MS could choose which list of features to define as EFA from which their farmers can choose. All MS except the Netherlands and Romania decided that set-aside land qualifies for EFA (European Commission, 2015). However, contrary to Pillar II of the CAP, this set of measures is mandatory in the sense that if farmers do not comply with them 30% of their direct payments will be withdrawn. In order to better understand the current rationale, we briefly describe the major steps in the integration of environmental concerns into agricultural policy, and we focus particularly on the first pillar of the CAP (for a more thorough review see Matthews (2013) and Erjavec and Erjavec (2015)).

The first green shift in the CAP happened in 1992 with the MacSharry reform. In the 70s and 80s the European Union (EU) was a victim of its own success in guaranteeing food supply and it swung decisively into surplus for most commodities. Support linked to production level led to a costly accumulation of stocks. The reform cut price support for key commodities, compensated farmers with direct payments, and introduced compulsory set-aside. Coupled direct payments were established on the basis of historical references and were therefore limited to predetermined quantities. By providing direct payments the EU aimed to reduce the negative externalities from intensive farming systems while set-aside was not yet perceived as a tool to promote environmental goods, but rather as a tool to reduce production volume.

The assessment of the 1992 reform from an environmental point of view was rather mixed (Winter, 2000). If the use of fertilisers and pesticides decreased overall, there was considerable variation between Member States (MS), with a reduction in high input countries and an increase in most other countries. By then, researchers had already highlighted the need to strengthen the link between crop and livestock production, and suggested a more targeted environmental policy which would take into account the heterogeneity in farming systems and landscapes (Winter, 2000; Holland et al., 1994). Furthermore, with the 1994 Uruguay Round Agreement on Agriculture, European agricultural policy became subject to international governance through the General Agreement on Tariffs and Trade. Consequently, with the anticipation of the new World Trade Organisation (WTO) rounds and the expansion of the EU to incorporate new countries, the Agenda 2000 reform further emphasised the shift from market price support towards direct income support in line with the McSharry reform. Additionally, the Agenda 2000 reform introduced Pillar II of the CAP with the rural development policy. However, if the reform intended to integrate more environmental concerns into Pillar I, it was left to MS to decide whether they would sanction or promote farmers respecting certain environmental rules. In fact, the European Commission rationale was: "The philosophy underpinning the environmental aspects of CAP reform is that farmers should be expected to observe basic environmental standards without compensation. However, wherever society desires that farmers deliver an environmental service beyond this base-line level, this service should be specifically purchased through the agri-environment measures."(European Commission, 1999). Hence, MS could define the minimum baseline level through cross-compliance and so apply the "Polluter-Pays-Principle", or they could decide that the provision of public goods goes beyond farmers' normal activities through the rural development program and apply the "Provider-Gets-Principle". This bivalence still remains in the current CAP.

Under the pressure of the WTO, the 2003 reform of the CAP set the baseline level for environmental services by making cross-compliance mandatory (Swinbank and Daugbjerg, 2006). Not only did cross-compliance become mandatory, MS had to maintain their ratio of permanent pasture. The reform introduced the decoupling of production from direct payments through the "Single Payment Scheme" and a modulation mechanism in order to initiate a shift of budget from Pillar I to Pillar II (Schmid, Sinabell and Hofreither, 2007). Regarding cross-compliance policy, according to the Organisation for Economic Co-operation and Development (OECD, 2010): "Cross-compliance neither pursues an income support objective nor is it the primary mechanism for enforcing environmental legislation. Rather, cross compliance is a tool linking payment schemes to the respect of a wide array of environmental requirements and fostering adherence to them". Indeed, as its basis, the adherence to cross-compliance is voluntary for farmers. In principle, farmers will enforce cross-compliance only if the cost of enforcement is lower than the amount of retained payment (H. Bennett et al., 2006). Hence, we can question whether cross-compliance constitutes a baseline, since farmers can choose whether or not to enforce what is stated as basic environmental standards (Matthews, 2013). Furthermore, such policy does not target all farmers evenly, but rather focuses on farmers who were historically eligible for most of the agricultural support and not those in the most environmental sensitive areas nor those where the highest environmental value would be achieved. If cross-compliance was seen as a tool to better integrate environmental standards into agricultural policy, it also increased the acceptance of direct payments under Pillar I by the civil society and the international scene.

The Health Check in 2008 was in line with the 2003 reform with a further transfer of budget from Pillar I to Pillar II, a simplification of cross compliance and a further decoupling of the remaining coupled support. In 2013, the EU enacted the CAP for the period 2014-2020. In order to further integrate environmental concerns, the EU had two options: to strengthen Pillar II and to further enhance the promotion of targeted environmental policy through agro-environmental measures, or to strengthen cross-compliance policy by enlarging its scope and the number of farmers affected. Instead, the reform introduced a new policy tool, the "Greening" of the CAP. The goals of the European Commission were to apply a universal set of measures to all farmers, to avoid a watering down of the policy by MS, to frame a policy incentive rather than a policy requirement, to link environmental standards to Pillar I in order to ensure the legitimacy of direct payment. The introduction of the greening requirement illustrates the struggle by the EU to integrate environmental policy while at the same time supporting farmers in need, between promoting or sanctioning, between the "Provider-Gets-Principle" and the "Polluter-Pays-Principle", between targeted flexible payments and a universal baseline level. In the end, the greening requirements are a mixture of both, aiming to be the same for all farmers in all MS, but with exemptions and a list of different options for MS and where enforcement of the legislation is problematic. Today, academics and Non-Governmental Organisations seriously question the effectiveness of such policy and ask that any payments made to farmers be linked to environmental services which are targeted, measurable and progress towards better integration of livestock and crop systems (European Envionmental Bureau and BirdLife, 2016; Matthews, 2015; Moore, 2016; Pe'er et al., 2014; Mouysset, 2014; Kirchner, Schönhart and Schmid, 2016; Balmann et al., 2010) . Furthermore, the reform of the CAP has reintroduced the opportunity to grant Voluntary Coupled Support (VCS) for specific farm types or sectors, representing 4.1% of the total amount of direct support in the EU. Almost all MS chose to support the cattle sector, headed by the beef and veal sector, accounting for 41% of the budget dedicated to VCS, followed by the dairy sector with 20% of this budget and by the sheep and goat sector with 11% of the budget (European Commission, 2015c). Coupled support is classified by the OECD as an environmentally harmful (Schmid et al., 2007) and trade distortive instrument. The reforms of 2000 and 2003 intended to eliminate such types of support. The main argument was to support agricultural sectors that are particularly important for economic, social or environmental reasons and which face certain difficulties. They should take the form of an annual payment and be granted within defined quantitative limits.

This dissertation contributes to the impact assessment of the greening measures by analysing the farm-level and regional-level responses and comparing these responses to two suggested alternative policy instruments. The first proposed policy instrument is a premium per hectare for permanent grassland. The second proposed instrument is a Counter Cyclical Capacity Payment (CCCP) for set-aside land. We suggest that set-aside land should be considered as a reserve agricultural capacity. This will provide a premium per hectare of set aside land, that is inversely correlated to commodity prices.

The option of a premium per hectare for permanent grassland would increase the competitiveness of permanent grassland and would ultimately lead to a decrease in forage costs. Similarly to VCS, it would indirectly support the livestock sector. However, in contrast to VCS, the provision of coupled support linked to permanent grassland instead of headage payments is expected to favour extensive livestock production and enhance the provision of environmental benefits. Indeed, permanent grassland provides more environmental and societal benefits than a feed and crop feed system such as corn silage. Additionally, by simulating the introduction of a premium per hectare for permanent grassland, we can determine the premium level for which permanent grassland would be maintained according to a given base year. Hence, the derived premium reflects the current opportunity costs for the maintenance of permanent grassland under the greening requirements of the CAP.

Set-aside land is recognised for its positive environmental impact. While the set-aside policy can be viewed through an environmental lens, we propose to also look at set-aside land in terms of agricultural capacity. Indeed, the agricultural sector exhibits high volatility prices with an inelastic demand. Given the risk averse nature of farmers, we consider set-aside land as a reserve agricultural capacity. The rationale underpinning reserve agricultural capacity is that in times of low commodity prices farmers will receive an incentive to withdraw land from production and vice-versa. In this case, it would promote the building of a agricultural production capacity buffering against the impact of price volatility, while providing environmental goods at the lowest opportunity cost. In this configuration, set-aside land could play a role beyond the provision of environmental goods by mitigating farm income volatility and even price volatility for processors or consumers of agricultural commodities.

1.2. Greening and the new challenges for modellers

Section 1.1 outlines the context of the research questions: the shift in the CAP from market-based policy instrument to farm-level decoupled subsidies and requirements. The introduction of the greening measures poses new methodological challenges for agricultural policy modellers. The greening measures are farm specific and intend to change the land allocation at farm level. Consequently, any ex-ante assessment should be able to take into account farm-level specificity and take up certain challenges. This section highlights the main modelling challenges associated with the greening of the CAP and then discusses our proposal to tackle them.

1.2.1. Challenges for modellers

- **Self-selection bias:**

The crop diversification measure aims to stimulate farms to adopt an additional crop within their crop plan. In a sample of farmers, farmers do not produce all available crops but a subset of them. The choice to produce or not reflects farmers' preferences, technological limitations, or environmental concerns, etc… In fact, the reasoning behind the farmer's decision whether or not to grow a crop is not known to policy modellers. This phenomenon is called the self-selection problem (Paris, 2001). It refers to the fact that a typical farm produces only a limited set of crops without a clear economic underpinning. In such situations, not accounting for farmer heterogeneity would yield inconsistent estimates of the impact of the crop diversification measure (Barrett et al., 2004; Crost et al., 2007; Kabunga, Dubois and Qaim, 2012).

- **Substitution patterns:**

One of the main challenges of agricultural policy models is that they lie at the interface between biological systems and the social system. The integration of nature and the social system exhibits complex relationships, playing at different scales (Antle and Capalbo, 2001). The substitution patterns between the different inputs are the essential relationships driving responses to policy or price shocks. Social scientists often take into account the embedded nonlinearity intrinsic to biological systems by approximating a production function via a Taylor polynomial. However, such an approach may have some drawbacks. First of all, we can question the interpretability of some estimated parameters such as interaction terms (Ai and Norton, 2003; Greene, 2010; Heckelei, Britz and Zhang, 2012; Mérel and Howitt, 2014). Second, nonlinear phenomena, such as threshold effects, are numerous. Biological systems may respond to an incremental change with a sudden regime shift. It is not only biological systems that may respond in a nonlinear fashion. Farm management decisions regarding the allocation and the expansion of inputs also exhibit threshold effects, for instance the substitution of maize forage by permanent grassland. The introduction of permanent grassland maintenance or ecological focus area requirements demands that policy modellers accurately simulate substitution patterns and their accompanying unknown threshold effects.

- **Aggregation bias:**

Policy impact assessments have been mostly carried out with a certain level of aggregation and this also applies to analysis of the greening measures (Pelikan, Britz and Hertel, 2015; Cortignani and Dono, 2015; Solazzo, Donati and Arfini, 2015). Such models often, aggregate and simplify representations of heterogeneous farm decisions. Often, representative farms are constructed representing a subset of farmers and encompassing all farmers' activities. Hence, aggregate models may display a different supply response from the actual aggregate behaviour of individuals. Aggregation was necessary due to data availability constraints, or computational difficulties in modelling all farmers. Aggregation was also performed to ensure representativeness. However, aggregated models implicitly assume a certain degree of substitution between farmers. For instance for a regional model, forage surplus of some farmers will compensate forage deficits of other farmers in the same region at no costs. In reality, forage might not always be tradable and certainly not without incurring a cost, leading to unrealistic results.

- **Uncertainty:**

The shift from market price supports to decoupled payment has exposed farmers to the intrinsic price volatility of agricultural commodities. Sckokai and Moro (2006) show the importance of assessing the impact of CAP reforms on farm income variability. So far, uncertainty has been mostly incorporated in "pure" econometric farm-level models (Oude Lansink, 1999; Carpentier et al., 2015). The introduction of risk and uncertainty in a farm-level model is challenging, since it often requires a larger amount of data than is available (Arata et al., 2014).

- **Data availability:**

One of the main challenges, which also relates to the abovementioned issues, is the availability of data. For the EU, only the Farm Accountancy Data Network (FADN) provides microeconomic data harmonised between MS and can be used to model the impact of farm income and land-use changes. However, FADN lacks representativeness for most variables except for holding size and holding specialisation. Despite a growing number of farm-level modelling exercises, most of the models are specified for a specific location and use other data sources, hence making the reuse of them difficult (Ciaian et al., 2013).

1.2.2. A non-parametric response

In the EU, one of the most widely used types of model to simulate the impact of the CAP is Positive Mathematical Programming (PMP). Heckelei et al. (2012) and Mérel and Howitt (2014) review the methodological developments and the applications of PMP. In order to account for the self-selection problem, Paris (2001) proposed using a symmetrical positive equilibrium problem methodology, where sample aggregated cost functions are used to derive the missing information in individual farms' cost functions for crops that are not cultivated. Unfortunately, a model based purely on statistics for gross margins of different crops cannot incorporate agent heterogeneity. In this study, we tackle the self-selection problem by proposing a non-parametric simulation model to predict land-cover changes, assuming that farmers may adopt the crop configuration of one of their peers.

One of the strengths of PMP is the explicit introduction of farm management practices (nitrogen use, tillage, irrigation etc.). However, it also requires econometric estimation of a production function, often a variable cost function, typically taking a quadratic form. The main disadvantage of econometrically estimating a production function lies in the rationalisation of the chosen functional form and in the bias due to functional form misspecification. Non-parametric approaches based on the identification of peers have also been used to estimate the impact of policy change. The main disadvantage of a non-parametric model is its sensitivity to noise. Hence, we perform an output validation for two methods, a parametric and a non-parametric approach, against synthetic data and assess the capability of the models in terms of revealing an unknown substitution pattern.

Based on the validation exercise, and in order to simulate the impact of the maintenance of permanent grassland and ecological focus areas, we develop a non-parametric farm-type regional model. This non-parametric farm-type regional model addresses the self-selection problem by assuming that farmers will adopt, either fully or partially, the activity mix of one of their peers or their own historical activity mix. The model addresses aggregation bias by simultaneously embedding individual production possibility constraints and partitioning farm-type regional responses into individual responses. To the best of our knowledge, it is the only study taking full advantage of the three dimensions of information available in FADN: unbalanced panel information at farm level, cross-sectional information at farm level and balanced panel information at farm-type regional level. Finally, such an approach enables us to introduce price uncertainty in a simple and straightforward way.

1.3. Objective and research questions

The objectives of this dissertation are threefold. First, we investigate the impact of the greening requirements at farm level on land-use change and, when data is available, on farm income. Second, we simulate alternative policies which could potentially achieve similar environmental targets. A premium per ha of permanent grassland could potentially support the livestock sector similarly to the current VCS but at a lower cost, while at the same time it insures the maintenance of permanent grassland. A CCCP for set-aside land could achieve the same level of set-aside at farm and regional level compared to the current requirement, while at the same time it could decrease production surplus in times of low commodity prices and reduce farm income volatility. Third, we develop a non-parametric mathematical programming model addressing self-selection bias, substitution patterns, aggregation bias and uncertainty. Specifically, this dissertation will seek to answer the following research questions:

(1). Does the greening measure, crop diversification, increase crop diversity?

(2). What is the opportunity cost for the maintenance of permanent grassland and could it be replaced by a premium per hectare?

(3). Does a CCCP for fallow land deliver similar environmental benefits to EFA and could it reduce farm income variability?

(4). What is the best approach to address the methodological challenges linked to the introduction of greening measures?

1.4. Outline of the dissertation

This dissertation is a compilation of individual studies where each study contributes to answering, either fully or partially, the abovementioned research questions. Each chapter can be read as a stand-alone piece of work where findings go beyond the overarching theme of the dissertation. Repetitions between chapters are kept to a minimum and references are made to other chapters when necessary.

Figure 1-1 presents the outline of the dissertation and how the different chapters address the modelling challenge described in section 1.2.1 and the greening measures and alternative policy instruments. Chapter 2 presents a non-parametric simulation model to predict land-cover changes while tackling the self-selection problem. We study the impact of crop diversification on land use and the Shannon diversity index (SHDI) is used as an indicator to measure the policy impact on crop diversity. Chapter 3 proposes an output validation methodology that enables researchers to test the performance of their model when they know that biophysical relationships might impact the underlying data-generating process. Two model types are compared: a parametric approach versus a non-parametric approach. Chapter 4 evaluates the impact of the maintenance of permanent grassland measure on farm income and land use and compares its efficiency to a premium per hectare for permanent grassland. The methodology developed further elaborates the methodology introduced in Chapters 2 and 3 while tackling the issue of aggregation bias. Chapter 5 simulates a CCCP for set-aside land by taking into account price uncertainty and its impact on farm income variability and land-use change. Finally, Chapter 6 concludes, provides some policy recommendations and possible future researches.

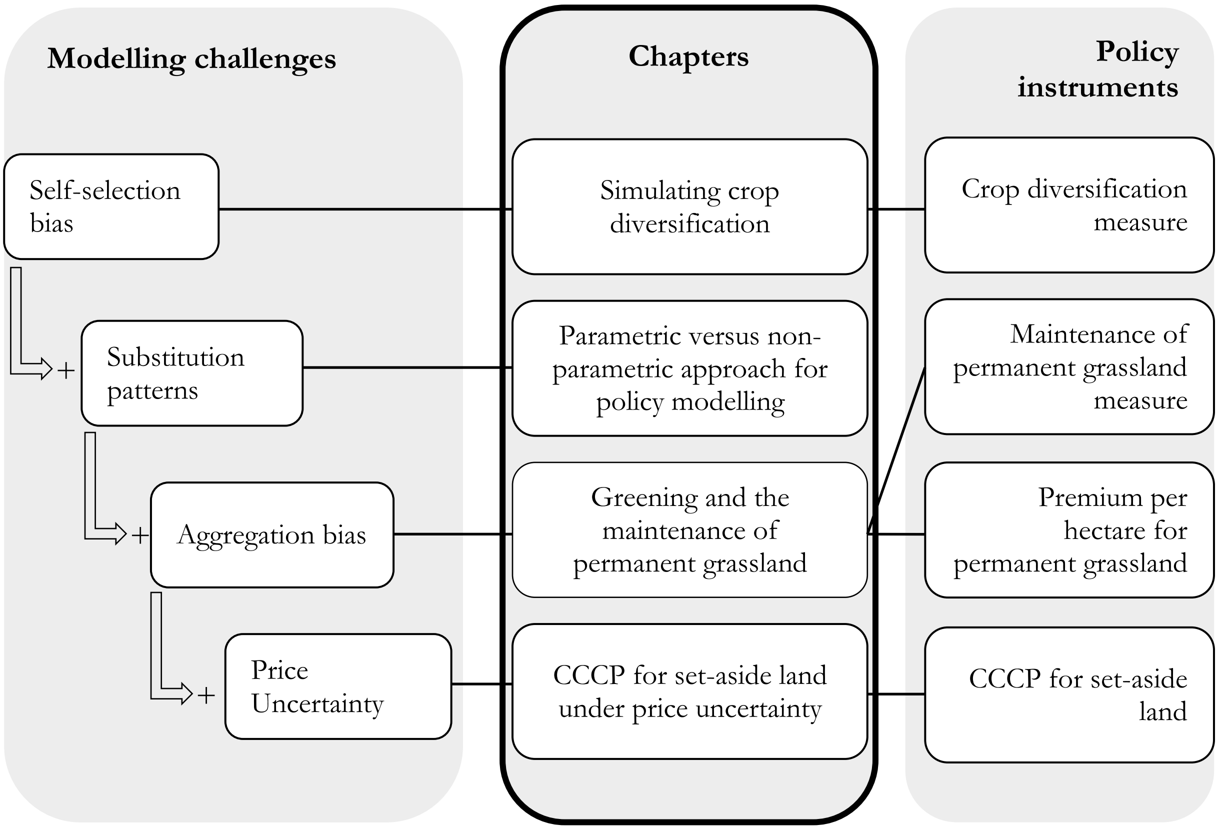

Figure 1-1. Outline of the dissertation and issues addressed by the different chapters

Chapter 2. Simulating farm-level response to crop diversification policy

Abstract

One of the new political instruments of the European Common Agricultural Policy-reform is the crop diversification measure. To comply with this measure, arable farmers will be required to grow a minimum number of crops on their land, in given proportions. In this paper, a non-parametric simulation model is developed to predict land cover changes while tackling the self-selection problem. Farmers' behaviour is based on their closest peer's behaviour. A comparison between the results for diversity, measured through the Shannon Diversity Index, and the policy impact on farms, shows a clear trade-off and the potential for targeting.

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2.1. Introduction

Agriculture is one of the most important land uses and its management practices have substantial impacts on the environment. Policy makers are trying to reduce the negative impacts and reinforce the positive ones through environmental regulation. One of the recent outcomes of this process is the greening of the EU's Common Agricultural Policy (CAP). One measure in this greening package, which aims to improve the diversity of agricultural landscapes, is crop diversification.

Evaluation of this measure is challenging for traditional policy simulation models. Assessing the impact using a regional simulation model is inadequate, because the policy measure is very specifically targeted at individual farm level. Crop diversification aims to stimulate farms to introduce an additional crop within their crop plan. Existing farm-level positive mathematical programming models (Buysse, Van Huylenbroeck and Lauwers (2007)) have difficulty with the evaluation of crop diversification because of the so-called self-selection problem. The self-selection problem refers to the fact that a typical farm produces only a limited set of crops without a clear economic underpinning (Paris, 2001). In order to tackle the self-selection problem and recover the missing price information for the non-produced crops at fam level, Paris (2001) used instead the average prices of the sample. Paris assumed that farmers are well aware of prices, costs, and technical coefficients for every crops and that this information is reflected by the average prices, accounting costs and technical coefficients. The missing information is recovered in a profit maximisation setting (see Paris, 2001). Hence, Paris' approach suffers from several limitations. First it does not account for non-economic factors to explain crop choices. Second, by using average prices, the advantages of incorporating agent-level heterogeneity are lost (Rounsevell, Robinson and Murray-Rust, 2012). Finally, the interpretation of the behavioural assumptions are debatable (Britz, Heckelei and Wolff, 2003)., Consequently, such models are also unable to deal with decisions about whether or not to produce an additional crop, whereas this is exactly what is needed to simulate the crop diversification policy measure.

Therefore, this chapter proposes and develops a non-parametric mathematical programming model based on peer behaviour, to predict the ex-ante impact at farm and landscape level. The Shannon diversity index (SHDI) is used as an indicator to measure the policy impact on crop diversity. This is currently the most widely used landscape diversity index and has been implemented within the CAPRI model[1] (Mittenzwei et al., 2007). The following section 2.2 is an introduction to the policy proposal analysed, followed by a methodological section 2.3, where the assumptions and the calculation of the model are described. Afterwards, section 2.4 outlines the simulated changes in farm-level crop allocations and landscape diversity. The final section 2.5 contains the conclusion, discussion and some suggestions for future research.

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[1] The Common Agricultural Policy Regionalized Impact model has been developed by European Commission research funds and is now the most widely used model by the European Commission to evaluate ex-ante impacts of the Common Agricultural Policy and trade policies on production, income, markets, trade, and the environment, from global to regional scale.

2.2. The EU's crop diversification measure

The latest reform of the CAP introduced that 30% of farmers' direct payments are conditional on three agri-environmental measures. The crop diversification measure aims to tackle the issue of decreasing diversity in agricultural landscapes - in other words the presence of monocultures. More diversified agricultural landscapes in time and space are supposed to increase soil- and ecosystem resilience (Weibull, Östman and Granqvist, 2003; Swift, Izac and van Noordwijk, 2004; Lin, 2011; Schouten et al., 2013). Farmers are required to have a minimum of two crops if they have between 10 and 30 ha of arable land[2]. If they have more than 30 ha, they need to have three crops. The first crop cannot cover more than 75% of the arable land, and in cases involving more than 30 ha of arable land, the first two crops are not allowed to cover more than 95% of the arable land[3] (Council of the European Union, 2012).

During the "trilogue" the European Commission (EC), the European Parliament (EP) and the Council of the European Union came up with their own proposals. Finally, a compromise was reached (further referred to as Final proposal). Some differences between these proposals are:

(1). Each proposal has different proportional requirements for different farm categories. The EC proposes to treat all farms above 3 ha equally. They need to have a minimum of 3 crops, the first of which should cover less than 70% of the arable land, the third should cover at least 5%. The EP, the Council and the final proposal have adapted requirements for smaller farms. Farmers with between 10 and 30 ha of arable land need to have 2 crops, and those above 30 ha 3 crops. Yet, there are some small variations in the percentages these crops should cover.

(2). The Council exempts some farms from diversification requirements. Those with large parts of their arable land covered with leguminous crops, grassland, herbaceous forage or fallow; as well as farmers who interchange parts of their land and provide in-crop rotation through this interchange. The EC exempts farmers with all of their arable land covered by grassland or fallow. The EP has no exemptions. The final proposal is a mixture of the three other proposals.

(3). It is also important to note that the Council adopts a different definition of 'crop' within its proposal. Additional to the EC and EP definitions of crops at genus level, the Council's proposal considers summer and winter varieties as distinct crops. Moreover, regarding the Brassicaceae, Solanaeceae, Cucurbitaceae families and the genus Triticum, the distinctions between crops are proposed at species level by the Council rather than at genus level. The Council's crop definition was adopted in the final proposal, except for the genus Triticum, which is treated as a genus as with

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[2] Arable land, as considered by the European institutions, hence in this paper, is distinct from land covered by permanent grassland and – crops. These permanent covers are non-rotational. They are considered as such as soon as they occupy the land for five consecutive years or longer (European Commission, 2011c)

[3] There are also a series of exemptions relating to land cover considered ecologically valuable, eg. grassland and land lying fallow (a complete overview of the final proposal can be found in (Council of the European Union, 2012)

most other crops (European Commission, 2011c; Council of the European Union, 2013a; European Parliament, 2016).

By simulating the impact of the different proposals, we indirectly capture the participation of small farmers to landscape diversity. Indeed, only the EC proposal requires that farmers below 10ha must grow three crops. We can also investigate the impact of the different grassland exemptions granted by the EC and Council, unlike the EP proposal which does not treat grassland differently. Finally, the definition of 'crops' in the Council proposal and in the final implementation give more flexibility to farmers. Keeping in mind that EC shall provide its first report on the performance of the CAP to the EP and the Council by the end of 2018 (European Commission, 2015b), a comparison of the different proposals is of particular interest by providing a chance to explore possible improvements.

To test the impact of the four proposals we model the impact of them in the Flemish case. The Flemish case is interesting because there are a lot of relatively small farms; it has a dominant crop (maize) and it has very detailed spatial information on the crops. The prime question is whether the different crop diversification proposals reverse homogenization. Although a positive relationship was found between the composition of a crop mosaic and biodiversity (Weibull et al., 2003; Swift et al., 2004; A. F. Bennett, Radford and Haslem, 2006; Billeter et al., 2007; Gardiner et al., 2009), we do not quantify or draw conclusions with respect to the policy impact on biodiversity. Hence, in this chapter, only the first step of the impact analysis on biodiversity is investigated, namely whether or not the crop diversification proposals increase crop diversity. The diversification requirement can be perceived as a public claim on former private property rights (Rodgers, 2009) and requires cautious implementation, which makes the standard ex-ante impact assessment procedures relevant (Thiel, 2009). The methodology suited to perform such an impact assessment is described in the following section.

2.3. Methodology

As explained in the introduction, neither regional nor farm-level positive mathematical modelling techniques are adequate to simulate the impact of crop diversification policies. Therefore, we choose another modelling route which is based on 'mimicking' behaviour, in the sense that we assume that farmers faced with the introduction of a new crop will act similarly to farmers who may already fulfil the crop diversification requirement. In other words, we assume they are likely to come to the same conclusion as other farmers in the same context. They might even copy the behaviour of a successful peer[4] (Polhill, Gotts and Law, 2001). This forms the basis of the proposed model.

To predict the reaction of farmer A to a newly imposed rule that requires him to change his crop allocation, we look at farmer B. The relative crop shares of farmer B are projected onto the total area of farmer A. To choose this farmer B we take the farmer who best matches farmer A in terms of crop

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[4] In the context of Chapter 2, 'peer' does not refer to the definition found in the Data Envelopment Analysis literature. Here, the word 'peer' is used to refer to a farmer that is selected given three variables: permanent grassland area, the number of crops grown, absolute crop area and distance (see model description).

allocation. Of course, only those farms with projections resulting in a new compliant crop configuration for farmer A are eligible to be farmer B. This type of approach focuses on observable proxies and the farmers' response. The model is built on the following four assumptions and, as we will discuss, the assumptions indirectly allow farmers' behaviour to reflect more objectives than simply maximizing profit:

(1). Farmers are rational, and try to get the maximum utility from their activity.
(2). The observed land allocation is optimal.
(3). Every non-compliant farmers want to comply and thus change their crop allocation.
(4). Apart from the crop diversification measure, all other things remain equal or constant

The first assumption is that every farmer wants to maximize utility. This is probably one of the most recurrent assumptions in agricultural economic models. Contrary to many models, we do not limit utility to profit (Debertin, 2012; Polhill et al., 2001). Since no explicit monetary value is used in the model, utility can be left undefined and comprise all elements considered by the farmer. The second assumption, that the observed land allocation is optimal, gives the model a positive basis (Buysse et al., 2007). The farmer optimizes his utility by making a decision on the crop allocation he perceives as optimal. This decision is determined by many factors (monetary- and non-monetary variables, social- and psychological factors, etc.).

A first implication of this second assumption is that any imposed deviation from the farmer's present allocation obstructs the maximization of his perceived utility. A second implication is that when a farmer changes his allocation due to the crop diversification rule, he would follow the reasoning of compliant farmers, since they have already made their optimal choices, determined by economic, social and other arguments. Both implications together imply that the existing, compliant crop combination that differs the least from the farm's current crop allocation can be used as a reference to predict a farmer's reaction to a newly imposed constraint - here, the crop diversification measure.

One of the advantages of this mechanism is that by looking at realized crop combinations, many factors can be taken into account - factors often unknown to, or beyond the possibilities of, modellers. For example, information on the relationships between crops, such as rotation and complementary machinery, or factors determined by the period when the crop choice is made, e.g. weather and prices. Many of these factors are equal or shared between farmers. This creates overlap in the individual decision-making contexts. By looking at the closest peer, this overlap is maximized.

A change from the current crop allocation to a new allocation is, in fact, a violation of the assumption of optimal choice made by farmers. However, since the environment changes, the optimal choice also changes. Hence, we introduce a third assumption, namely that all farmers want to comply. This is an overgeneralization. However, direct payments, becoming partially dependent on the crop diversification measure, form a considerable proportion of farm income (European Commission, 2011b).

For a more demanding greening package than the one actually discussed[5], it has been estimated that in Belgium the total average cost per eligible[6] hectare would be 117 euro. This overestimated cost still comes below 30% of the direct payments per hectare (European Commission, 2011b). From this we can infer that many farmers could be compelled to comply. Therefore, under the three assumptions indicated, we come to full, but minimal, compliance simulations.

The model decides upon peer farms based on the following four proxy variables: The first one is crop areas. By taking into account the individual crop areas we actually take into account three variables: which crops the farmers have in common, the area of those individual crops and the total farm area. Considering the latter, Danckaert, Deuninck and Gijseghem (2012)) showed that the diversification criteria, the number of crops and/or their proportional allocations, depend on the farm size. More precisely, small farms comply less with the proposed diversification requirements. This argument, together with the fact that policy makers are interested in the impact on different farm sizes and the structural change within the sector[7] (Buysse et al., 2007), makes it reasonable to use absolute crop areas as the matching variable. Second, as a small number of Flemish farms have a high number of crops and the idea is to simulate minimal compliance, the eligible peer farms are limited to those with a maximum of two types of crop more than the original farm. It is unlikely that a farmer will adopt a high number of new crops because of the crop diversification measure, but in some cases farmers will have to adopt a maximum of two new crops. For instance, a plus 30 ha mono-cropping farmer growing maize will have to comply with the new regulation by growing at least two additional crops. Since we simulate minimal compliance, the chosen peer farmer grows maize and (not more than) two other crops. A third variable, the geographical distance between the farms' communities, is also incorporated to further distinguish the peers. A lower distance goes together with higher chances of sharing economic, physical and social conditions. Genius et al. (2014) investigate the role of information transmission in promoting agricultural technology adoption and diffusion through extension services and social learning. They show that a larger stock of adopters in the farmer's reference group induces faster adoption while a greater distance between adopters increases time before adoption.

A fourth variable is linked to the permanent grassland[8]. In the reference year, because of the CAP's cross-compliance measures, Flemish farmers are also obliged to preserve their area of permanent grassland (Danckaert et al., 2012). This will be maintained under the greening measures. To receive the payments linked to the crop diversification measure, farmers will also have to maintain at least 95% of their permanent grassland (European Commission, 2011c; European Parliament, 2016; Council of the European Union,

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[5] Option 3 in the impact assessment of the European Commission, with 10% EFA and 70% green cover, identical crop diversification and permanent grassland requirements (European Commission, 2011b).

[6] Eligible agricultural area refers to the farm area eligible for direct payments.

[7] Two notes have to be made here. (1) Several proposals increased the lower threshold for the diversification rule, so the smallest farms no longer have to comply. (2) Farms that choose the small farmers scheme, a special measure that regulates the subsidies for small farmers, do not have to comply with the greening measures to receive their full direct payments (European Commission, 2011c).

[8] Grassland is classified as permanent as soon as it remains for 5 years on the same parcel (European Commission, 2011c). This is the same criterion as for permanent crops, hence it is not considered arable land.

2013a). In other words, lowering a farm's relative area of permanent grassland goes against the incentive for crop diversification. On the other hand, increasing the area of permanent grassland goes together with future limitations on land use, and thus decreasing land prices for the newly classified permanent grassland (Vanoost, 2007). To prevent unrealistic changes, the choice of reference farms B is limited to those with relative areas of permanent grassland within a range of 95–100% of the relative permanent grassland area of the non-compliant farm A. The inclusion of this variable is supported by expert opinions that indicate that farmers have developed a considerable fear of creating nature amenities because of limitations on future land-use decisions.

Finally, the fourth assumption is that all other factors remain equal, the so-called ceteris paribus condition. Inherent to ex-ante impact analyses is that one has to make an extraction of reality. One cannot know the farmers' future decision-making environment. Therefore it is assumed that the decision-making environment remains equal, which is a necessary simplification. However, it also allows analysis of the impact of the crop diversification measure, with less interference.

To implement the model, we use data on the region of Flanders in Belgium. Because of the obligatory, annual crop declaration for farmers there is a full coverage of data on farms' crop allocations. It is also an area which has some dominant crops, which is a problem targeted by the measure under investigation. The raw data on Flemish crop land is provided by the Flemish Agency for Agriculture and Fisheries. This dataset provides the cover for each agricultural parcel for the year 2012, for 24,839 farmers (Agentschap voor Landbouw en Visserij, 2012). Farms are categorized by communities (Agiv, 2000) and crops by crop categories.

Next we identify the closest peer to project its crop allocation onto the total area[9] of the original farm to make the latter compliant. Let us consider a set of n farms, with the possibility to have m different land uses. Among the different possible land uses, several need to be specified independently as they are related to different rules in the policy packages. Hence, c represents the different crops, p represents permanent grassland, g stands for temporary grassland, h is herbaceous forage, f is the index for fallow, and leguminous crops are indexed by I. Eq. (2.1) identifies the closest peer for farm n, referred to as *peer*. Variables are represented by Greek symbols. α is a dummy variable with value 1 if the conditions in (2.2) regarding the permanent grassland measure in the greening package are met, the high weight refers to the final assumption, without which it makes no sense to adapt the crop configuration. The same goes for β, a dummy variable with value 1 if the condition in (2.3) regarding the number of crops is met and where the presence of a crop on a farm is accounted for by δ a dummy variable. To make sure that no peer is selected with a high number of crops, each covering small areas, β receives a higher weight than the differences in crop areas. The area allocated to each crop is depicted by the variable σ. Eq. (2.1) takes the sum of the absolute differences in hectare per crop type between the farms. Finally, γ represents the geographical distance between the communities of the respective farms, to distinguish between farms with an equal

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[9] Both permanent and arable crops are included in the model.

outcome for the former variables - therefore a low weight. As can be noted, the substantial differences in weights attributed to the variables make the selection process function as a cascade. First, the selection is based on permanent grassland. This selection is followed by the criterion of the number of crops, then the crop areas. If there are still several peers in the selection, the distance should discriminate between them.

$$\text{Min } 10^6\ \alpha_{n,peer} + 10^3\ \beta_{n,peer} + \sum_c \left|\sigma_{c,n} - \sigma_{c,peer}\right| + 10^{-4}\gamma_{n,peer} \tag{2.1}$$

s.t.

$$if\ \ 0.95\ \frac{\sigma_{p,n}}{\sum_c \sigma_{c,n}} \leq \frac{\sigma_{p,peer}}{\sum_c \sigma_{c,peer}} \leq \frac{\sigma_{p,n}}{\sum_c \sigma_{c,n}}, then \tag{2.2}$$

$$\alpha_{n,peer} = 1, otherwise\ \ \alpha_{n,peer} = 0$$

$$if \sum_c \delta_{c,peer} \leq \sum_c \delta_{c,n} + 2, then \tag{2.3}$$

$$\beta_{n,peer} = 1, otherwise\ \beta_{n,peer} = 0$$

However, not all farms are eligible as representative farms. Each proposal has some options for compliance. For each of these, a subset of equations is added to the general Eqs. (2.1), (2.2) and (2.3), where the largest crop on a farm is represented by index 1, the second largest by 2 and the third largest by 3. The variable ρ is introduced to distinguish the arable area of a farm from the total area, because the latter also comprises permanent grassland and permanent crops. It is also necessary to introduce the star superscript, representing the variable under optimality after simulation, such as $\sigma^*{}_{c,n}$. More precisely, for the EC's "normal" way of compliance the policy constraints are:

$$if\ \ \rho_n^* > 3, then \tag{2.4}$$

$$\sigma_{1,peer} < 0.7\rho_{peer}\ and\ \sigma_{3,peer} \geq 0.05\rho_{peer} \tag{2.5}$$

$$or\ \rho_{peer} = \sigma_{g,peer} \tag{2.6}$$

$$or\ \rho_{peer} = \sigma_{f,peer} \tag{2.7}$$

Eq. (2.4) represents the requirement relating to the total arable area after the simulation. If the projected arable area is more than 3 hectares, the eligible peer farms have to comply with the rules represented in Eqs. (2.5), or (2.6) or (2.7). In Eq (2.5), the first crop cannot cover more than 70% of the arable area, while the third crop has to cover more than 5% of the arable area. The other options for compliance are exemptions. In Eq (2.6), the farmer is exempted if the area of arable land is covered by grassland. In Eq (2.7), the farmer is exempted if the area of arable land is laid fallow. Finally, Eq. (2.8) shows that if the project arable area is less than 3 hectares, the farmer is also exempted.

$$if\ \rho_n^* \leq 3, then\ no\ additional\ constraints\ the\ farmer\ n\ is\ exempted \tag{2.8}$$

For each combination of *n* and *peer*, the right set[10] of equations gives an outcome in Eq. (2.1). The combination with the lowest outcome for farm *n* is the basis for the final step, which is the projection of the new crop configuration on the total area of the affected farm. After this projection the formerly non-compliant farm becomes compliant[11]:

$$\sigma^*_{c,n} = \sigma_{c,peer} \times \frac{\sum_c \sigma_{c,n}}{\sum_c \sigma_{c,peer}} \tag{2.9}$$

Table 2-1 shows a full description of the indexes and variables used in our model.

Table 2-1. Description of indexes and variables

Indexes	Description
$\boldsymbol{n}$	Non-compliant farmers
$\boldsymbol{peer}$	Identified peer farmers
$\boldsymbol{m} = (\boldsymbol{c} \cup \boldsymbol{p} \cup \boldsymbol{h})$	Land use = crops, permanent grassland and herbaceous forage.
$\boldsymbol{c}$	Crops
$\boldsymbol{p}$	Permanent Grassland
$\boldsymbol{h}$	Herbaceous forage
$\boldsymbol{f}$	Fallow land
Variables	**Description**
$\boldsymbol{\alpha_{n,peer}}$	Binary variable for permanent grassland taking the value 1 or 0
$\boldsymbol{\sigma_{m,n}}$	Land cover *m* area of the non-compliant farmer (ha)
$\boldsymbol{\sigma_{m,\mathrm{peer}}}$	Land cover *m* area of the peer farmer (ha)
$\boldsymbol{\beta_{n,peer}}$	Binary variable for the number of crops taking the value 1 or 0
$\boldsymbol{\gamma_{n,peer}}$	Geographical distance between the non-compliant farmer and the peer farmer.
$\boldsymbol{\delta_{c,peer}}$	Binary variable taking the value 1 if the peer farmer grow the crop c or taking the value 0 if the peer farmer does not grow the crop.
$\boldsymbol{\rho_{n^*}}$	Arable area of the non-compliant farmer (ha)
$\boldsymbol{\rho_{peer}}$	Arable area of the peer farmer (ha)
$\boldsymbol{P_m}$	Relative share of Land cover *m* (ha)

An overview of the options and their respective set of equations can be found in Table 2-2. Note that the Council's compliance options relating to agri-environmental measures and the interchange of land are not modelled, nor is the option on interchange of land for the final measure modelled. This is due to uncertainty about future agri-environmental measures and insufficient data on the interchange of land.

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[10] In the EC scenario the possible sets are: 1–6/1–3, 7/1–3, 8/1–3, 9.

[11] Compliant farms remain the same since they will be the 'closest peer' to themselves.

Table 2-2. Overview of the proposals and their respective options and equations.

$\boldsymbol{\rho_{n^*}}$ **(ha)**	**n/peer requirements**	**Comments**
	European Commission	
≤ 3	/	Farms up to 3 ha are exempted
> 3	$\sigma_{1,peer} < 0.7\rho_{peer}$ $\sigma_{3,peer} \geq 0.05\rho_{peer}$	Proportional requirements for first and third crop
$= \sigma_{g,n^*}$	/	Farms with the arable land completely covered by grassland are exempted
$= \sigma_{f,n^*}$	/	Farms with the arable land completely lying fallow are exempted
	European Parliament	
< 10		Farms below 10 ha are exempted
≥ 10 and ≤ 30	$\sigma_{1,peer} < 0.8\rho_{peer}$	Respective proportional requirements
≥ 30	$\sigma_{2,peer} < 0.75\rho_{peer}$ $\sigma_{1,peer} + \sigma_{2,peer} < 0.95\rho_{peer}$	Respective proportional requirements
	Council of the European Union	
< 10	/	Farms below 10 ha are exempted
≥ 10 and ≤ 30	$\sigma_{1,peer} < 0.75\rho_{peer}$ or $\sigma_{1,peer} < \rho_{peer}$ $\sigma_{1,peer} = \sigma_{g,peer}$	Respective proportional requirements, incl. the derogation with relaxed proportions, but still two crops need to cover the arable land
≥ 30	$\sigma_{1,peer} < 0.75\rho_{peer}$ $\sigma_{1,peer} + \sigma_{2,peer} < 0.95\rho_{peer}$ or $\sigma_{1,peer} + \sigma_{2,peer} < \rho_{peer}$ $\sigma_{1,peer} = \sigma_{g,peer}$	
$\leq \frac{4}{3} \left(\sigma_{g,n^*} + \sigma_{f,n^*} + \sigma_{l,n^*} + \sigma_{h,n^*}\right)$	/	Exemption for farms where 75% of the total el. area is covered by grass (permanent–and/or temporary)
	Final adopted proposal	
< 10	/	Farms below 10 ha are exempted
≥ 10 and ≤ 30	$\sigma_{1,peer} < 0.75\rho_{peer}$ or $\sigma_{1,peer} < \rho_{peer}$ $\sigma_{1,peer} = (\sigma_{g,peer}\ or\ \sigma_{h,peer}\ or\ \sigma_{f,peer})$ $\{\sigma_{2,peer} < 0.75(\rho_{peer} - \sigma_{1,peer})$ or $\sigma_{2,peer} = (\sigma_{g,peer}\ or\ \sigma_{h,peer}\ or\ \sigma_{f,peer})\}$	Respective proportional requirements, incl. the derogation with relaxed proportions, but still two crops need to cover the arable land
$\leq \frac{4}{3} \left(\sigma_{g,n^*} + \sigma_{f,n^*} + \sigma_{l,n^*} + \sigma_{h,n^*}\right)$	$\rho_{peer^*} - \left(\sigma_{g,n^*} + \sigma_{f,n^*} + \sigma_{l,n^*} + \sigma_{h,n^*}\right) \leq 30$	Exemption for farms where 75% of the arable land is covered by grassland or other herbaceous forage, leguminous crops or lying fallow
Exemption related to eligible agricultural area		
$\frac{3}{4} \sum_{c} \sigma_{c,n^*} \leq \left(\sigma_{g,n^*} + \sigma_{f,n^*}\right)$	$\rho_{peer^*} - \left(\sigma_{g,n^*} + \sigma_{f,n^*} + \sigma_{l,n^*} + \sigma_{h,n^*}\right) \leq 30$	Exemption for farms where 75% of the total el. area is covered by grass (permanent–and/or temporary)

Finally, the last step is the evaluation of the crop landscape diversity in each proposal. Diversity matters more at landscape level than farm level (Swift et al., 2004), hence the SHDI is measured at community level (LAU2-level), which serves as a proxy for the former. The SHDI measures the number of crops, to calculate the richness (*m*), and also their relative shares (*P*), which are used to calculate the evenness (Weibull et al., 2003; Brady et al., 2009).

$$\mathrm{SHDI} = -\sum_{m} (P_m \times \ln P_m) \tag{2.10}$$

Also, the diversification efforts at farm level are measured, the number of adapting farms is calculated and the quantity and quality of land-cover changes; how much land and how many farmers are affected and which crops become more or less present.

2.4. Results

The simulated crop allocations are presented in this section. First, we look at the impact of the different proposals (Table 2-3). In the EC proposal, 35% of all farmers need to change their crop allocation to comply and 6% of the eligible farm area is affected. In the EP proposal, due to the exemption of farms below 10 ha and the moderate requirements for farms between 10 and 30 ha, only 11% of the farms need to adapt their crop configuration and 2% of the eligible farm area is affected. The Council's proposal has the lowest impact on farms as well as on eligible farm area. Only 8% of Flemish farms need to change their crop areas to comply corresponding to 1% of the eligible farm area being affected. This is because of the similar two thresholds system as in the EP proposal, and the adapted definition of crop, plus the exemptions relating to grassland, herbaceous forage, fallow land and leguminous crops. Hence, the Council proposal is the least constraining proposal for farmers. The final adopted crop diversification proposal is very similar to the EP's proposal in terms of impact. 11% of the farms are estimated to change their crop areas which affect 2% of the eligible area

Table 2-3. Non-compliant farmers and eligible farm area affected for all proposals

	EC	**EP**	**Council**	**Final**
% of non-compliant farmers	35%	11%	8%	11%
% of eligible farm area affected	6%	2%	1%	2%

Danckaert et al. (2012) calculate the number of non-compliant farmers per farm size categories for the first draft of EC's proposal using the same data source than us, but use 2010. In the first draft, the EC used another definition of crop than in the final EC's proposal used in this study, nevertheless Danckaert et al. found that the first draft of the EC proposal would result in a lower impact on farms with a larger area of arable land compared to their smaller counterparts. Figure 2-1 shows that these findings can be confirmed for the crop data from 2012 (Agentschap voor Landbouw en Visserij, 2012) in combination with the latest proposed crop definition from the EC (European Commission, 2012), the Council (Council of the European Union, 2013b) and the final definition (European Parliament and Council of the European Union, 2013a). Note also the difference in compliance in the EC and EP simulations among the largest farms, caused by the differences in proportional requirements (max. 70% vs 75% for the first crop).

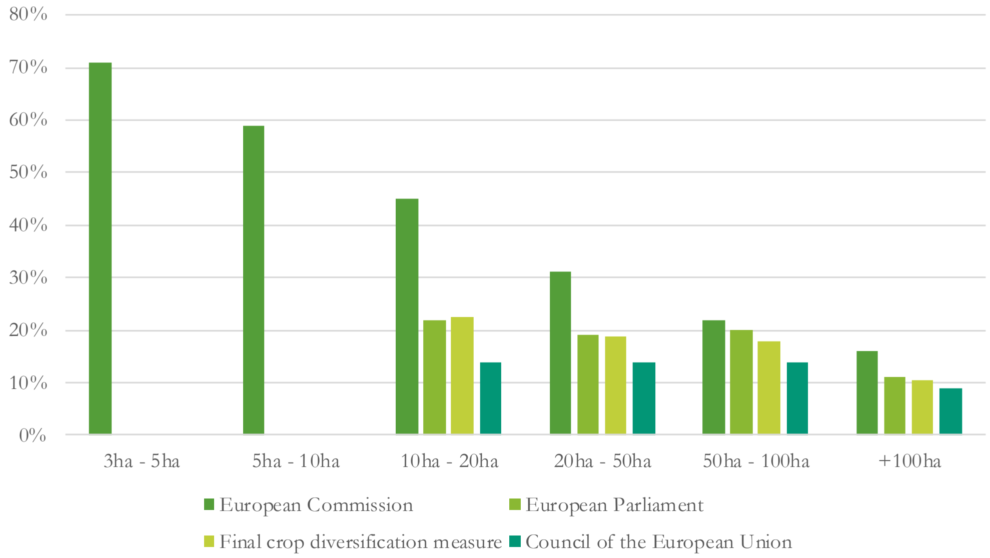

Figure 2-1. Non-compliant farms represented by arable area for all proposals.

As for the EC's proposal, the adapting small farms also change a higher proportion of their farm areas to become compliant. Figure 2-2 shows the average proportion of the total eligible farm areas adapted per affected farm. In the EP, Council and final proposal, the largest among the adapting farms seem to diverge most from their original crop configuration. This is partly because of the two threshold system with more stringent requirements for the farms above the second threshold. The EP's relaxed requirements for farms above the first threshold make the total adapted area in the respective category 61% smaller than in the EC case. The implementation in the EC's proposal of this isolated part of the EP amendments would result in a decrease of 22% in the EC's total adapted area. Regarding the smallest farms it should be mentioned that in the EC's proposal, 7,849 ha or 22% of the adapted farm area comes from farms below 10 ha.

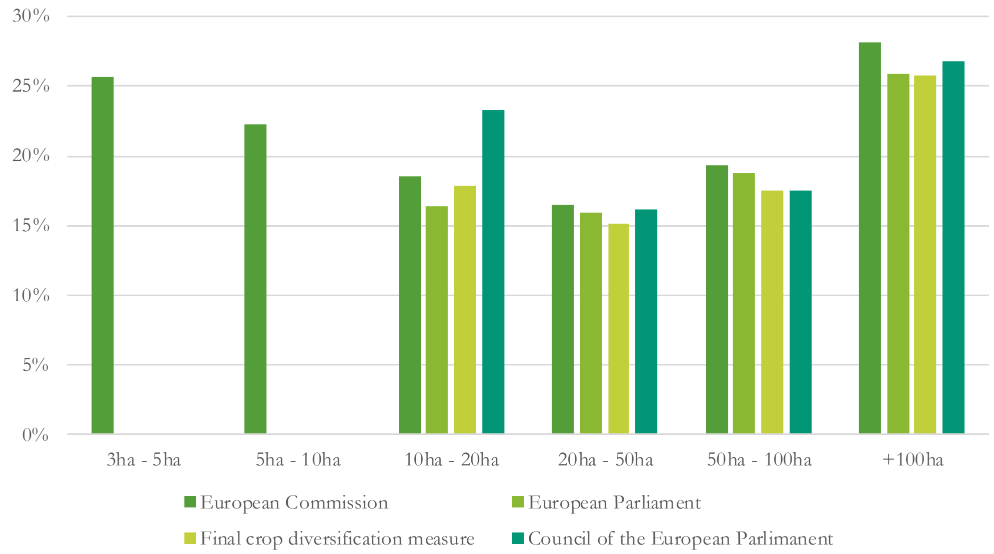

Figure 2-2. Average proportion of the eligible farm area adapted per affected farm, represented by total arable area.

Table 2-4 shows that a substantial part of the aggregated maize area goes to other dominant crops. This effect is the most pronounced in the EC's proposal, followed by the proposal of the EP and Council respectively (Table 2-4). Given that utility is left undefined and encompasses monetary and non-monetary factors while the overlap between individual decision-making context is maximised, the chosen crops are the ones maximising utility of the selected compliant peers. Hence, the chosen crops are the ones maximising utility of the selected compliant peers. If maize, winter wheat, potato and sugar beets are the most dominant crops in Flanders, it also likely that these dominant crops are grown by the selected compliant peers. In fact, dominant crops are the crops with the highest utility in Flanders. The different results for temporary grassland also indicate that the exemptions relating to grassland (EC and Council) have an effect on the aggregated grassland area.

Table 2-4. Changes in crop areas compared to the reference (2012).

	Before (ha)	**Eur. Commission (%)**	**Eur. Parliament (%)**	**Council of the Eur. Union (%)**	**Final measure (%)**
Maize	191 270	−7	−3	−3	−4
Permanent grassland	145 531	−1	0	0	0
Temporary grassland	84 713	+3	−1	+2	+2
Winter wheat	55.658	+6	+3	+2	+3
Potato	47 809	+8	+4	+2	+3
Sugar beets	22 250	+7	+4	+4	+4
Rest	86 179	+5	+3	+2	+2

The magnitude of changes in crop areas is in line with the changes to SHDI scores at community level. Table 2-5 shows that the EC proposal has the highest SHDI. It has the highest mean SHDI score, followed by the final measure, the EP and the Council, respectively. They all are higher than the mean SHDI score before the simulations. The Wilcoxon signed rank test (Table 2-6) was performed on the differences between the simulated proposals and the previous situation. The results indicate statistically significant increases to the SHDIs in all simulations. Also shown in Table 2-6 are the effect sizes. Since the data is non-normal, Cliff's delta was used to calculate these. Contrary to the robust statistical significance, there is considerable overlap between SHDI scores before and after the simulation. Nevertheless, the EC simulation has almost double the effect of the EP – and the final compromise proposal. It triples the effect of the Council's proposal.

Table 2-5. Descriptive statistics of the SHDIs at community level in all simulations.

	N	Mean	Std. deviation	Minimum	Maximum
EC	304	2.035	0.263	0.787	2.604
Final	304	2.001	0.277	0.796	2.594
EP	304	2.000	0.274	0.796	2.601
Council	304	1.992	0.277	0.796	2.573
Before	304	1.966	0.286	0.796	2.567

Table 2-6. Wilcoxon signed rank test and Cliff's delta. ([a] Based on negative ranks)

	EC – before	EP – before	Council – before	Final – before
Z	−14.251[a]	−15.087[a]	−15.087[a]	−15.087[a]
Asymp. Sig. (2-tailed)	0.000	0.000	0.000	0.000
Cliff's delta	−0.130	−0.070	−0.050	−0.070

2.5. Discussion and conclusion

Several researchers have proclaimed their doubts on the effectiveness of the crop diversification measure on farmland diversity and its farm-level impact (Murphy-Bokern and Stoddard, 2012; Westhoek et al., 2012; Matthews, 2012). This study has tried to respond to these doubts by elaborating a new approach for the modelling of farm behaviour. The results of this intuitive approach, applied to the Flemish case, showed that the implementation of the proposed diversification mechanism carries the potential of having the following effects.

Monocultures are the implicit target of the crop diversification measure. At landscape level, it is indeed maize, the most dominant crop, which would see the largest reduction in area. In this sense, the mechanism is effective. However, the largest part of the ‘freed’ area was absorbed by other dominant crops, which reduces the overall crop diversification effect at landscape level. The measure has, in its present form, limited effect at landscape level. It is advisable to conduct further research on this issue, on how the crop diversification measure can be refined to correspond with the series of goals it has to meet. A plausible research direction was indicated by Matthews (2012) who suggested targeting specific types of crop diversity through the definition of “crop”.

Contrary to the general trend of larger farms determining the impact of a land-use policy (Walford, 2002), small farms play a significant role in the overall diversification impact in Flanders. In the final measure, a discriminatory approach was taken, reducing the impact on small farms but also the diversifying impact. Because of this contradiction, and because there are other ways to achieve soil- and ecosystem resilience (Angileri, Loudjani and Serafini, 2011), which possibly yield similar diversity effects to the EC's proposal, further research on complementary mechanisms should be conducted, including the exemption implemented for farms practicing rotation and interchange of land and other types of landscape diversification (Lin, 2011).

With respect to the methodology, there are also some points of discussion and conclusions to be mentioned. Because of the trend reversal in largest farm impacts, less farms need to adapt their areas in this category, however, if they adapt, they change a larger proportion of their farm area. This might reflect reality but it might also indicate a weakness in the model, namely the dependence on closest peers. If the closest peer strongly differs from a given farm, the changes might be overestimated. Rare crop configurations have a higher chance of this type of overestimation since they have less (close) peers. For these farms, a more normative approach could be followed, where crop configuration projections would depend on the minimum requirements for compliance, i.e. a farmer would change to the threshold of compliance and no further, in between the old and projected crop configuration.

Related to this, is the problem of 'outdated' reference farms. The decision-making environment of 2012 will be outdated when the crop diversification measure comes into full force (2015). Due to the ceteris paribus assumption, the simulated results give an indication of what would have been the impact of an isolated implementation of the crop diversification measure in the reference year and region. Furthermore, due to the static nature of the reference farms, reactions based on their behaviour can be considered partially outdated. This is because coping strategies, and other dynamics specific to crop diversification, are not fully simulated - for example, diversification into winter and summer varieties. Ideally, the methodology developed should be part of a more dynamic model and comprise a wider geographical scope.

A third methodological issue relates to the unconsidered cropping possibilities. The option of non-compliance was not modelled. The crop diversification measure seems to induce a higher burden for some farm categories. Full compliance might be unrealistic in those categories. Additionally, two of the options for compliance in the Council's proposal were not modelled[12]. Hence, the reactions of a set of farmers might be different from those simulated, and is probably overestimated.

Depending on the policy context, the methodology might need some refinements to deliver accurate impact assessments. Nevertheless, we believe the methodology is innovating in the sense that it indicates a path through which the self-selection problem can be tackled. The model allows the many variables underlying cropping decisions to play, but could benefit from an ex-post validation. In terms of

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[12] The one for farms with agri-environmental schemes and for those who interchange their land.

policy impact analysis, it would be good to further investigate the effect on the broader biodiversity of both increasing crop diversity and the quality of that crop diversity.

Chapter 3. Parametric versus non-parametric approaches for policy modelling: a validation exercise in a controlled environment

Abstract

As agricultural policies continue to evolve, they integrate environmental and climatic concerns. Consequently, ex-ante impact assessment models for agricultural policies incorporate more components of environmental models. However, model validation remains a bottleneck in the development of models. This paper presents an output validation exercise against a synthetic dataset using two models, a parametric model versus a non-parametric model. We use a bio-economic model to generate data to reflect a real world scenario where non-linear relationships, such as biophysical relationships, exist. In general, the performance of a model is reduced by data heterogeneity or an increase in the uncertainty of input data. When the input data is a panel dataset, results show that the non-parametric and the parametric approach are unbiased and consistent. However, the non-parametric approach is more efficient for a small sample size. Furthermore, the non-parametric approach is less sensitive to data heterogeneity and data uncertainty and is therefore deemed superior to the parametric approach.

3.1. Introduction

One of the main challenges of agricultural policy models is that they lie at the interface between biological and social systems. We understand agricultural policy models as one or several model components used to predict the future impact of policy measures on agricultural, environmental and natural resources. The integration of these systems creates complex relationships that span different scales from micro to macro levels (Antle and Capalbo, 2001). Furthermore, the scope of agricultural policies has grown from farm income issues to environmental and societal issues (Buysse et al., 2007; Mattison and Norris, 2005) and it is becoming more relevant to accurately simulate the impact of policies on this complex system. For instance, the recent reform of the Common Agricultural Policy (CAP) in Europe has placed significantly more emphasis on the provision of public goods by farmers, such as biodiversity, landscape and climate stability (European Commission, 2013). In order to address market failure to account for environmental concerns, policy makers have introduced farm level policy measures. For instance, the greening requirements under the new CAP post-2013 has introduced three measures imposed at farm level and deemed beneficial for the environment and the climate. These measures intend to change the decision making process of farmers and the accompanying land use allocation choice. For instance, Chapter 2 illustrates the impact of the crop diversification measure on crop choices. Therefore, agricultural policy models need to account for farm specific context and inherit more structure and components from environmental models.

In order to model farm specific context and account for the production of externalities, three types of models are used in the literature: econometric models, Positive Mathematical Programming (PMP) models and Normative Mathematical Programming (NMP) models (Howitt, 1995; Buysse et al., 2007). Econometric and PMP models are rooted in the positive economic philosophy while NMP models are rooted in the normative economic philosophy. The distinction between positive and normative economics is sometimes hard to make because positive economic is often used as a tool to achieve normative goals. Normative economics is concerned by "what ought to be" and rather reflects value judgment, while positive economics is concerned by "what is". In a seminal paper, Friedman defines the role of positive economics "to provide a system of generalizations that can be used to make correct predictions about the consequences of any change in circumstances"(Friedman, 1953). In the context of agricultural policy models, researchers intend to predict what will be the impact of a policy change, hence any modelling approaches are framed within the positive economic philosophy. Therefore, in this study we focus on positive agricultural policy models which can only be judged by their predictive power. Unfortunately, the validity of models cannot be tested in a "controlled experiment" rendering it difficult to interpret results and reject hypotheses underlying the model structure.

It is well established in the literature that non-linearities exist in biophysical and ecological systems (Kinzig et al. 2006, Liu et al. 2007, Crépin et al. 2012, Schlüter et al. 2012) and that they are entangled with other hierarchical processes across space and time. Integrated assessment has been promoted as the answer to this multi-disciplinary challenge. The most common approach to integrate environmental and agricultural policy modelling is by developing "coupled component models" (Kelly (Letcher) et al., 2013). Coupled component models involve linking models from different disciplines, implemented at different scales to generate economic, environmental and social outcomes. These models are based on quantitative secondary data or outputs from sub-models and are used to predict the impact of policies.

Britz et al. (2011) demonstrates the effect of linking two modelling approaches to assess the impact of land changes and their impact on nitrogen input and nitrogen balance in Freiburg, Germany. They indicate that linking models is very relevant for policy simulation, but they acknowledge the lack of validation in such a large-scale integrated model.

Uthes et al. (2012) present three policy impact assessment tools and evaluate their policy relevance. While they acknowledge that each tool contributes towards better informed political decision-making, given their respective focus, they also identify some challenges to be addressed in future research. One of these recommendations is to focus on non-linearities and uncertainties at the level of individual components.

More recently, Doole and Marsh, and Daigneault et al. have exchanged their views on the New Zealand Forest and Agriculture Regional Model (NZFARM) (Landcare Research, 2016), including model validation (Doole and Marsh, 2014; Daigneault, Greenhalgh and Samarasinghe, 2014; Doole and Marsh, 2013). The NZFARM model aims to assess land use, farm management and environmental output responses to future policy scenarios. Data inputs often come from accounting databases, or have been simulated from other models. Hence, the NZFARM illustrates the typical difficulty in representing relationships between farm management and environmental processes at different levels. The main critic from Doole and March is the use of PMP for calibrating the baseline scenario. More specifically, they argue that the introduction of production function and its functional form specification are arbitrary. In fact, they suggest that the use of PMP invalidates the application of the NZFARM model, leading to arbitrary and counter intuitive output outside of the calibrated baseline. Finally, Doole and Marsh emphasise the absence of validation of the NZFARM model and state: "Meaningful output validation is necessary to provide confidence in the model to extrapolate away from sample data" The debate between Doole and Marsh, and Daigneault highlights the challenge behind the development of validation methodology and the need for clear communication from scientists on the validation framework used and their accompanying results.

In this study we perform a validation exercise. According to literature, verification is the process of establishing that the model performs as intended, while validation assesses the predictive power of the model (Aumann, 2007; Aumann, 2011; Jakeman, Letcher and Norton, 2006; Jakeman and Letcher, 2003; Doole and Pannell, 2013). Hence, verification is rather easily implemented and consists in debugging and ensures that the modeller does what he intended to do. However, the main concern of model validation is to choose the correct methodology and the correct model. This involves checking if the model accurately represents the initial data generating process (DGP) at play, in such a way that we cannot distinguish the output coming from the DGP or the developed model.

The contribution of this study to the literature is that only a few studies (Schwanitz, 2013; Bennett et al., 2013; Kanellopoulos et al., 2010; Janssen and van Ittersum, 2007) have attempted to validate the economic component of prediction models. We propose an output validation methodology that enables researchers to test the performance of their model when they know that biophysical relationships might impact the underlying DGP

The chapter is structured as follows: Section 3.2 discusses the proposed approach for output validation. Section 3.3 describes the DGP and the generated samples and performance criteria used in this study. Section 3.4 explains the parametric approach adopted in this paper. Section 3.5 illustrates the non-parametric methodology. Section 3.6 provides the results of our simulation exercise. Finally, Section 7 concludes, discusses limitations and further possible research.

3.2. Positive agricultural policy models

Farm level econometric models are widely used in the literature (Sckokai and Moro, 2006; Antle and Capalbo, 2001; Carpentier et al., 2015). The main limitation of econometric models is the large data requirement (Buysse et al., 2007), often leading researchers to develop models at a higher level of aggregation, such as sector level. However, by not accounting for farmers heterogeneity , self-selection bias can significantly impact model response (Koutchade, Carpentier and Féménia, 2015). In order to address the issue of data requirement and to account for biophysical processes, agricultural economists have increased the use of PMP. De Frahan et al. (2007). Heckelei et al. (2012) and Mérel and Howitt (2014) review the methodological developments and the applications of PMP. PMP enables the explicit introduction of farm management practices (nitrogen use, tillage, irrigation etc.), but also requires an econometric estimate of a production function, often a variable cost function, typically taking a quadratic form (Buysse et al., 2007). The main disadvantage of econometrically estimating a production function lies in the rationalisation of the chosen functional form and in the bias due to functional form misspecification. It is often assumed that a parametric approach is a good approximation of reality, however, only a few studies (Bennett et al., 2013; Kanellopoulos et al., 2010; Janssen and van Ittersum, 2007; Schroeder, Gocht and Britz, 2015) have attempted to assess the substitution patterns driving responses to policy or price shocks and so to validate the prediction performance of their models.

Taking into account farmer heterogeneity ultimately leads to tackle the problem of aggregation bias. McCarl (1982) addressed the problem of aggregation bias by developing a linear programming model, where the extreme points solutions reflect the full representation of the constraint sets of individual farms. Based on the Dantzig-Wolf algorithm, McCarl forced the solution of the linear programming problem to lie within the convex hull generated by a set of historical cropping patterns. It is interesting to note that two pans of literature, both forcing the solutions to lie within the convex hull of past observations, coexist in parallel but without ever being connected namely, the historical crop activities mixes (McCarl, 1982) and the inverse Data Envelopment Analysis (DEA) (Wei, Zhang and Zhang, 2000). In fact, both approaches lend themselves to a solution by the Dantzig-Wolfe decomposition algorithm, and both approaches can be qualified as Positive Linear Programming (PLP) model. PLP models originates from NMP models, however a fundamental distinction exist between them. PLP models assume that the observed input and output mixes at farm level are optimal which give their positive basis.

In the context of agricultural policy models, the inverse DEA approach has also been used to estimate the impact of policy change at farm level (Oude Lansink and van der Vlist, 2008; Frija et al., 2011; Speelman et al., 2009). In these studies, during the first step the authors estimate a production frontier defined by a convex hull around the technically efficient observations. In this configuration, inputs and outputs are used as parameters to determine objective values, and hence efficiency scores. During the second step, the model can estimate the changes required in inputs or outputs due to policy change, while preserving the initial technology frontier. The optimal solution is then a weighted average of observations, preserving the initial efficiency score.

We now illustrate the inverse DEA model and its solution method with a simple example. Let's consider one farmer for who we have observations for four years referred as (Year 1, Year 2, Year 3 and Year 4), using two inputs ($x_1;\ x_2$) and producing the same amount of output[13] each year. Figure 3-1 shows that the isoquant is defined by the extreme point solutions, which are historical observations, also called the efficient point. Note that in such configuration all observations are efficient observations. Year 4 is the initial situation, where the input prices of x_1 and x_2 are respectively 2.3 and 1 and are represented by the initial isocost line (plain line). Now, we simulate price changes of both inputs, and the new isocost line is depicted by a dash line. In order to maintain the efficiency score of the farmer (here 1), the model will move along the isoquant, in the meantime, the model tries to find a point that minimise cost. If we imagine a parallel shift of the new isocost line until it becomes tangent to the isoquant, the tangency point Year 1 is the inputs combination preserving the efficiency score of the farmer and minimising its costs under the new price conditions. Hence, the new simulated input mix is the one observed in Year 1.

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[13] The exposition could aslo be done by considering three different farmers or different output levels.

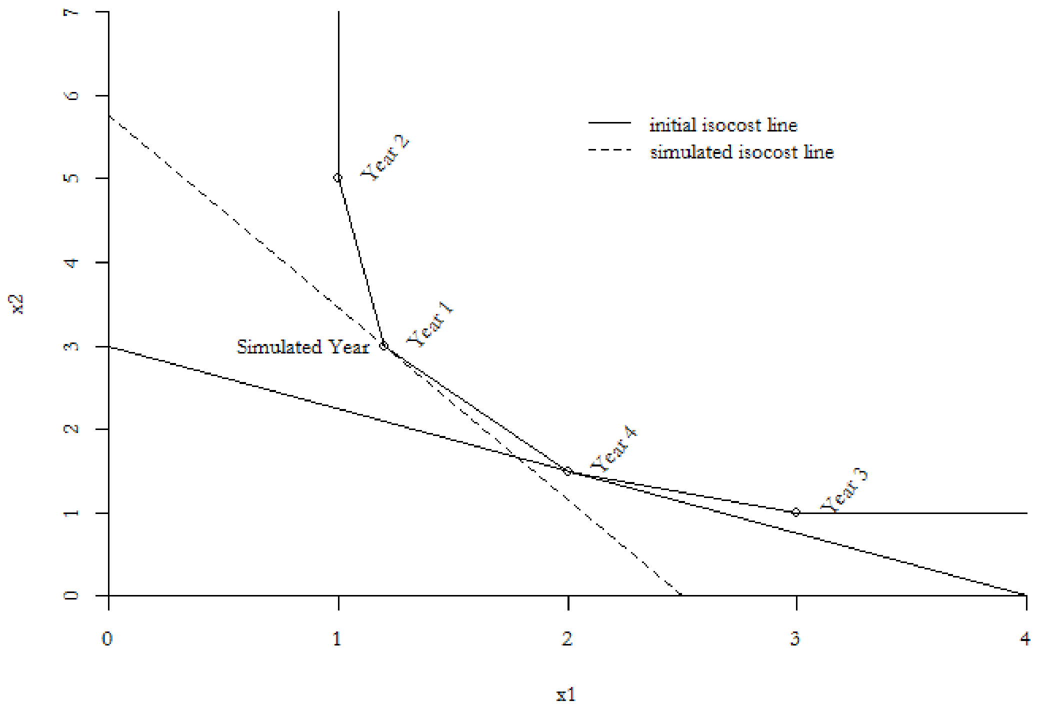

Figure 3-1. A simple example of the inverse DEA solution method

This simple example shows that the response to price changes is not linear but characterised by a stepwise response. The higher the number of observations, the more likely the steps are to be small and the response smooth. Hence, even though the inverse DEA model relies on fewer assumptions than the parametric approach, the non-parametric nature of such methodology renders it more sensitive to noise than an econometric approach. Indeed, there is no unique derivative at the extreme-(efficient) points. The discontinuity of the derivatives is an intrinsic property of the DEA methodology. To the best of our knowledge, despite its use to predict the impact of certain policy changes, the performance of non-parametric estimation of a production function using inverse DEA in order to predict future states has never been assessed.

If partial validation has been conducted against historical data and expert screening, model output validation should not rely solely on a peer-review process and traditional “historical matching” but also on the development of protocols (Jakeman and Letcher, 2003). Given the need to evaluate model performance (Aumann, 2007; Aumann, 2011; Jakeman, Letcher and Norton, 2006; Jakeman and Letcher, 2003; Doole and Pannell, 2013), we propose to test two production function estimation methods, an econometric and a inverse DEA approach, against synthetic data.

3.3. Proposed approach for output model validation

Doole and Pannell (2013, p. 94) recall three necessary conditions for effective model validation. These are:

(1). "Model structure to be consistent with the stylised facts of important system processes.
(2). Input data to be consistent with expected or reported values.
(3). Output to be consistent with expected or reported values for a range of scenarios."

In this paper, we focus on point (3): output validation. Output validation is an arduous task because ex-ante modelling aims to predict future states, while social scientists are never in a position to know the true underlying data-generating process. Therefore, the key issue is to quantify the model's capabilities, to reveal the underlying process and predict future states. Here, we focus on the capabilities of the model to reveal the underlying processes, and argue that these capabilities serve as a prerequisite for predicting future states. To achieve this, we propose to generate a synthetic dataset. Therefore, we rule out point (2), consistency of input data, since we have full control over it. However, in the real world, input data can exhibit wide variability due to different sources of uncertainty, such as inappropriate sampling or errors in the detailed sub-model. Hence, it is critical to evaluate the ability of the model to cope with input data uncertainty. To do this, we artificially introduce errors into our input dataset (see further discussion in Section 3.4.1). Finally, concerning the model structure in point (1), both parametric and non-parametric approaches do not comprehensively model the complex relationships taken into account by biophysical models. Instead, these approaches reduce the set to emerging and more likely behaviour. Hence, both approaches fail to satisfy point (1), but are often used in the literature. The validation of our model structure is tackled in a more flexible way and is discussed later in this paper.

Consequently, the objective is to compare two approaches that are applied in the literature, a parametric simulation versus a non-parametric simulation, and to then evaluate them against a known DGP. As we are in a policy modelling context, we use DGP to produce an input and output dataset expressed in physical units with additional price information.

To evaluate the performance of the methods, many authors have used a parametric specification for the DGP (Krüger, 2012; Banker, Gadh and Gorr, 1993). The disadvantage of using either a parametric or a non-parametric approach rooted in linear programming as a DGP is that the results are predictable and do not provide insights into the reliability of the methods when the DGP is not known.

Given that integrated assessments are being used more frequently, and that biophysical relationships might play a role between environmental and economic outcomes, we compare the results of both models against a DGP that is conceptually different from both the parametric and non-parametric policy models. Therefore, our approach uses a mathematical programming DGP based on Non-Linear Programming (NLP). We refer to this model as a bio-economic model, as it maximises profit subject to biophysical constraints. We chose a bio-economic DGP that is relevant to agricultural policy because biophysical, real world situation binding constraints are very common. Hence, any policy model should be able to reveal the small changes occurring at lower levels that subsequently impact on the higher levels. For both estimation approaches, we test whether or not estimators are consistent, whether or not they are biased and how sensitive the models are to input uncertainty. Finally, we assess the extent to which inferences can be drawn.

3.4. Data Generating Process

3.4.1. Specification of the DGP

In this paper we are simulating the optimal feed input ration of a dairy cow. To simplify the model, only three different feed inputs can be chosen and only one output is simulated, milk production. The objective of the model is to maximise profit given different input prices and output prices, subject to feeding constraints. This is computed using General Algebraic Modelling System (GAMS) software and as our model is a non-linear optimisation problem we use the CONOPT solver (see Appendix I).

For a sample of *J* observations with each observation *j (1* to *J),* where subscript *r* (1 to *R*, here *R*=1) and *k* (1 to *K*, here *K*=3) corresponds to outputs and inputs respectively, we can generate our data with the following non-linear optimisation problem (3.1):

$$Max_{X_{k,j},Y_{r,j}} \quad \pi_j = Y_{r,j} \times p_{r,j} - \sum_k (X_{k,j} \times p_{k,j}) \tag{3.1}$$

S.t

$$\begin{aligned} \sum_k X_{k,j} \times Intake_{capacity_{k,j}} & \\ &\le \left(d_j \times Max_{Intake_{capacity_j}}\right) + Max_{Intake_{capacity_j}} \\ &\quad + Conversion_{Factor_{capacity}} \times Y_{r,j}^2 \end{aligned}$$

$$\sum_k X_{k,j} \times Intake_{energy_{k,j}} \ge Min_{Intake_{energy}} + Conversion\_Factor_{enery} \times Y_{r,j}^2$$

$$\sum_k X_{k,j} \times Intake_{protein_{k,j}} \ge Min_{Intake_{protein}} + Conversion\_Factor_{protein} \times Y_{r,j}^2$$

where $Y_{r,j}$ and $X_{k,j}$ are the decision variables of output quantities and input quantities for each *j* observation. The model maximises the profit π_j given the fact that each observation faces different input prices $p_{k,j}$, and output prices $p_{r,j}$. Prices are drawn from a uniform distribution and reflect the feed characteristics in terms of energy, protein and maximum intake (see Appendix I). The first constraint ensures that the total feed intake does not exceed the maximum feed intake capacity of the cow.

We want to test the extent that sample heterogeneity impacts the predictive power of our tested model. Hence, for each sample size generated, we introduce four different disturbance term d_j. d_j is randomly drawn from the following distribution (3.2):

$$d_j \sim N(0; 0) \; or \; d_j \sim N(0; 0.05) \; or \; d_j \sim N(0; 0.15) \; or \; d_j \sim N(0; 0.2) \tag{3.2}$$

The disturbance term introduces different variances for the maximum feed intake capacity[14]. When the variance is zero, each observation is defined by an identical relationship between inputs and outputs. Thus, each observation has an identical maximum feed intake capacity. The generated dataset is considered as a time series for one dairy cow. The feed intake of one dairy cow is recorded for different prices that could have been observed at different points in time. As soon as the disturbance term is introduced on the right hand side of the first constraint, the maximum feed intake capacity is different for each observation. Hence, we can consider that we generate a dataset for several dairy cows at one point in time facing different prices. The second and the third constraint ensure that the respective energy and protein requirements are fulfilled. We also investigate the effect of the sample size using six different sample sizes: 1000, 500, 200, 100, 50 and 10 observations.

Researchers often assume statistical errors and input data uncertainty which may have different sources of origin, such as data collection errors. To address this, we also add an error term after simulation (3.3) that is randomly drawn from the distribution mentioned in (3.4). For each of the four possible distributions for d_j and e_j, knowing that they are mutually exclusive, we generate a dataset with the six different sample sizes and we obtain 36 samples[15]. These 36 samples are used later on to estimate the parametric and the non-parametric models.

$$X_{k,j} + e_j \times X_{k,j} \; with \; (k = 1,2,3) \tag{3.3}$$

$$Y_{r,j} with \; (r = 1)$$

$$e_j \sim N(0; 0) or \; e_j \sim N(0; 0.05) \; or \; e_j \sim N(0; 0.15) \; or \; e_j \sim N(0; 0.3) \tag{3.4}$$

Finally, we need points of reference against which the accuracy of both approaches will be tested. In the context of ex-ante agricultural policy models, we intend to predict, for instance, the change of inputs used due to price changes. Therefore, we implement price changes for inputs by simulating model (3.1)[16] holding output prices fixed. Subsequently, we only generate samples with different degree of heterogeneity d_j but without introducing a statistical error e_j. The number of samples generated after price changes,

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[14] The introduction of the disturbance term only has an impact if the maximum feed intake capacity is a binding constraint. We visually check that it was the case after simulation.

[15] In order to simplify the notation, samples generated from our DGP are in capital letters (X_j, Y_j) while the simulated inputs and outputs from the Restricted Linear Regression and the inverse DEA are in lower case letters (x_j, y_j).

[16] Problem (3.1) is a non-linear problem where we use the CONOPT solver. It should be noted that CONOPT does not guarantee an optimum solution, but rather a feasible solution. Additionally, for efficiency reasons, it is often recommended to specify initial starting values for the variables. In order to avoid bias and remain as close as possible to real situations, we use the set of initial inputs $X_{k,j}$ as initial starting values.

against which the parametric and the non-parametric model are tested, is lower.(16 samples). In fact we run the model (3.1) for the six different sample sizes and the four different disturbance terms d_j mentioned in (3.2). Then, we obtain the following set of inputs and outputs:

$$\begin{aligned} &X_{k,j}^{*} \; with\; (k = 1,2,3) \\ &Y_{r,j}^{*} \;\; with\; (r = 1) \end{aligned} \tag{3.5}$$

$X_{k,j}^{*}$ and $Y_{r,j}^{*}$ are the new set of inputs and outputs respectively, optimising profit under the new input price conditions. It should be noted that the new input prices are drawn from the same distribution as the initial prices. In other words, the parametric and the non-parametric model are tested within the initial production set, and the performance of the models outside the production range is not assessed. This will indicate how well estimated parametric and non-parametric models can simulate the same set of inputs $X_{k,j}^{*}$ and output $Y_{r,j}^{*}$ after price changes, using the dataset $X_{k,j} + e_j \times X_{k,j}$ and $Y_{r,j}$ for their estimation.

3.4.2. Simulation Scenario

The models tested are the parametric model, "Restricted Linear Regression model" (RLR) versus the non-parametric linear programming, Inverse DEA model under Variable Return to Scale (IDvrs) (see Section 3.6). We refer to the parametric approach as a restricted model as we impose the economic properties of a production function, such as monotonicity and concavity. Figure 3-2 provides an overview of the comparison procedure:

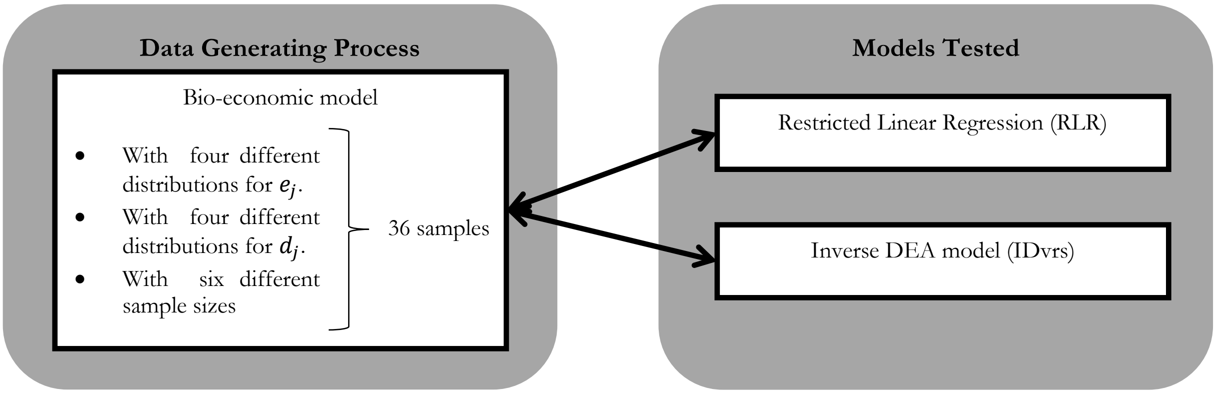

Figure 3-2. Simulation design

3.4.3. Performance criteria

The accuracy of the simulation models can be defined by their bias and their efficiency. Different types of statistical bias exist, including measurement, sampling, and estimation (Walther and Moore, 2005). Measurement and sampling bias refer to the intrinsic structure of the dataset and do not usually disappear with an increase in sampling effort. In our simulation, measurement bias is captured by the introduction of the error term e_j in the DGP. Sampling bias is not introduced and thus not considered in this paper. Estimation bias is the difference between the estimated input changes and the "true" input changes due to price change. Estimation bias should decrease with an increasing sample size. The model could be unbiased, so it is important to take into account the variance. Indeed, if the model is biased, an increase in the sample size simply decreases the variance around a wrong estimate. On the other hand, if both the variance and bias tend towards zero our model is consistent.

Bias measures typically account for the difference between the estimated value and the true value. One common measure is the Mean Deviation (MD), which is the difference between the new quantities of the input mix and output after price changes from the DGP (noted $X^*_{k,j}$, and $Y^*_{r,j}$), and the predicted quantities of the input mix and output after price changes calculated in the different scenarios (noted $x^*_{k,j}$ and $y^*_{r,j}$). Another indicator is the Mean Absolute Deviation (MAD). It considers the difference between the estimated input changes and the true input changes, but also eliminates the direction of the difference, which considers the variance of the estimates. The MAD assesses the overall consistency of the model taking into account bias and efficiency. The mathematical formulae of the MD and MAD for inputs and outputs are as follows: (3.6):

$$MD = \left[\sum_j \sum_k \left(X^*_{k,j} - x^*_{k,j}\right) + \sum_j \sum_r \left(Y^*_{r,j} - y^*_{r,j}\right)\right] \times \frac{1}{J \times R} \tag{3.6}$$

$$MAD = \left[\sum_j \sum_k \left|X^*_{k,j} - x^*_{k,j}\right| + \sum_j \sum_r \left|Y^*_{r,j} - y^*_{r,j}\right|\right] \times \frac{1}{J \times R}$$

To gain additional insight, we also used graphical descriptive statistics, such as a boxplot of the MD, as a performance criterion.

3.5. The parametric approach

As a parametric approach, we test a very flexible functional form as it promises a better fit to the data. We tested several polynomial functions until the fourth order. However, in the interests of parsimony we only present the results of the most relevant one, a cubic production function. When necessary we omitted the non-significant parameters. Unfortunately, a third order flexible functional form comes at the cost of violating economic properties such as monotonicity and curvature. Therefore, we impose concavity and monotonicity for each observation permitting a choice of input levels that maximize profit (Lau, 1978) and refer to our model as the RLR model.

We use Ordinary Least Square methodology to estimate the unknown parameters. We can derive the following non-linear optimisation problem (3.7) where subscript *j (1* to *J*) is observation, subscripts *k*, *l* and *m* (1 to *K*) represent inputs and subscript *r* (1 to *R*) is output. We also include the aforementioned term e_j. $Y_{r,j}$ and $X_{r,j}$, obtained from problem (3.1).

$$Min_{\beta_k,\delta_{k,l},\gamma_{k,l,m}} \sum_j \varepsilon_j^2 \tag{3.7}$$

S.t
$$Y_{r,j} = \alpha + \sum_k \beta_k (X_{k,j} + e_j \times X_{k,j}) + \sum_k \sum_l \delta_{k,l} (X_{k,j} + e_j \times X_{k,j})(X_{l,j} + e_j \times X_{l,j}) + \sum_k \sum_l \sum_m \gamma_{k,l,m} \big(X_{k,j} + e_j \times X_{k,j}\big)\big(X_{l,j} + e_j \times X_{l,j}\big)\big(X_{m,j} + e_j \times X_{m,j}\big) + \varepsilon_j$$

$$\frac{\partial Y_{r,j}}{\partial (X_{k,j} + e_j \times X_{k,j})} \geq 0 \; for \; r = 1, \dots, R \; and \; k, l, m = 1, \dots, K$$

$$\frac{\partial^2 Y_{r,j}}{\partial^2 (X_{k,j} + e_j \times X_{k,j})} \leq 0 \; for \; r = 1, \dots, R \; and \; k, l, m = 1, \dots, K$$

where $\alpha, \beta, \delta \; and \; \gamma$ are the parameters to be estimated. Here, it is important to note that $X_{k,j}$ and $Y_{r,j}$ contrary to the model in (3.1) are not decision variables, but actual input and output values. According to economic theory, *Y* must be monotonic and concave. The first and second constraints ensure local monotonicity and concavity respectively.

Once we have estimated the production function we can simulate changes in input mix and output due to a change in input prices. We then solve the following non-linear optimisation model (3.8):

$$Max_{y_{r,j} x_{k,j}} \sum_j \left[y_{r,j}^* \times p_{r,j} - \sum_k (x_{k,j}^* \times p_{k,j}^*) \right] \tag{3.8}$$

S.t
$$y_{r,j}^* = \alpha' + \sum_k \beta_k' x_{k,j}^* + \sum_k \sum_l \delta_{kl}' \; x_{k,j}^* x_{l,j}^* + \sum_k \sum_l \sum_m \gamma_{klm}' x_{k,j}^* \, x_{l,j}^* x_{m,j}^*$$

$$\frac{\partial y_{r,j}^*}{\partial x_{k,j}^*} \geq 0 \; for \; r = 1, \dots, R \; and \; k, l, m = 1, \dots, K$$

$$\frac{\partial^2 y_{r,j}^*}{\partial^2 x_{k,j}^*} \leq 0 for \; r = 1, \dots, R \; and \; k, l, m = 1, \dots, K$$

where $y_{r,j}^*$ and $x_{k,j}^*$ are the decision variables maximising profit under the new input price conditions $p_{k,j}^*$ subject to the production function constraint estimated in problem (3.7), monotonicity and concavity constraints. The model (3.8) estimates the optimal $x_{k,j}^*$ and $y_{r,j}^*$ given the estimated parameters α', β_k', δ_{kl}' and γ_{klm}' derived from model (3.7).

3.6. The Inverse DEA approach

Wei extended the inverse optimization problem beyond efficiency measurement, to the DEA framework for short-term input and output estimation (Wei et al., 2000). In this configuration, inputs and outputs are used as parameters to determine objective values. The model can estimate the changes required in the input combination due to policy change, while preserving the initial technology frontier. The model is input oriented and exhibits variable return to scale (VRS). Input substitution is feasible given the change in policies. The procedure has two steps. First, the firm-level inefficiency is measured with DEA and secondly, the observed peers are used as a piece-wise linear technology frontier during simulation.

3.6.1. Estimating the production technology with DEA

DEA uses linear programming methods to construct a non-parametric piece-wise frontier which envelops the observed input and output data for all observations. In this paper, we used the DEA models under constant and variable return to scale (Banker, Charnes and Cooper, 1984). For a given observation, denoted with the subscript *o,* we can derive the following linear problem, known as the *envelopment form* (3.9):

$$Min_{\theta,\lambda_j}\,\theta_o \tag{3.9}$$

$$\text{S.t.}\quad \sum_j \lambda_j Y_{r,j} - Y_{r,o} \geq 0$$

$$\theta_o(X_{k,o} + e_o \times X_{k,o}) - \sum_j \lambda_j (X_{k,j} + e_j \times X_{k,j}) \geq 0,$$

$$\lambda_j \geq 0$$

$$\sum_j \lambda_j = 1$$

where θ is a scalar and λ is a $J \times 1$ vector of constants and both are the decision variables. Here again, note that $X_{k,j}$ and $Y_{r,j}$ contrary to the model in (3.1) are not decision variables, but actual input and output values. The value of θ obtained is the technical efficiency (TE) score for the *j*-th firm. The value of θ lies between zero and one, where one indicates that the considered observations are on the frontier and so technically efficient. The problem (3.9) must be solved *J* times, once for each observation denoted with the subscript *o*.

3.6.2. Inverse DEA simulation

The second step is to apply an Inverse DEA model (IDvrs) to simulate the impact of policy changes, such as an input price change $p^*_{k,j}$. Here, we need to calculate the new optimal input level given the new prices for a given observation noted $x^*_{k,o}$which maximises revenue while at the same time preserving the TE score of DMU*o* found in problem (3.9). We can derive the following linear problem (3.10):

$$\underset{\lambda_{jpeer}, y^*_{r,o}, x^*_{k,o}}{Max} \sum_r p_{r,o} y^*_{r,o} - \sum_k p^*_{k,o} x^*_{k,o} \tag{3.10}$$

S.t.

$$\sum_{jpeer} \lambda_{jpeer} Y_{r,jpeer} \geq y^*_{r,o}$$

$$\sum_{jpeer} \lambda_{jpeer} X_{k,jpeer} \leq \theta_o{}' x^*_{k,o}$$

$$\lambda_{jpeer} \geq 0$$

$$\sum_{jpeer} \lambda_{jpeer} = 1$$

The model maximizes the profit for observation *o* given its output price $p_{r,o}$ and its new input prices $p^*_{k,o}$. The constraints make sure that the efficiency score $\theta_o{}'$ derived from model (3.9) remains the same and *jpeer* refers to the peer observations defining the production frontier. In other words, *jpeer* are the observations in model (3.9) with an efficiency score of one and, consequently, they are the support points for the piece-wise production frontier. The new optimal input vector $x^*_{k,o}$ and output vector $y^*_{r,o}$ calculated by the model maximise profit under the new market conditions and preserve the initial efficiency score.

3.7. Results

First, we examine the MAD and MD for the IDvrs and the RLR models over six sample sizes and with d_j=e_j=0. The solid lines in Figure 3-3(A) show the changes in the MAD scores with changing sample size, while the dashed line illustrates the impact of the sample size on the MD scores.

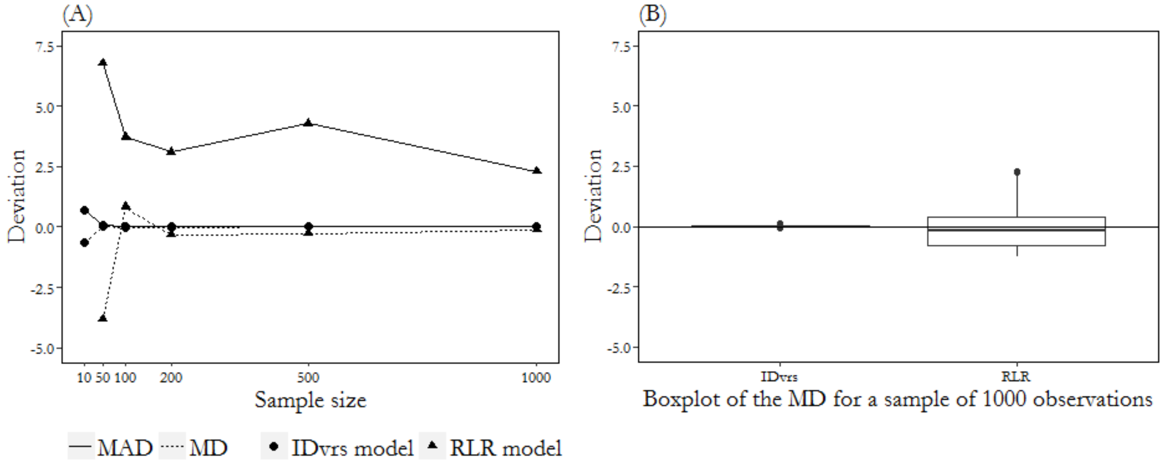

Figure 3-3. MAD and MD of the different tested models from a DGP with d_j=e_j=0[17]

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[17] Note, that from a sample size of 50 to 1000 observations, the MAD and the MD of the IDvrs models are close to zero. As a results both lines are confounded with the horizontal axis.

In this ideal scenario, we can consider that our DGP generates a time series dataset for one dairy cow for different prices, free of measurement bias (see Section 3.4.1). Figure 3-3(A) shows that the MD for the RLR and the IDvrs models both converge towards zero. For small sample sizes, the IDvrs model performs better than the RLR model. The MD of the IDvrs model is close to zero for a sample size of 10 observations, while the RLR starts to converge towards zero from a sample size of 100 observations. The non-parametric approach does not require a large sample size, and in the context of a panel dataset, 10 observations appear to be sufficient for reliable results.

If we look at the variance of both models, the MAD of the IDvrs model in Figure 3-3(A) converges towards zero, but the MAD of the RLR model converges towards a value. Figure 3-3(B) shows the boxplots of the MD from the IDvrs model and the RLR model. Recalling that the efficiency is measured by the variance of our estimates, we can observe that the variance of IDvrs is almost zero, demonstrating that the model is unbiased, consistent and hence efficient. The interquartile range (IQR) for the RLR's boxplot is still low. Hence, the RLR model is unbiased but less efficient. In such a setting, where each observation results from the same technology, and without any data collection errors, both modelling approaches are efficient.

In the second step of the assessment, a disturbance term d_j or an error term e_j, are introduced in the specification of our DGP. By introducing a disturbance term within the feed intake capacity constraint, we introduce variation in the stomach capacity of ± 5%, 15% and 20%. Therefore, we do not simulate the DGP of one cow but of several cows, indicating that it mimics the situation of cross-sectional data. The first column of Figure 3-4 and Figure 3-5 illustrate the impact of the introduction of d_j on the MAD and the MD of both models. As real datasets contain some measurement errors, we also investigate the impact of error term e_j. This is illustrated in the second column of Figure 3-4 and Figure 3-5. We introduce ± 5%, 15% and 30% in the three inputs used. In both situations, the introduction of the disturbance term d_j excludes the introduction of the error term e_j and vice versa.

The first column of Figure 3-4 shows that the IDvrs model performs better than the RLR model. For d_j randomly drawn from *N~(0,0.05)*, the MD of the IDvrs converges towards a value close to zero, so the model is consistent but slightly biased upward. Similar findings can be drawn from the MAD's trend. The MAD of the IDvrs model converges with an increase in the sample size, so the model is consistent but towards a value, meaning the model is biased. With an increase in the variance of d_j, the performance of the IDvrs model decreases. The MAD and MD are stable around a value, which indicates that the model is consistent, although bias increases along with the heterogeneity of the sample. In fact, the introduction of the disturbance term d_j does not change the value θ_o found in problem (3.9). In problem (3.9) we assume a single technology for all observations. Therefore every observation is technically efficient, but the scale efficiency could differ. In problem (3.10), we simulate changes in inputs and output due to changes in input prices. However, we define only one technology for all cows, while in reality each cow has a different stomach capacity, hence different technologies. Consequently, a cow can 'adopt' the input mix and output of another one that it is the most profitable given the new market conditions. As a result, given the fact we introduce a disturbance term in the maximum intake capacity constraint and that this constraint is binding, one cow might adopt the input mix and output of another cow with a bigger stomach capacity. This explains why the IDvrs overestimates the changes in inputs and output when the variance of d_j increases.

For the RLR model, the MD does not converge clearly towards a value. The performance of the model decreases with increased sample heterogeneity. Our results show that the RLR model is more sensitive to the heterogeneity of the dataset. However, even though the MD or the MAD of the RLR are not zero, the lack of a clear trend with an increase in the sample size questions the consistency of the model. For the most extreme case where d_j is randomly drawn from *N~(0,0.2)*, the MAD and the MD increase along with the sample size.

Although IDvrs appear to have a greater performance, such non-parametric methods rely heavily on the quality of the dataset and are sensitive to noise. The second column of Figure 3-4 shows the impact of introducing an error term after generating the data. We recall that in such a configuration where the disturbance term $d_j = 0$, we generate a panel dataset where we introduce measurement bias. For the RLR and IDvrs models, the introduction of an error term increases the bias of the model, but both are consistent as the MD tends to converge towards a value.

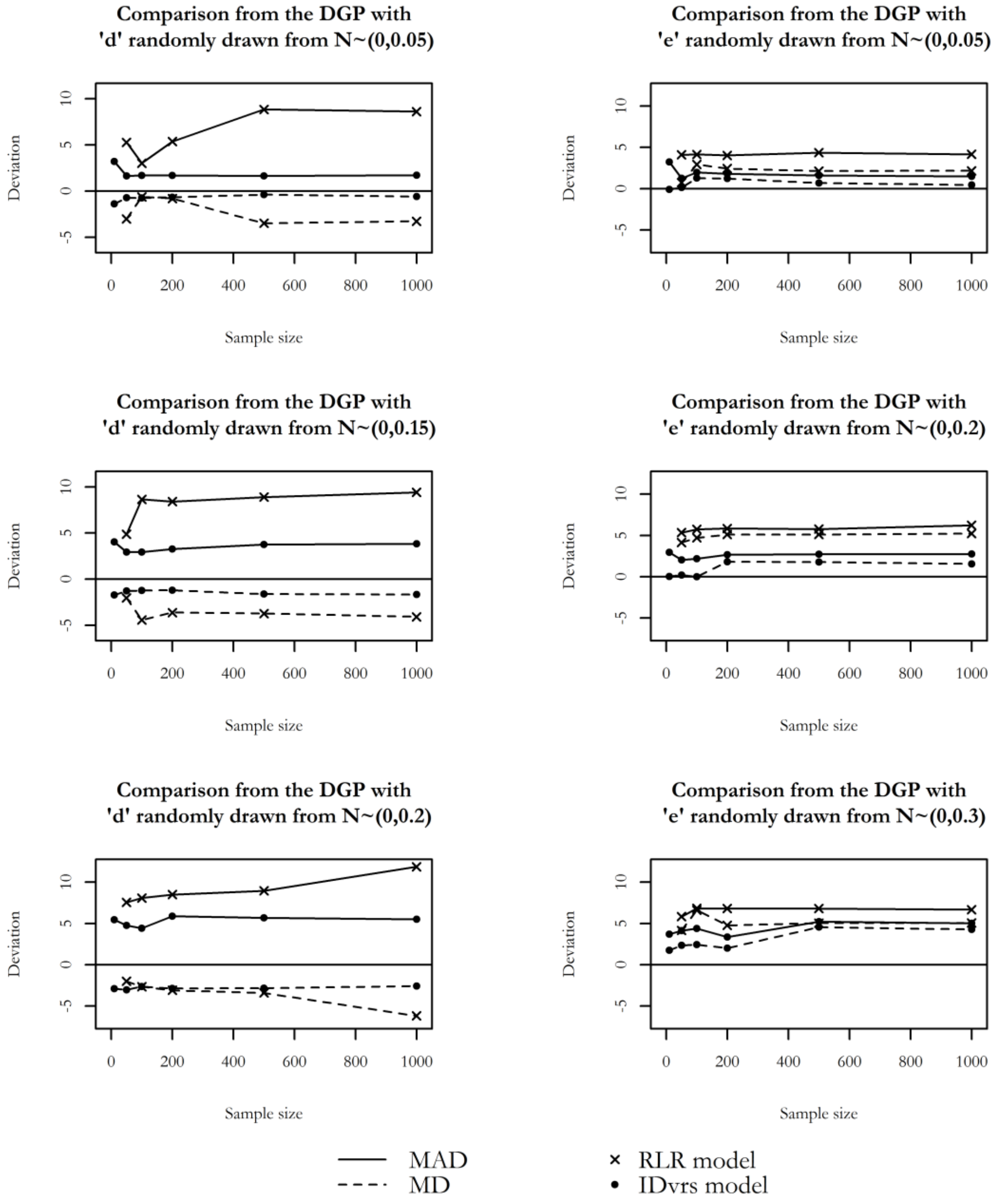


Figure 3-4. MAD and MD of the different tested models from a DGP including a disturbance term or an error term

Interestingly, both models are now underestimating changes in the input mix and output. By introducing an error term, some observations artificially perform better as they use fewer inputs to produce the same amount of output. In the case of the IDvrs, some observations are now technically inefficient and are benchmarked against observations that artificially perform better. Consequently, in problem (3.10), all observations are going to preserve their efficiency scores. However, their new input mix and output are a weighted average of the best performing artificial observations that use less inputs for the same amount of output. Similar reasoning can be applied to the RLR.

Figure 3-5 shows the variance of the MD for a sample size of 1000 observations for each scenario and demonstrates the efficiency of the model. The first column of Figure 3-5 shows the impact of the introduction of a disturbance term. For a variation of ± 5% in maximum intake capacity, the height of the notches and the IQR of the IDvrs remain small, indicating that the model is efficient. However, an increase in the variance of d_j results in a loss of efficiency of the model towards being more upward biased and with greater variance. The introduction of a disturbance term has a greater impact on the RLR model, especially in terms of model bias, while the variance increases slightly.

The second column of Figure 3-5 shows the impact of introducing the error term e_j. The variance of the MD for the IDvrs model increases with increasing e_j, but the IDvrs appears to cope better with uncertainty rather than the heterogeneity of the dataset. Indeed, the height of the IQR notches are smaller than when d_j is introduced. However, the model becomes more downward biased with an increase in e_j. For the RLR model, the variance of the MD remains large. Furthermore, the presence of outliers when e_j is randomly drawn from *N~(0,0.3)* demonstrates the model's lack of efficiency.

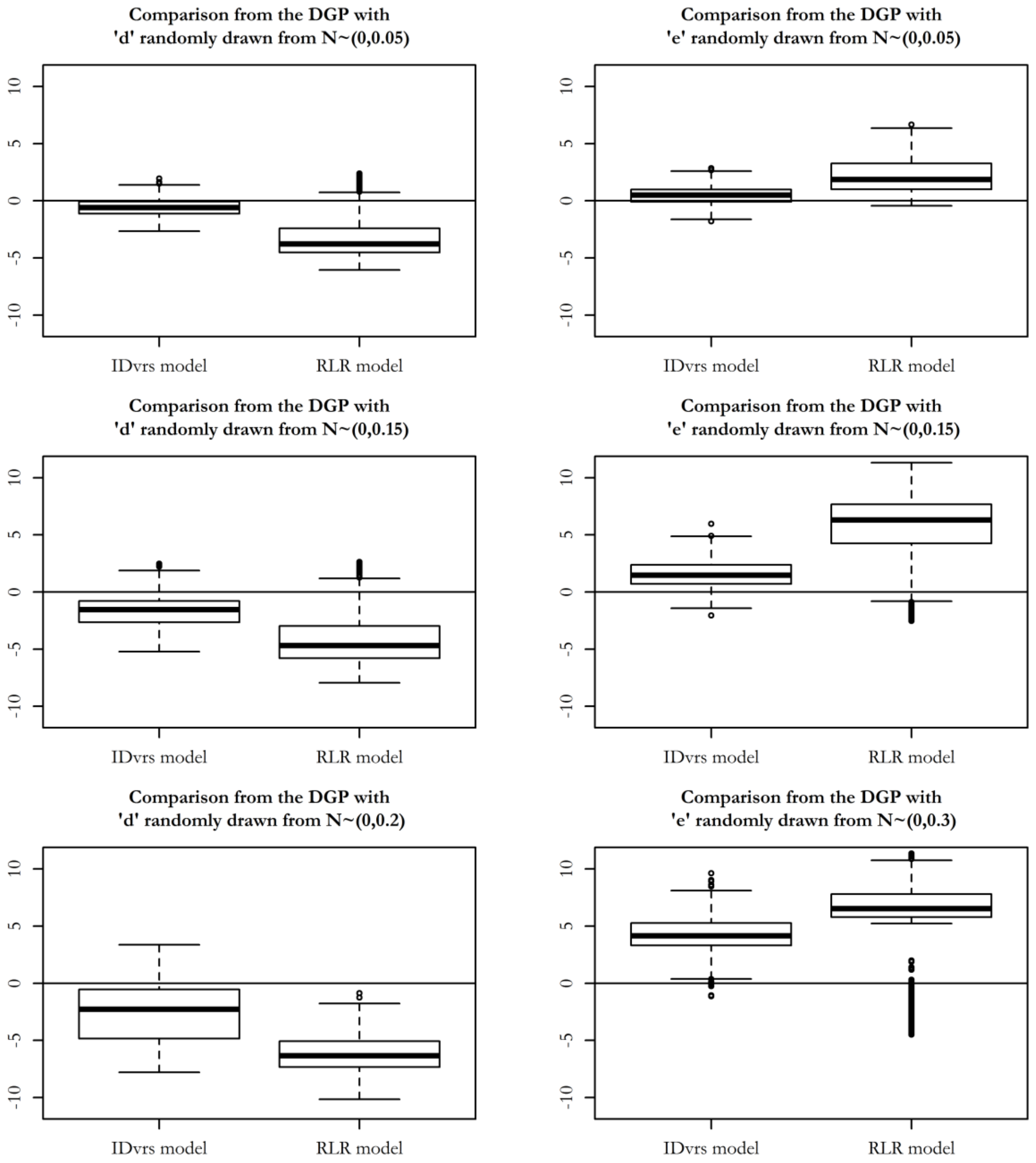


Figure 3-5. Variance of the MD for the different models tested from a DGP including an error term.

In this experiment, we chose a bio-economic DGP that we ran for a different set of prices in order to generate our production function. Such a DGP is peculiar and results must be interpreted with caution because a small change in price may trigger discontinuous changes in inputs or output. Nevertheless, as discussed in section 0, such DGP plays a role in complex systems and assessing the model's accuracy is not trivial. We propose a new approach for partial output validation, where the researcher has full control over the DGP. The DGP reflects the behaviour that researchers intend to predict or know to be at play. Such approach enables researchers to assess the performance of the economic component in capturing emerging behaviour. When the DGP generates a cross-sectional dataset, we observe that the IDvrs model performs well only if the technologies do not differ too much between observations. The IDvrs model tends to overestimate changes. The RLR is affected more by data heterogeneity. Nevertheless, RLR performance remains satisfactory with panel datasets. When we introduce an error term, we evaluate the performance of the model to cope with data uncertainty. The IDvrs and the RLR models are consistent and perform well for a small error term but underestimate changes.

3.8. Conclusion

One of the main challenges in ex-ante policy modelling is to construct the most accurate model that captures the underlying behaviour of the DGP. As researchers are never in a position to know the 'true' DGP, they often cast reasonable assumptions. These assumptions involve using estimators that have desirable properties to allow these properties to be inferred. Furthermore, these assumptions should not impose any restriction that does not reflect reality, which could lead to misleading conclusions. The different estimation techniques are like a continuum ranging from fully parametric estimation, through semi-parametric estimation, to fully non-parametric estimation. This also applies to the number and the strength of assumptions made.

Often researchers choose to parametrically estimate a functional form. By adopting a functional form we assume a continuous relationship between variables. The continuity of these relationships does not always occur in the real world, but as researchers never know the true functional form, this approach is compelling enough to be chosen. The problem becomes even more complex as there are a large number of possible functional forms. Indeed any parametric estimation is, by design, incorrect, and biases may increase if the wrong functional form is chosen. In order to account for non-linearities intrinsic to biological systems, researchers approximate a production function via a Taylor polynomial (Qureshi et al., 2013). However, such an approach may have some drawbacks. First of all, we can question the interpretability of estimated parameters such as interaction terms (Greene, 2010; Heckelei et al., 2012; Mérel and Howitt, 2014). Second, non-linear phenomena such as threshold effects are frequent. Biological systems may respond to an incremental change with a sudden regime shift. For example, a response in milk production to an increase in energy intake is nonlinear. In addition to biological systems, farm management decisions may also respond in a non-linear way. In particular, the allocation and the expansion of fixed costs, such as machinery and labour, exhibit threshold effects. The main disadvantage of such a method lies in the rationalisation of the chosen functional form and in the bias in the case of misspecification.

The main contribution of this paper is to propose a methodology for the partial validation of a model output. Partial output validation involves testing model output accuracy within the initial production possibility set. Validation of policy models is very complex because there is no opportunity to conduct real world experimental design. Researchers often use ex-post experiments and/or peer-review processes. Ex-post experiments assume that model performance is solely driven by model specifications. However, external factors, such as structural and environmental changes, could potentially improve model performance by chance. Therefore, this paper attempts to compare methods in a controlled environment.

This is one of the few attempts in policy modelling to test or validate methods. The findings highlight the main challenge for social scientists in the practice of agricultural policy modelling when non-linearities and thresholds might hold. In general, the RLR model performs poorly as we have generated datasets of 1000 observations with different prices and free of any measurement or sampling bias. This amount of data is far beyond the real world policy simulation, where typically less than 20 observations per farm are available and the amount of price variation is limited. One of the main strengths of the IDvrs model is the ability to obtain reliable results for a small sample.

In this paper, we have tested a specific situation where non-linearities exist in the DGP. For the RLR model, we have used a very flexible form of the production function. Our results show the importance of using panel data or robust grouping technics in order to maximise homogeneity in the sample. Model performance is negatively affected by an increase in heterogeneity and it tends to overestimate change if heterogeneity is large. Both modelling approaches remain consistent when uncertainty is introduced, however they underestimate change when it prevails. Another advantage of the IDvrs model is the computing speed. The IDvrs model is a linear programming model, and consequently does not require complex algorithms to find optimal solution.

Further research could be conducted in two ways. First, the proposed output validation methodology could be extended. For instance, we could generate data at a higher level, such as farm level. Farms exhibit greater variation in their technology and may change behaviour more gradually. Second, assuming we have access to panel data at farm level, the IDvrs model could be improved to correct for bias in using bootstrapping technics and drawn inferences. If access to panel data is not feasible, we could further develop the IDvrs models in order to cope with data heterogeneity by preserving technical and scale efficiency scores.

Chapter 4. Greening and the maintenance of Permanent grassland: an analysis of farm activity changes in France

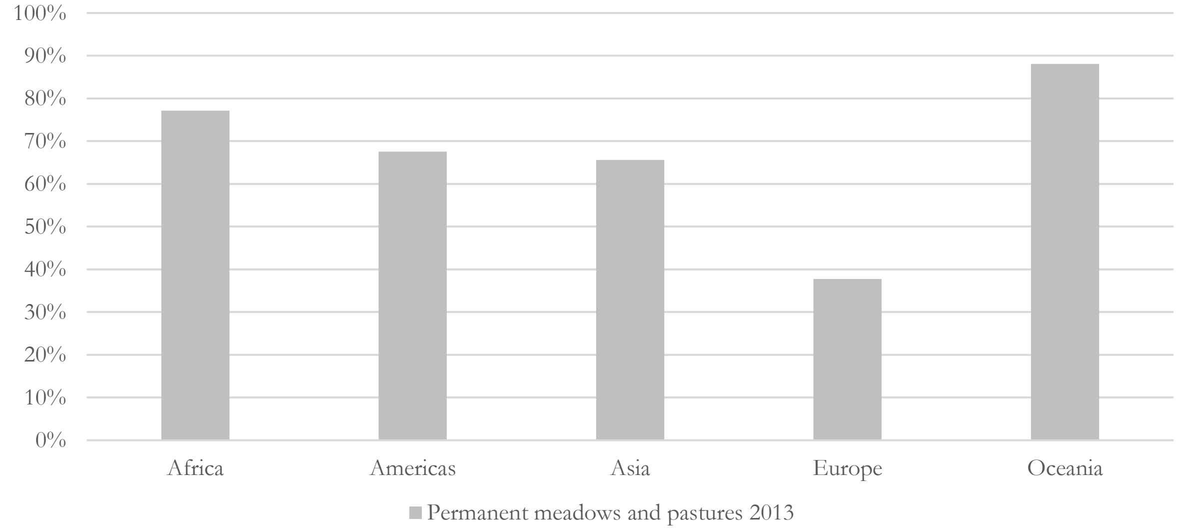
Abstract

The contribution of permanent grassland to biodiversity and environmental services is well recognised by scientists and policy makers and it has been addressed in agricultural policy. Under the new greening requirements in the Common Agricultural Policy, farmers are required to maintain their ratio of permanent grassland to utilised agricultural area. In this paper, we study the case of France and investigate the opportunity cost at farm-type regional level for maintaining the ratio of permanent grassland at the 2009 level. Additionally, we compare the effectiveness of this greening requirement to the introduction of an alternative policy: a premium per hectare for permanent grassland. Results show that a premium of 100€/ha for permanent grassland for all farmers in France would, as a minimum, maintain permanent grassland at the 2009 level. Furthermore, a premium per hectare would increase diversification in farm production by increasing cattle production for every farm type and so strengthen the link, at farm level, between crop and livestock production. Such a policy would match current budget expenditure under the Voluntary Coupled Support scheme introduced by the Common Agricultural Policy reform in 2013.

4.1. Introduction

Permanent grassland provides more environmental and societal benefits than cropland. Therefore, the importance of integrating environmental concerns into agricultural policy has been increasingly emphasised. According to the European regulation, permanent grassland (PG) is defined as “the land used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that is not included in the crop rotation of the holding for five years or longer”. Grassland, including temporary and permanent grassland, is mainly valorised through forage production for grazing livestock (EIP-AGRI, 2016). However its contribution to biodiversity (Nilsson, 2009; Gardi et al., 2002), carbon sequestration into soils (Conant, Paustian and Elliott, 2001; Michael Abberton, 2010; Lugato et al., 2014), clean surface and ground water (Xiao et al., 2015; Souchère et al., 2003; Benoît et al., 2004), and the provision of an attractive landscape are well recognized in scientific literature. Nevertheless, livestock production is increasingly shifting from a forage-based system[18] to a feed and crop feed system (Naylor et al., 2005). A reduction in the competitiveness of grassland and, to a greater extent, permanent grassland has led to the progressive conversion of permanent grassland to the profit of arable land.

According to the Food and Agriculture Organization of the United Nations (FAO), in 2013 permanent grassland represented 68% of the total agricultural area in the world. However, areas of permanent grassland vary considerably across the world (see Figure 4-1). In the European Union (EU), permanent grassland represented 34% of the total agricultural area in 2013, but between 2000 and 2013, its area decreased by about 8 %, a loss of approximately 5.45 million hectares.



Permanent meadows and pastures is the land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land)

Figure 4-1. Share of Permanent meadows and pastures in the total agricultural area in 2013 (FAOstat, 2016)

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[18] Forage is defined as “Edible parts of plants, other than separated grain, that can provide feed for grazing animals or that can be harvested for feeding” (Allen et al., 2011)

Due to the importance of permanent grassland to farmers' livelihoods and the ecological benefits, permanent grassland is specifically addressed in agricultural policies. In the United States (Feng, Hennessy and Miao, 2013), the loss of grassland has been addressed by the Grassland Reserve Program. China has implemented a program for 'restoring grazing land to grassland', and a grassland eco-compensation mechanism (Li, Wang and Schwarze, 2014; Wang et al., 2016). In the EU, the maintenance of permanent grassland was formerly addressed by the Cross-Compliance policy and it is now part of the greening requirements in the Common Agricultural Policy (CAP).

Under the new greening requirements in the CAP, Members States (MS) need to ensure that the ratio of permanent grassland area to total Utilized Agricultural Area (UAA) does not fall by more than 5% compared to the baseline year (2012), plus arable land converted to permanent grassland in 2015. MS could choose whether to implement this ratio at national, regional or farm level. Almost all MS decided to manage the ratio of permanent grassland at national level. Only four MS opted for implementation at the regional level (Belgium, France, Denmark, and the United Kingdom) (European Commission, 2015a). Nevertheless, during the former period of the CAP, permanent grassland was addressed twice in EU regulations: the ratio of permanent grassland area to the total agricultural area could not decrease by more than 10 % compared to the base year and, with the definition of "Good Agricultural and Environmental Condition" standards for the protection of permanent grassland defined at MS level (such as the maintenance of permanent grassland in Natura 2000 areas).

In France, the new greening requirements for permanent grassland are not expected to have a large impact. Indeed, since 2010 (Ministere de l'alimentation de l'agriculture et de la pêche, 2010) farmers are under an obligation to maintain 100% of their reference area under permanent grassland. Derogation to convert permanent grassland is granted up to a maximum of 5% by the local authority and is potentially revertible. Faïq et al (2013) observed a decline in permanent grassland between 2006 and 2010 by -6.3%. If they acknowledge that the Cross-Compliance policy may slow down the loss of permanent grassland, part of the decrease could be attributed to farmers' declarative[19] artefacts on their land use in order to limit future constraints. Permanent grassland might have been declared as temporary grassland or fallow land. Pflimlin (2013) observed similar trends and accuses the 2003 reform of having sanctioned farmers who kept permanent grassland and did not convert permanent grassland ahead of the legislation. Additionally, he questions the effectiveness of such a measure given its untargeted nature.

The introduction of permanent grassland requirements, the change of reference year, and the uncertainty around future reforms to the CAP may have created an incentive for farmers to convert permanent grassland to arable land in advance, whether this is factual or not. Indeed, farmers wishing to retain some flexibility in their land allocation in the future, may have decided to reduce permanent grassland

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[19] In order to receive direct payments, farmers have to declare their land use to the authority. A declarative artefact refers to for instance a farmer declaring one land use for another such as permanent grassland declared as temporary grassland.

area to the profit of arable area, even though arable areas are subject to the crop diversification measure and ecological focus area requirement. This phenomenon has also been reported recently by Natural England (Pinches and Chaplin, 2014) in the United Kingdom. They have observed a decline in the absolute area under permanent grassland since the implementation of the Cross-compliance policy in 2005. Additionally, in 2012, they witnessed an increased number of applications to plough up or intensify grassland.

Nitsch et al. (2012) investigate the land-use change between permanent grassland and arable land in four German federal states. They identify the loss of permanent grassland due to its conversion into arable land, or due to a loss of UAA. They found an overall loss of permanent grassland between 2005 and 2007 of 80 000 hectares, from which 41 300 hectares was attributed to conversion to arable land. They identify decoupled payments as one of the drivers for the conversion of permanent grassland. Indeed, Germany implemented an Single Payment Scheme hybrid model[20] which has progressively smoothed the difference in payments between sectors. Historically, the livestock sector received a coupled premium payment per head, turning grassland into an attractive source of feed via grazing. Over the years, the redistribution of payments decreased the competiveness of permanent grassland to the profit of arable land. Consequently, the internal convergence policy implemented in the post 2013 CAP and the current low prices for livestock products will certainly increase the pressure on permanent grassland.

In 2010, eighty experts from Europe co-signed a declaration (Balmann et al., 2010) and advocated that: “All subsidies should be closely linked to the provision of public goods. Any subsidy that is not differentiated according to farmers’ provision of public goods, such as the Single Farm Payment, should be progressively phased out.” The strengthening of the link between land and livestock is also recognized as a means to internalize negative externalities (Naylor et al., 2005; Lemaire et al., 2014; Herrero et al., 2015). If the goal of the greening requirement is to internalize negative externalities, the production costs of the farmers should reflect the value of negative externalities produced (Polluter-Pays-Principle), and the rules should apply to all farmers uniformly. If the goal of the greening requirement is to promote the provision of public good using subsidy, the costs should be bared by the society (Provider-Gets-Principle). Whether the greening requirements tend to internalize negative externalities or promote the provision of public good is unclear (Matthews, 2013). Indeed, given that greening requirements apply uniformly across agricultural sectors and European regions without taking into account individual specificities, some farmers will potentially opt to reduce the payments received and not respect what is stated in “[…] adopting and maintaining farming systems and practices that are particularly favourable to environmental and climate objectives because market prices do not reflect the provision of such public goods.”(European Commission, 2011d). Furthermore, the reform of the CAP has introduced the possibility of granting Voluntary Coupled Supports (VCS) to specific farm types or sectors, representing 4.1% of the total amount for direct support

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[20] Member States had three main options for calculating the value of payment entitlements: (1) on the basis of the payments received by the individual farmer during a reference period ("historical model"), (2) taking all payments received in a region and dividing them by the number of eligible hectares ("regional model"), (3) a mixture between these two models ("hybrid model").

in the EU. Twenty four MS chose to support the beef and veal sectors, accounting for 41% of the budget dedicated to VCS (European Commission, 2015c). For France, the provision of support represents an average premium per suckler cow of 71 to 132 euros per annum, depending on the farm size. Coupled support is also applied in the milk sector and the sheep and goat sectors. Coupled support is classified by the OECD as an environmentally harmful (Schmid et al., 2007) and trade distortive instrument. The reforms of 2000 and 2003 intended to eliminate such types of support.

Given the questions regarding the environmental effectiveness of the maintenance of permanent grassland (Mouysset, 2014; Hauck et al., 2014), the ongoing internal convergence of support and the observed recoupling of support, we consider the option of a premium per hectare for permanent grassland in France. Increasing the competitiveness of permanent grassland would ultimately lead to a decrease in forage costs and would support the livestock sector per se. The provision of coupled support linked to permanent grassland is expected to favour extensive livestock production and enhance the provision of environmental benefits. By simulating the introduction of a premium per hectare for permanent grassland, we can determine the premium level for which permanent grassland would be maintained according to a given base year. Hence, the derived premium reflects the current opportunity costs for the maintenance of permanent grassland. Furthermore, we differentiate support per farm type and region, enabling us to investigate the effectiveness of such a premium, its impact on production and to compare it to the current greening requirement. The case of France is particularly relevant, since its agricultural sector and landscape characteristics are very diversified. Hence, any supports provided uniformly might have severe impact on the overall budget.

In section 4.2, we examine the evolution of permanent grassland areas in France during the period 1995-2009, and compare our observations to studies using other data sources. Section 4.3 explains the methodology used and section 4.4 illustrates the results found. Finally, section 4.5 discusses the main findings, the limitations and section 4.6 concludes.

4.2. Current state of permanent grassland in France

In this study, data are extracted from the Farm Accountancy Data Network (FADN) for the period 1995-2009. Holdings are selected to take part in the survey on the basis of a sampling plan. The sampling plan provides a representative dataset along three dimensions: region, economic size and type of farming. An individual weight is defined for each holding, corresponding to the number of holdings sampled divided by the number of farms they intend to represent. In France, the total number of holdings selected cover 93.1% of the total UAA and 97.2% of the total number of holdings.

According to FADN data, in 2009, permanent grassland represented between 86% of the total UAA (Corsica) and 1.6% of the total UAA (Île-de-France). Figure 4 2 illustrates the variation in permanent grassland in the UAA between the different regions.

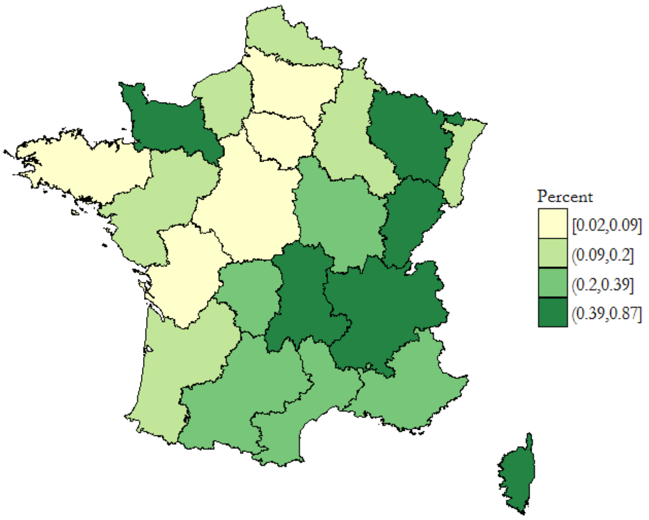

Figure 4-2. Share of permanent grassland in the total UAA in 2009.

Source: authors calculation based on FADN

We observe that permanent grassland dominates other land use in mountainous areas such as Franche-Comté and Auvergne, except for Lower-Normandy on the West coast which is characterized by wooded pasture. Regions oriented towards cereal production (Ile de France region), or intensive livestock production (Brittany region) have the lowest share of permanent grassland. Even though we use FADN data, we do not observe any significant differences with land-cover data (Faïq et al., 2013; Xiao et al., 2015).

Figure 4-3 illustrates the use of permanent grassland depending on the farm-type[21] activities. Not surprisingly, beef cattle and dairy producers have the highest share of permanent grassland in their UAA. In regions with limited potential to plough clay soils, agricultural production is oriented towards grazing-

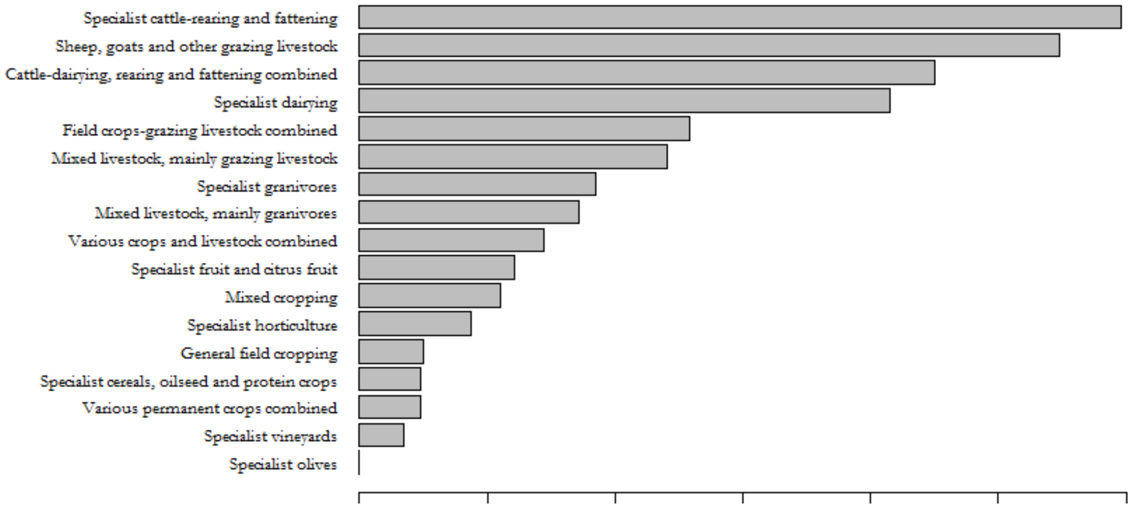

Figure 4-3. Share of permanent grassland in the total UAA per type of farmer in 2009.

Source: authors calculation based on FADN

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[21] We use TF8 grouping as defined by the European Regulation 2003/369 (EC).

livestock production. Consequently, permanent grassland is the main component of the fodder mix (Caillaud et al., 2013).

Figure 4-4 and Figure 4-5 show different trends regarding the share of permanent grassland in the UAA across regions compared to the absolute change in permanent grassland. Expansion of permanent grassland occurred in eastern mountainous regions. On the other hand, we observed a strong reduction in permanent grassland in Brittany and the Centre region. In fact, permanent grassland decreases in regions where intensive livestock production or combined crop and livestock production are important activities. These observations concur with other studies, identifying a shift from permanent grassland to temporary grassland and crops (Bouty, Barbottin and Martin, 2014; Faïq et al., 2013; Xiao et al., 2015).

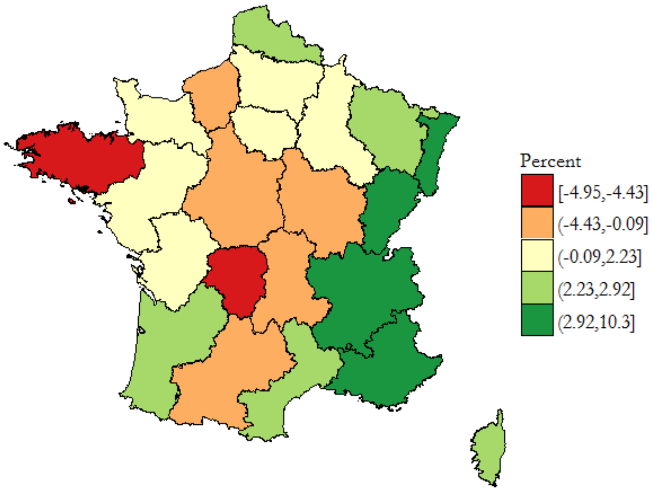


Figure 4-4. Change in the share of permanent grassland in the total UAA between 1995 and 2009

Source: authors calculation based on FADN

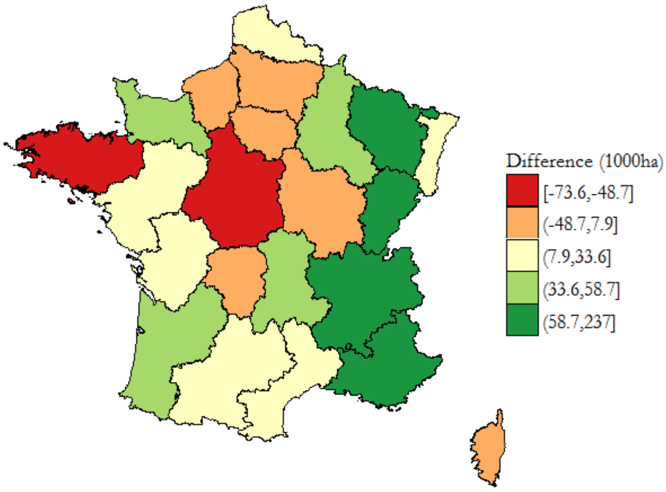
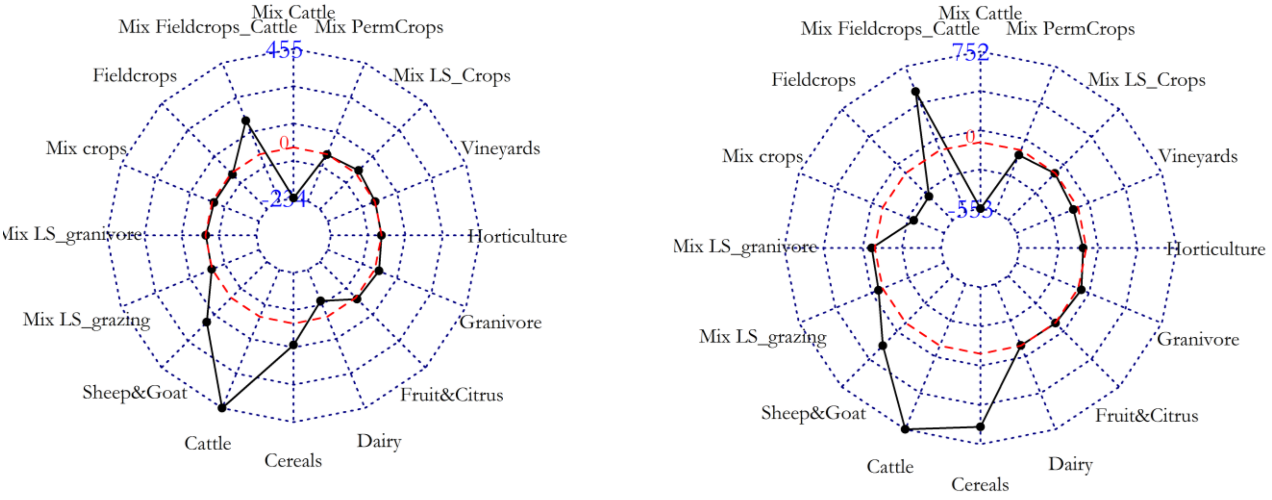


Figure 4-5. Change in permanent grassland (1000ha) between 1995 and 2009

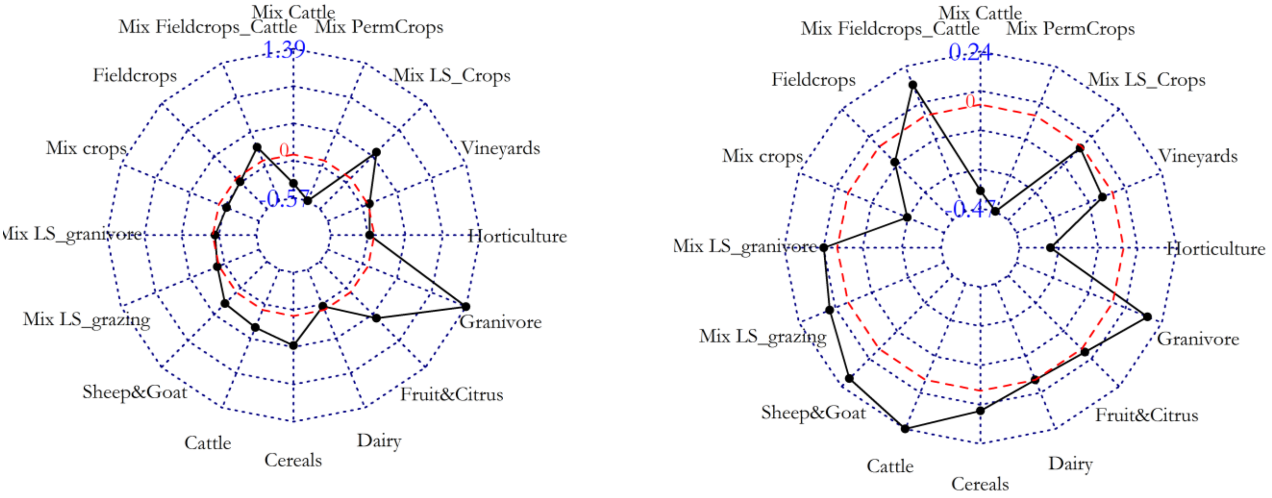
Source: authors calculation based on FADN

In contrast to Faïq et al (2013), we do not observe a net loss of permanent grassland in the FADN. Overall, the share of permanent grassland in the UAA stayed stable at around 26% between 1995 and 2009. Figure 4-6 depicts the absolute change in permanent grassland and UAA per type of farming activity along with the relative change between the year 1995 and 2005. On the one hand, some sectors reduced their UAA. Roots crops (Field crops), beef and dairy combined (Mix Cattle), and mixed cropping (Mix Crops) sectors experienced the most important reduction in UAA (Figure 4-6 b and d), but the associated decrease in permanent grassland is less than proportional to their loss of UAA (Figure 4-6 c). Specialized dairy farmers reduced their permanent grassland in terms of absolute value, but their UAA remained stable, indicating intensification in their farming systems. On the other hand, during the same period, some sectors saw their UAA increase. Interestingly, specialists in cereals, farmers combining field crops and grazing livestock, and specialist granivores have increased permanent grassland; proportionally more than their UAA, indicating a gain in permanent grassland over other land uses (Figure 4-6 c and d). For specialist granivore (Granivore), fruit and citrus (Fruit&Citrus) and various crops and livestock combined (Mix LS_Crops), the relative change is important, but corresponds to small absolute values and may be due to important variations in the dataset or conversion to organic farming. Finally, specialist cattle-rearing and fattening (Cattle) experienced the greatest increase in both UAA and permanent grassland (Figure 4-6 a and b) but with a relatively lower change for permanent grassland than for UAA. A more detailed analysis shows that grazing livestock production is the sector that experiences the highest increase or decrease in permanent grassland depending on the region. Consequently, permanent grassland in this sector shows the highest degree of substitution with other land use and we expect that this sector will be the most price-sensitive to a premium per hectare of permanent grassland.



a. Absolute change of PG (1000ha)

b. Absolute change of UAA (1000ha)



c. Relative change of PG (%)

d. Relative change of UAA (%)

Figure 4-6. Change in permanent grassland and UAA between 1995 and 2009.

Source: authors calculation based on FADN

The difference in trends observed between FADN data and the Faïq et al (2013) study may be due to several factors. First of all, as explained above, FADN data does not account for every farmer and the sampling method does not guarantee a good representation of permanent grassland. However, our results are in line with the Farm Structure Survey that reports a relative constant share of permanent grassland in the UAA of about 29% between 2000 and 2013 (see Appendix III for further details), but shows an overall loss of permanent grassland (specifically between 1995 and 2000) along with a loss of UAA. Nevertheless, the French FADN excludes farmers with a Standard Output below 25 000 euros, and they are not considered within this study per se. Yet, it is likely that farmers with a Standard Output below 25 000 euros receive lower direct payments. Since ‘small farmers’ are exempted from greening requirements, their exclusion from the FADN will not affect the results of this policy simulation.

4.3. Data and methodology

Mathematical programming models are widely used for policy impact assessment at the farm, regional, and sectoral levels. They originate from the normative mathematical programming model, where farmers' decisions are represented by a series of linear constraints under explicit specification of their goal, usually profit maximization. One of the major drawbacks to using a normative approach in policy impact assessment is that solutions do not always represent the observed reality, and might exhibit jumpy behaviour, otherwise termed the "extreme specialization problem" (Baker and McCarl, 1982; Buysse et al., 2007).

When using a normative approach at sectoral or regional level, the problem of extreme specialization becomes more severe due to aggregation bias (Önal and McCarl, 1991; Chen and Onal, 2012; Paris and Howitt, 1998; Baker and McCarl, 1982). To remedy this situation, several alternatives have been developed by modellers: the use of additional constraints, the crop mix approach and the introduction of risk (Mérel and Howitt, 2014). To obtain a smooth supply response, to reproduce the observed reference situation and enhance reliability in the results, positive mathematical programming models have been developed. This approach involves introducing nonlinearity into the objective function, and calibrates the unknown parameters to the given reference situation (comprehensive reviews of the methods and its applications are provided by Mérel and Howitt 2014; Heckelei et al. 2012).

Despite the methodological developments mentioned above, policy impact assessments have been mostly carried out with a certain level of aggregation, and this also applies to the analysis of the greening measures (Pelikan et al., 2015; Cortignani and Dono, 2015; Solazzo et al., 2015). Often, representative farms are constructed representing a subset of farmers and encompassing all farmers' activities. Aggregation was necessary due to data availability constraints, or computational difficulties in modelling all farmers. Furthermore, for agricultural policy focused on market policy instruments (import/export taxes/subsidies, quota etc…) an aggregate supply response was sufficient (Buysse et al., 2007). Nowadays agricultural policy and more specifically the CAP tends to internalize negative externalities. Policy makers design new instruments, such as the maintenance of permanent grassland, in order to change the production system at farm level. Consequently, aggregated models implicitly assume a certain degree of substitution between farmers, leading to unrealistic results.

We develop a farm-type regional model using historical activity mixes that we extend using individual farm production frontier constraints defined by the historical activity mix for the observed farmers and their associated peers. Such an approach enables us to take full advantage of the information available within the FADN dataset, from individual farm information to regional information and even though full calibration is not obtained, it greatly mitigates the problem of overspecialization. Nevertheless, the impact assessment of policy instruments is only feasible to the extent that policy instruments and market conditions resemble those of the past and do not fall outside the production possibility set. Our approach, which we will discuss below, is a partial answer to aggregation bias and remains easy to implement at a practical level.

4.3.1. Using all dimensions of FADN data

In order to get a clear understanding of what is meant by a farm-type regional model, a short description of the information available in FADN is required. Table 4-1 shows what information is available within our dataset. The strength of FADN data is to be an unbalanced panel dataset that is representative of the population each year. For instance, some farmers have their information recorded for the full duration of our dataset (1995-2009). Other farmers can be recorded for a single year (Farmer 3). In fact, FADN data provides three dimensional information: panel information at farm level (e.g. Farmer 2), cross-sectional information at farm level (e.g. Column 2007) and panel information at farm-type regional level (the bottom row).

Table 4-1. FADN dataset description

Regions	*Type of farm*	*Farmers*	*1995*	…	*2007*	*2008*	*2009*
Alsace	Specialist dairy	Farmer 1	$x_{f1,1995}$	$x_{f1,..}$			
		Farmer 2	$x_{f2,1995}$	$x_{f2,..}$	$x_{f3,2007}$	$x_{f3,2008}$	$x_{f3,2009}$
		Farmer 3					$x_{f4,2009}$
		Farmer 4			$x_{f4,2007}$	$x_{f4,2008}$	$x_{f5,2009}$
Total for the specialist dairy farm in Alsace			$\boldsymbol{X_{1995} = \sum_{f} weight_{f,1995} \cdot x_{f,1995}}$	$\boldsymbol{X_{...}}$	$\boldsymbol{X_{2007}}$	$\boldsymbol{X_{2008}}$	$\boldsymbol{X_{2009}}$

Our approach maximizes profit at farm-type regional level where the optimal solution:

(1). is a linear weighted average of historical farm-type regional activities mixes.
(2). is the sum of individual solutions which themselves are a linear weighted average of their historical and/or peer activity mix.

Point 1 above is derived from the historical crop mix approach suggested by McCarl (1982) and based on the Dantzig-Wolfe decomposition principle (Dantzig and Wolfe, 1961) introducing the notion of extreme point representation. Önal and McCarl (1991) show that the optimal solution for an aggregate model including all decision makers is one-to-one correspondence with the optimal solutions for individual models. In fact, an extreme point (the corner solution of a linear programming model) of the aggregate model is formed by stacking the extreme points (the different corner solutions) of the individual models and conversely, the extreme points of individual models can be obtained by partitioning the extreme points of the aggregate model. This approach was used in order to alleviate the researcher's need for full information about micro-level input-output data (Chen and Onal, 2012). Our approach, discussed here, is different in nature to what is suggested, in the sense that despite generating an aggregate farm-type regional model, we also partition the aggregate optimal solution into an individual optimal solution (given the weight provided in FADN) in order to improve the model accuracy and model farmer's adoption outside her historical production set.

Point 2 ensures that the individual optimal solution is a convex combination of the individual and/or peer historical activities. As shown in Table 4-1, FADN is an unbalanced panel dataset and some farmers are only present for a single year (e.g. Farmer 3). In order to obtain correct representation, we only simulate the policy impact for farmers present in 2009. For those without records prior to 2009, it would be infeasible to model input/output changes without a set of agronomic and economic constraints. Instead, we assume that a farmer can partially or fully adopt the activity mix of his peers. This approach is similar to Oude Lansink and van der Vlist (2008), Frija et al. (2011) and Speelman et al. (2009). In these studies, the authors estimate a production frontier defined by a convex hull around the technically efficient observations. In this configuration, inputs and outputs are used as parameters to determine objective values (similar to the historical activity mix approach), and hence efficiency scores. Subsequently, the model can estimate the changes required in inputs or outputs due to policy change, while preserving the initial technology frontier. The optimal solution is a linear weighted average of peer observations, preserving the initial efficiency score. Consequently, the first step of our modelling exercise is to define peer farmers. Similar to the aforementioned studies, we will first calculate the efficiency scores for all farmers present in 2009 against all farmers from 1995 to 2009 in their farm-type category and region. Then peer farmers are defined as the farmers against which individual farmers are benchmarked (for complete details of the model selecting peer see Appendix IV). Additionally, using peer behaviour enables farmers to adopt farm activities outside their individual production possibility set, while the farm-type regional activities remain within the production possibility set. Similar to chapter 2, the use of peers for simulating adoption addresses the self-selection problem defined in Paris (2001).

4.3.2. A farm-type regional model using Mathematical programming and farm activity mix

The model consists of farm-type regional models with the goal to maximize their profits π_{FTR}. For clarity, and to avoid too many indexes, we illustrate the case of a single farm-type regional model. Nevertheless, the model is solved for every farm type in each region. This gives, for a specific farm type in a given region:

$$\max_{y,c,x} \pi = \sum_{f} W_f \,.\left(\sum_{k} P_k . y_{f,k} - \sum_{j} D_j \,. c_{f,j} + \sum_{i} S_i . x_{f,i,} + DS_f \right) \tag{4.1}$$

where f indexes the farm, k the outputs of the farmers, j the different categories of input costs and i the different inputs used by the farmers. W_f is the weight for each farmer in the sample. $y_{f,k}$ is a column vector of production quantities, $x_{f,i}$ is a column of vector of input activities, such as crops areas, and $c_{f,j}$ is a column vector of input costs recorder in euros, such as fertiliser costs. P_k is the average outprice observed in 2009 per farm type in a given region and D_j is the index price for the different input cost categories in 2009. S_i is a possible premium for a given activity or any coupled subsidies received in 2009 by a farmer, and DS_f is the sum of decoupled payments and rural development subsidies received by a farmer in 2009.

One of the limitations of the FADN data is that it does not provide data on input quantities, such as fertilizer or concentrate use, and does not allocate them to specific farm activities. Instead, FADN provides the total amount spent by the farmers for specific cost categories. One of the options could be to partition input costs per activity. Yet, partitioning input costs given, for instance, the participation share of such activities to farm income is somewhat arbitrary. Another option is to directly use input costs as an endogenous variable. Indeed, Eurostat provides a detailed input price index for the different input cost categories, allowing us to deflate them and use input costs as variables. This approach is in line with the model logic. Since the optimal solution is a linear weighted average of past observations, input costs from the past certainly reflect the activity set.

Three sets of constraints ensure that the farm-type regional endogenous variables, Y_k the produce quantities, X_i the input activities and C_j the input costs, are partitioned according to the weight of each farmer.

$$Y_k = \sum_f W_f \, . y_{f,k} \tag{4.2}$$

$$X_i = \sum_f W_f \, . x_{f,i} \tag{4.3}$$

$$C_j = \sum_f W_f \, . c_{f,j} \tag{4.4}$$

Four sets of constraints illustrate the historical activity mix approach proposed by McCarl in 1981:

$$Y_k - \sum_t \lambda_t \, \widehat{Y_{t,k}} = 0 \tag{4.5}$$

$$X_i - \sum_t \lambda_t \, \widehat{X_{t,\iota}} = 0 \tag{4.6}$$

$$C_j - \sum_t \lambda_t \, \widehat{C_{t,J}} = 0 \tag{4.7}$$

$$\sum_t \lambda_t = 1 \tag{4.8}$$

where t indexes the different years from 1995 to 2009. $\widehat{Y_{t,k}}$, $\widehat{X_{t,\iota}}$, and $\widehat{C_{t,J}}$ are, respectively, the historical farm-type regional observations for production quantities, input activities, and input costs and are exogenous to the model. Hence, constraints (4.5), (4.6) and (4.7) restrict production quantities, input activities, and input costs to a weighted sum of historical observations, where the weights λ_y are to be determined by the mathematical program as endogenous variables. Constraint (4.8) restricts the sum of the weight to 1.

Finally, the last set of constraints ensure that farm level solutions are themselves a linear weighted average of their historical or/and peer activity mix.

$$y_{f,k} - \sum_{t} \delta_{f,t}\, \widehat{y_{f,k}} - \sum_{peer} \beta_{f,peer}\, \widehat{y_{peer,k}}/\theta_f = 0 \tag{4.9}$$

$$x_{f,i} - \sum_{t} \delta_{f,t}\, \widehat{x_{f,\imath}} - \sum_{peer} \beta_{f,peer}\, \widehat{x_{peer,\imath}}/\theta_f = 0 \tag{4.10}$$

$$c_{f,j} - \sum_{t} \delta_{f,t}\, \widehat{c_{f,\jmath}} - \sum_{peer} \beta_{f,peer}\, \widehat{c_{peer,\jmath}}/\theta_f = 0 \tag{4.11}$$

$$\sum_{t} \delta_{f,t} + \sum_{peer} \beta_{f,peer} = 1 \tag{4.12}$$

$$\sum_{i} x_{f,i} \leq maxUAA_f \tag{4.13}$$

where i corresponds to crops acreage.

$$\delta_{f,t}, \beta_{f,peer}, c_{f,j}, x_{f,i}\ and\ y_{f,k} \ \geq 0 \tag{4.14}$$

where $\widehat{y_{f,k}}$, $\widehat{x_{f,\imath}}$ and $\widehat{c_{f,\jmath}}$ are, respectively, the historical farm observations for production quantities, input activities, and input costs and are exogenous to the model. $\widehat{y_{peer,k}}$, $\widehat{x_{peer,\imath}}$ and $\widehat{c_{peer,\jmath}}$ are, respectively, the historical peer observations of production quantities, input activities, and input costs and are exogenous to the model. θ_f is the efficiency score for each individual farmer and its value lies between 0 and 1. Hence, constraints (4.9), (4.10) and (4.11) restrict the production quantities at farm level, input activities and input costs to a weighted sum of the farmer's historical and peer observations. However, a farmer will adopt the production set of another farmer reduced by the efficiency score. Appendix IV provides a more detailed explanation of how we derived the efficiency score for each farmer and defined his peers. Constraint (4.12) restricts the sum of weights to 1. Constraint (4.13) restricts the total UAA of the farmers to the maximum observed UAA for the same given farmer. Finally, constraint (4.14) imposes a non-negativity restriction on all endogenous variables.

We run the above model for 50 different premiums for permanent grassland (S_i) from 0€/ ha to 500€/ha. Here, we intend to determine for which premium level we will observe the same allocation of permanent grassland as in 2009 at farm-type regional level. As mentioned in the introduction section, the new greening requirements for permanent grassland in France is not expected to have a large impact. Under the standards for good agricultural and environmental conditions, farmers could not convert permanent grassland. Hence we considered that farmer in 2009 could not reduce their amount of permanent grassland. In estimating the premium level for which farmers allocate the same amount of permanent grassland than in 2009, we can determine their opportunity costs (equal to the level of premium per ha that leads to the same level of permanent grassland), and the impact on production. Additionally, we can determine a farm-type regional level or regional level area-based payment that would ensure the 'maintenance of permanent grassland' according to the 2009 base year.

By integrating farm-type regional constraints and farm-level constraints, we reduce the problem of overspecialization. Indeed, if the model was run at farm level, every farmer would adopt the production set of the most profitable farmer. On the other hand, if the model was run at regional level, without farm constraints, it would be infeasible to simulate policy at farm level, for instance the adoption of new activities at farm level. This approach enables us to reconcile 'regional' versus 'individual' modelling in a rather simple framework.

4.4. Results

In this section, we first run our model given 2009 prices while not imposing any obligations regarding permanent grassland. The baseline scenario reveals which farm type in each region is sub-optimal in 2009 and would change their production possibility set. In other words, given that in 2009 farmers were obliged to maintain permanent grassland, the baseline scenario determines which farmers change their amount of permanent grassland if there is no obligations. Second, we determine the opportunity costs for maintaining permanent grassland at farm-type regional level. Third, we determine the opportunity costs at regional level, and look at the impact of the introduction of a regional premium on production. Finally, we take the highest observed regional opportunity cost and implement a premium for permanent grassland equal to it for all regions and farm types. We also illustrate the impact on production.

4.4.1. Baseline scenario: no greening and no premium

The baseline scenario takes into account the 2009 prices, but does not impose the maintenance of permanent grassland or implement a premium per hectare of permanent grassland. In this scenario, given the market and policy conditions, we identify farm-type regions that reduce their amount of permanent grassland and so are sub-optimal in 2009 - in other words, farm-type regions that reduce their permanent grassland area when there is no requirement to maintain permanent grassland.

Figure 4-7 shows the relative change in permanent grassland area and UAA. Overall, the change to UAA remains small, since constraint (4.13) in our model imposes a restriction at farm level, in the sense that farmers can reduce/increase their UAA to the extent that they remain below the maximum historical value observed. Nevertheless, the regions plotted in shades of grey show an increase in permanent grassland. For those regions, the maintenance of permanent grassland, and how it is implemented today, does not change their land use and it is considered as having no impact. We expect that the opportunity costs will be close to zero. Three other categories of regions all experience a decrease in permanent grassland (regions plotted yellow, orange and red). The regions plotted with the lightest shade of yellow exhibit a decrease in permanent grassland along with an increase in UAA and, for the regions plotted in orange and red of the decrease in permanent grassland is partly due to the decrease in UAA.

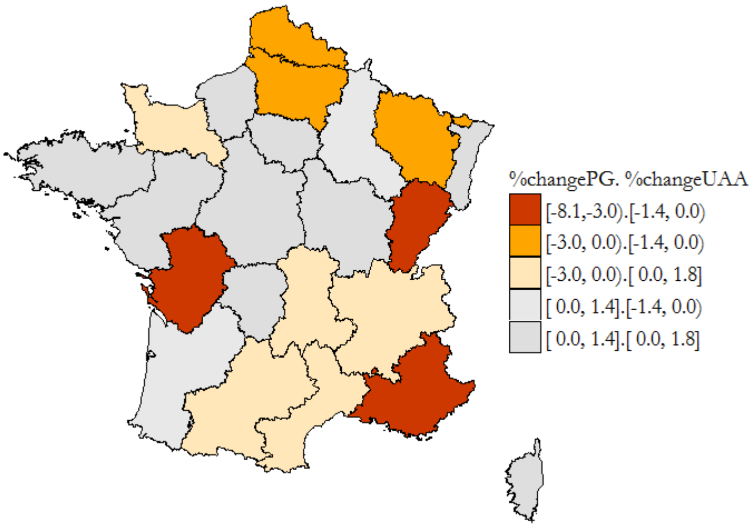


Figure 4-7. Relative change in permanent grassland and UAA for a simulation model without subsidies, compared to 2009.

Figure 4-8 shows the absolute change in permanent grassland given the different type of farming activities for a simulation model without subsidies and compared to the base year 2009. If we look at the average change between regions, as expected, specialist cattle-rearing and fattening displays the largest decrease, followed by specialist dairy, specialist cereals, oilseed and protein crops. However, taking into account the variation between regions, sheep and goat farming and, mixed crop farming, despite having a positive average, exhibit wide variation and also tend to reduce permanent grassland. For other farm types, the change in permanent grassland is not very significant.

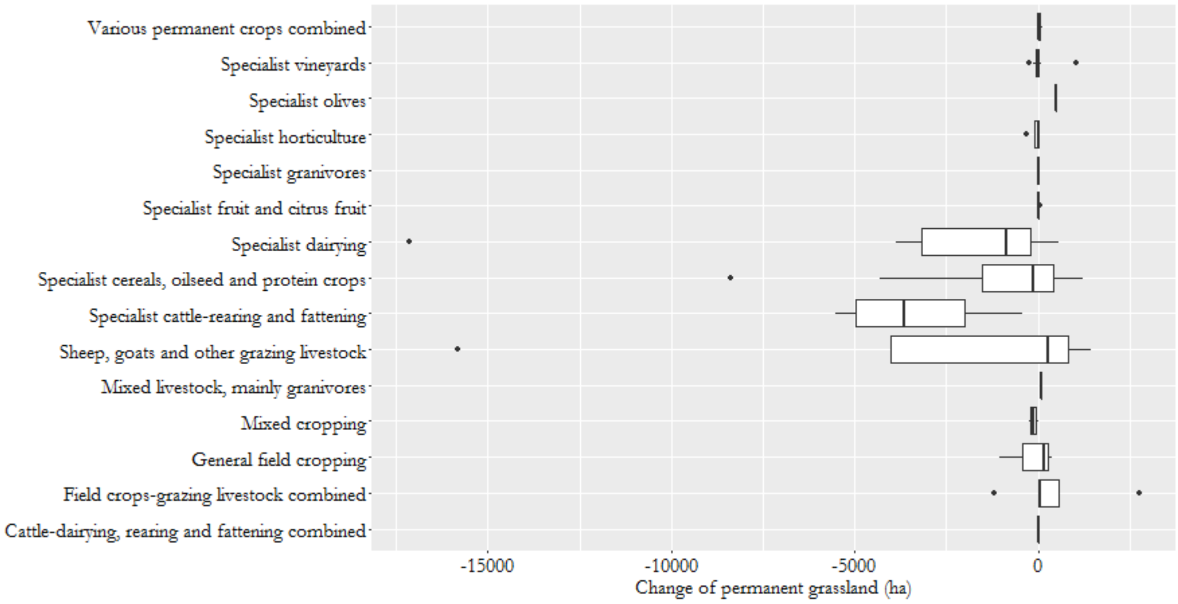


Figure 4-8. Box plot of the change in permanent grassland at farm-type level between the baseline scenario and observations in 2009.

4.4.2. The opportunity cost of permanent grassland

In this scenario, we run our model for 50 different premiums for permanent grassland (S_i) from 0€/ ha to 500€/ha, and identify the premium level for each farm-type region that results in the same permanent grassland area as in 2009. Thus, the premium paid corresponds to the opportunity cost for the current maintenance of permanent grassland under the greening requirements. Table 4-2 shows the results at farm-type regional level with an opportunity cost above zero. For all other farm-type regions they have the same amount of permanent grassland as in 2009, or above, without any premium. As expected, regions in grey shades in Figure 4-7 are not present in Table 4-2, except for three regions: Centre, Champagne-Ardenne and Haute-Normandie. For these three regions, only one farm type is involved and the opportunity costs, along with the area of permanent grassland concerned, remain relatively small. In these specific regions, when the premium is zero, some farm types within the region compensate for the loss of permanent grassland for other farm types in the same region. This will be discussed in more detail below. The opportunity cost for permanent grassland varies from 5.9 €/ha to 240€/ha depending on the region and the farm type. The area of permanent grassland concerned represents about 22% of the total area of permanent grassland in 2009.

The total budget spent on such coupled payments is approximately 72M€, which is much lower than the VCS for the beef sector in France for the year 2015, which is approximately 652M€. This illustrates that targeted policies taking farmers' and regional specificities into account can increase efficiency. If we assume that, from a legal perspective, policy makers could decide to implement a farm-type regional area base payment for permanent grassland, they would reduce their budget drastically. If we sum the total area of permanent grassland and the budget spent on specialist dairy farming, specialist cattle-rearing and fattening, and sheep and goats, they represent 97% of the permanent grassland area receiving support and

97% of the total budget spend. Hence, any coupled support to permanent grassland would benefit current targeted sectors under VCS, but would also be a partial answer to the societal demand to link support to positive externalities.

Table 4-2. Opportunity costs for maintenance of permanent grassland for the different French regions.

Regions	***Type of farming***	***Opportunity costs (€/ha)***	***PG area (ha)***	***Budget spent (€)***
Auvergne	Specialist cereals, oilseed and protein crops	20.0	13 293	265 856
Auvergne	Specialist vineyards	30.0	165	4 935
Basse-Normandie	Specialist cattle-rearing and fattening	20.0	111 602	2 232 032
Basse-Normandie	Specialist dairy	70.0	301 196	21 083 713
Basse-Normandie	Specialist horticulture	240.0	358	86 016
Centre	Specialist dairy	9.5	6 847	65 049
Champagne-Ardenne	Sheep, goats and other grazing livestock	10.0	1 786	17 860
Franche-Comté	Specialist dairy	100.0	307 789	30 778 880
Haute-Normandie	General field cropping	30.0	17 886	536 580
Languedoc-Roussillon	Specialist cattle-rearing and fattening	5.9	145 743	859 883
Languedoc-Roussillon	Specialist dairy	12.6	29 296	369 132
Lorraine	Specialist cereals, oilseed and protein crops	20.0	54 835	1 096 700
Midi-Pyrénées	Specialist cattle-rearing and fattening	10.0	250 109	2 501 093
Midi-Pyrénées	Specialist dairy	10.0	31 086	310 862
Nord-Pas-de-Calais	Field crops - grazing livestock combined	100.0	60 410	6 040 980
Nord-Pas-de-Calais	Specialist cereals, oilseed and protein crops	40.0	5 895	235 788
Picardie	Specialist cereals, oilseed and protein crops	90.0	16 937	1 524 366
Poitou-Charentes	Mixed cropping	40.0	10 682	427 292
Poitou-Charentes	Specialist cattle-rearing and fattening	20.0	44 835	896 694
Provence-Alpes-Côte d'Azur	Sheep, goats and other grazing livestock	7.9	109 162	862 380
Provence-Alpes-Côte d'Azur	Specialist granivores	30.0	58	1 752
Rhône-Alpes	Specialist cereals, oilseed and protein crops	70.0	29 048	2 033 367
France			*1 549 018*	*72 231 210*

4.4.3. Policy scenarios at regional and country level

Let's assume first, that instead of determining a premium at farm-type regional level, we seek a regional premium identical across farm types. Then, the premium level is set when the permanent grassland allocation at regional level (and not at farm-type regional level) is the same as in 2009. Table 4-3 shows the opportunity costs for the maintenance of permanent grassland for the different French regions. Regions in yellow in Figure 4-9 are all regions for which we do not observe any change in permanent grassland allocation (as explained above) and for which the opportunity cost is zero. The highest opportunity cost is in the region of Nord-Pas-de-Calais and is about 100€/ha at regional level. However, it varies a lot from region to region, ranging from 5.8€/ha to 100€/ha.

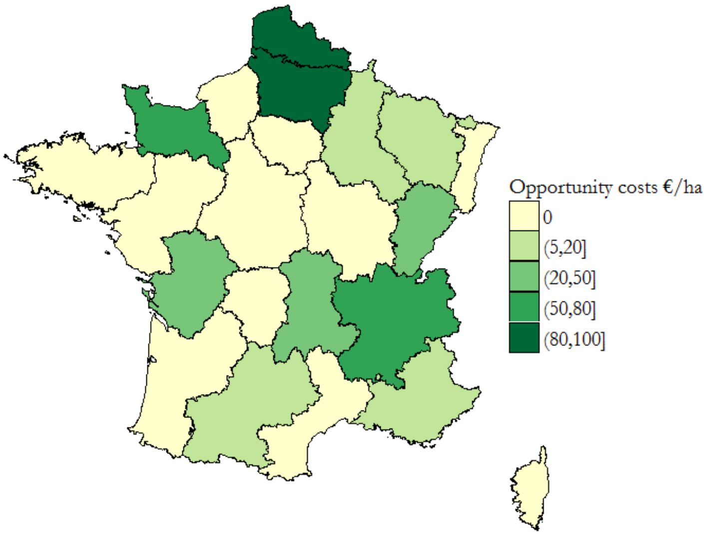


Figure 4-9.Opportunity costs for maintenance of permanent grassland for the different French regions

Table 4-3 shows that in order to maintain permanent grassland at the 2009 level, a premium per hectare defined at regional rather than farm-type regional level (Table 4-2) would multiply the budget by about 2.5 and the area of permanent grassland affected by the measure would be multiplied by three. Indeed, about 66% of the area under permanent grassland in France would receive a premium per ha, compared to 22% of the total area of permanent grassland in the case of a premium determined at farm-type regional level. Also, three regions – Centre, Haute-Normandie and Languedoc-Roussillon – do not receive any premium, while we observe a non-zero opportunity cost for certain farm types in these regions. As mentioned earlier, some farm types will compensate for the loss of permanent grassland in others, resulting in the absence of opportunity costs at regional level. Consequently, the variation in opportunity costs is also smaller, ranging from 5.8€/ha to 100€/ha.

Table 4-3. Opportunity costs for maintenance of permanent grassland for the different French regions.

Regions	Opportunity costs (€/ha)	PG area (ha)	Budget spent (€)
Auvergne	30	885 291	26 558 730
Basse-Normandie	69.7	582 580	40 605 805
Champagne-Ardenne	10	277 457	2 774 572
Franche-Comté	29.8	447 478	13 334 841
Lorraine	18.7	504 254	9 429 555
Midi-Pyrénées	9.4	561 285	5 276 080
Nord-Pas-de-Calais	100	159 279	15 927 880
Picardie	83.5	126 755	10 584 034
Poitou-Charentes	37.6	159 267	5 988 443
Provence-Alpes-Côte d'Azur	5.8	189 496	1 099 076
Rhône-Alpes	63.7	752 327	47 923 204
Total		**4 645 468**	**179 502 221**

Table 4-4 shows the impact on financial results of the introduction of a premium per hectare for permanent grassland derived from the opportunity costs in Table 4-3. The highest impact on profit is observed for specialist cattle-rearing and fattening, followed by farm-type categories where grazing livestock is the most important source of income. Even though specialists in dairy farming receive the biggest share of the subsidy (about 35% of the total budget), the introduction of a premium for permanent grassland, has less impact on their profitability than for specialist cattle-rearing and fattening. This phenomenon can be explained by the higher profitability of the dairy sector, and the capacity of the dairy sector to obtain the highest added value for permanent grassland (Caillaud et al., 2013; Kellermann and Salhofer, 2014; Havet et al., 2010). By comparing the absolute change in profit and subsidy, we can conclude that most of the change in profit is due to the introduction of a premium (except for specialist horticulture and specialist vineyards). However, this positive change in profit is not only due to the increased amount of subsidies that farmers received. Indeed, the model picks the most optimal farm-type regional production set, and a change at farm level impacts the complete production possibility set. For instance, for specialist dairy farming we observe an increase in the total cost and a decrease in revenue compared to the baseline. Farmers who change their production and increase their permanent grassland partially adopt the production possibility set of another farmer and/or their own historical production possibilities and therefore also the accompanying costs and revenue structures. Some farm types, such as mixed livestock, mainly grazing livestock, do not change their production but still benefit from the premium since the premium is set at region level and not at farm-type regional level.

Table 4-4. Impact of a regional premium for permanent grassland on financial results.

	Relative change compared to baseline (%)			**Absolute change compared to baseline (M€)**		
Type of farming	**Cost**	**Revenue**	**Profit**	**Profit**	**Subsidies**	**% of Subsidies received from the total budget**
Specialist horticulture	0.03	0.12	0.89	3.20	3.26	0.02
Specialist vineyards	-0.05	-0.02	3.29	86.22	86.47	0.46
Specialist fruit and citrus fruit	0.00	0.00	10.28	54.61	54.61	0.29
Various permanent crops combined	0.00	0.00	35.51	14.20	14.20	0.08
Specialist granivores	-0.09	-0.09	62.10	31.57	31.57	0.17
Mixed cropping	0.15	-0.06	66.95	213.76	214.57	1.15
Specialist cereals, oilseed and protein crops	3.84	0.56	71.35	717.51	765.31	4.11
Various crops and livestock combined	0.00	0.00	76.06	118.71	118.71	0.64
General field cropping	-0.01	-0.01	114.97	576.34	576.39	3.10
Field crops - grazing livestock combined	1.55	0.70	307.13	2674.50	2685.96	14.44
Specialist dairy	1.08	-0.20	466.67	6513.70	6545.79	35.19
Cattle-dairy, rearing and fattening combined	0.00	0.00	598.28	1172.21	1172.21	6.30
Mixed livestock, mainly granivores	0.00	0.00	677.27	104.26	104.26	0.56
Mixed livestock, mainly grazing livestock	0.00	0.00	857.36	283.66	283.66	1.53
Sheep, goats and other grazing livestock	0.70	0.23	972.73	1824.45	1827.04	9.82
Specialist cattle-rearing and fattening	0.41	-1.30	2223.71	4103.84	4115.17	22.12

Figure 4-10 shows the major impacts on land use, livestock and input use per type of farming. For specialist cattle-rearing and fattening, the introduction of a premium leads to an increase in permanent pasture. They substitute temporary grassland, common wheat and rough grazing areas for permanent grassland. At the same time, they reduce their livestock density (we observe a decrease in pigs LU, indeed despite being specialist some farmers raise pigs as a small proportion). Interestingly, their consumption of fodder purchased outside the farm also increases, indicating that the increase in permanent grassland along with a reduction in livestock density does not fully compensate for the loss of fodder production. Specialist cereals, oilseed and protein crops reduce fallow land, common wheat and dry pulse areas to the profit of permanent grassland but also to the profit of oilseed crops and fodder maize. The introduction of a premium for permanent grassland gives them an incentive to diversify their production and increase their cattle production. As mentioned before, although being classified as specialist cereals, oilseed and protein crops, some farmers in these categories have a small share in cattle production. In the case of the introduction of a premium for permanent grassland, those farmers are selected as peers. Other farmers partially adopt their production structure and so increase their number of cattle. Given that grassland is mainly valorised through forage production for grazing livestock, specialist cereals, oilseed and protein crops have an incentive to increase their livestock production if permanent grassland is subsidised. The increase in livestock for specialist cereals, oilseed and proteins crop farm types can explain the increase in rapeseed production. Indeed, rapeseed cake is a source of protein in the feeding ration and the oil can be used for the biodiesel market (Britz and Hertel, 2011; Bernard and Prieur, 2007). Besides, the results show that specialist cereals, oilseed and protein crops would also rely on the purchase of fodder. For specialist dairy farming, a similar phenomenon is observed and they diversify their production by decreasing the dairy herd and increasing the cattle herd. Additionally, they replace fodder maize with grassland, while they rely more on the purchase of fodder. Field crops/grazing livestock combined farm types do not increase permanent pasture area; instead they intensify their livestock production by increasing the cattle number, the fodder maize area, fertilizer use and concentrate purchase. By implementing a homogenous premium per hectare across farm type, other farm types with lower opportunity costs will produce permanent grassland. Finally, no major changes are observed for mixed cropping or sheep, goats and other grazing livestock farm types except for rough grazing area. Rough grazing area is defined as permanent pasture and received the same premium in our simulation exercise (similar to the legislation), nevertheless farmers prefer permanent pasture to rough grazing areas except for sheep, goats and other grazing livestock farm types. It is likely that sheep and goats can access, and so valorise, rough grazing areas more easily. During the period 1995 to 2009, the UAA for the sheep, goats and other grazing livestock farm types has decreased. In our simulation exercise, this farm type has the largest relative increase in UAA due to the existing variation in our dataset. The relatively low level of information for the sheep and goats farm type, and the large variations observed, limit the interpretability of the results.

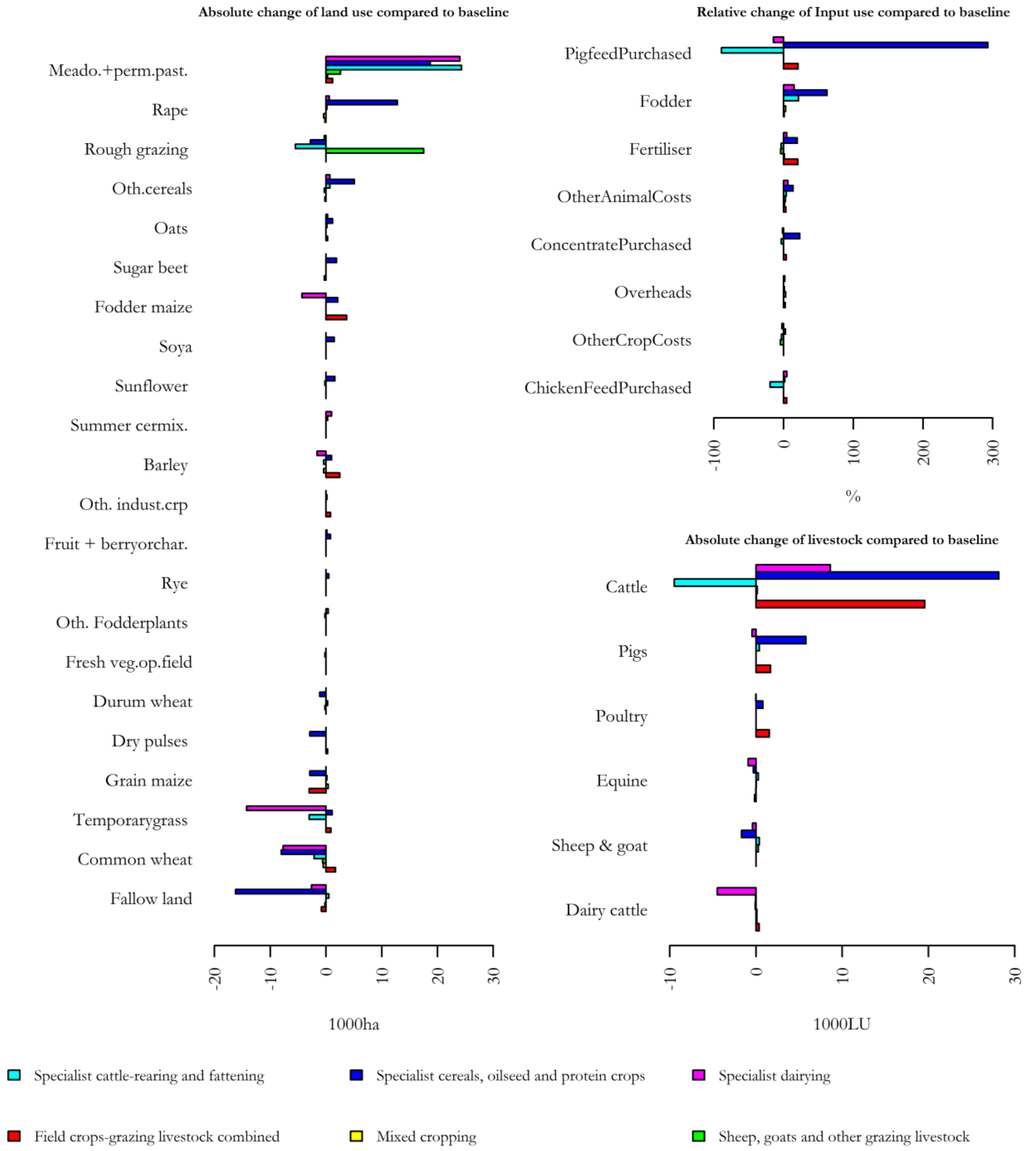


Figure 4-10. Impact on production of the introduction of a regional premium per ha for permanent grassland.

Even though from an effectiveness and budgetary point of view, asymmetric premium levels for permanent grassland among farm types and regions perform the best, such policy might hamper the level playing field for farmers. National authorities might choose a symmetric premium across farm type and region. According to our results, the highest opportunity cost is observed in Nord Pas De Calais and it is estimated at 100€/ha. In this last scenario, we assume a premium of 100€/ha for permanent grassland for all farmers in every region. In such a case, the total budget is about 720M€, where 46% (339M€) is allocated to specialist cattle-rearing and fattening and field crops/grazing livestock combined, 22% (163M€) to specialist dairying, and 13% (91M€) to sheep, goats and other grazing livestock. In comparison, the VCS scheme adopted in France for the beef and veal, dairy cow and dairy product and, sheep and goats sectors amounts to 922.62M€ with the following respective distribution: 70%, 15%, 15%. Nevertheless, such support does not guarantee the delivery of public goods.

The impact of a symmetric premium across farm types and regions varies between regions. Figure 4-11 shows the impact of a premium for permanent grassland on farmers' profits depending on the share of budget allocated to them. We define budget as the total amount of subsidies potentially spent by the national authority for permanent grassland. In general, regions with the highest impact are regions with the highest opportunity costs and the largest share of permanent grassland in the UAA.

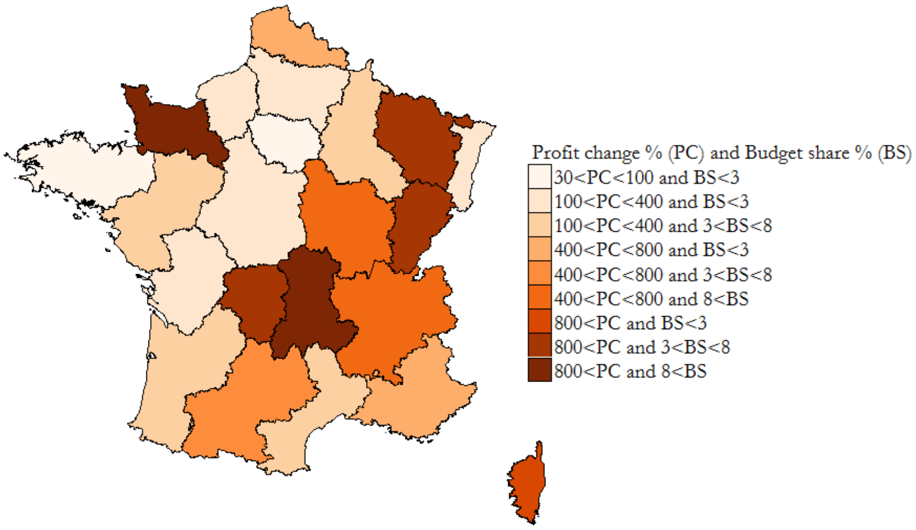


Figure 4-11. Impact of premium of 100€/ha on profit, given the respective budget share.

Whether we introduce an asymmetric premium per hectare base for the regional opportunity costs, or a symmetric premium of 100€/ha for everyone, the impact on production follows the same trend. Figure 4-12 shows the impact on land use, livestock, input use and their relative changes at French level. Regarding land use changes, specialist cattle rearing and fattening, specialist cereals, oilseeds and protein crops and specialist dairy all substitute fodder crops (such as temporary grassland and fodder maize) for permanent grassland. Regarding livestock, a similar diversification phenomenon is observed, where cattle production decreases for specialist cattle rearing and fattening, but increases for other farm types. Regarding input use, every type of farmer relies more heavily on the external purchase of fodder. Nevertheless, the bottom right corner of Figure 4-12 shows the relative change at the French level of all variables. We observe a decrease above 1% only for equine livestock, and land allocated to seed products, fodder crops and fallow land. On the other hand, we observe an increase above 1% for fertilizer, permanent grassland (meadow, permanent pasture and rough grazing area) and purchased fodder.

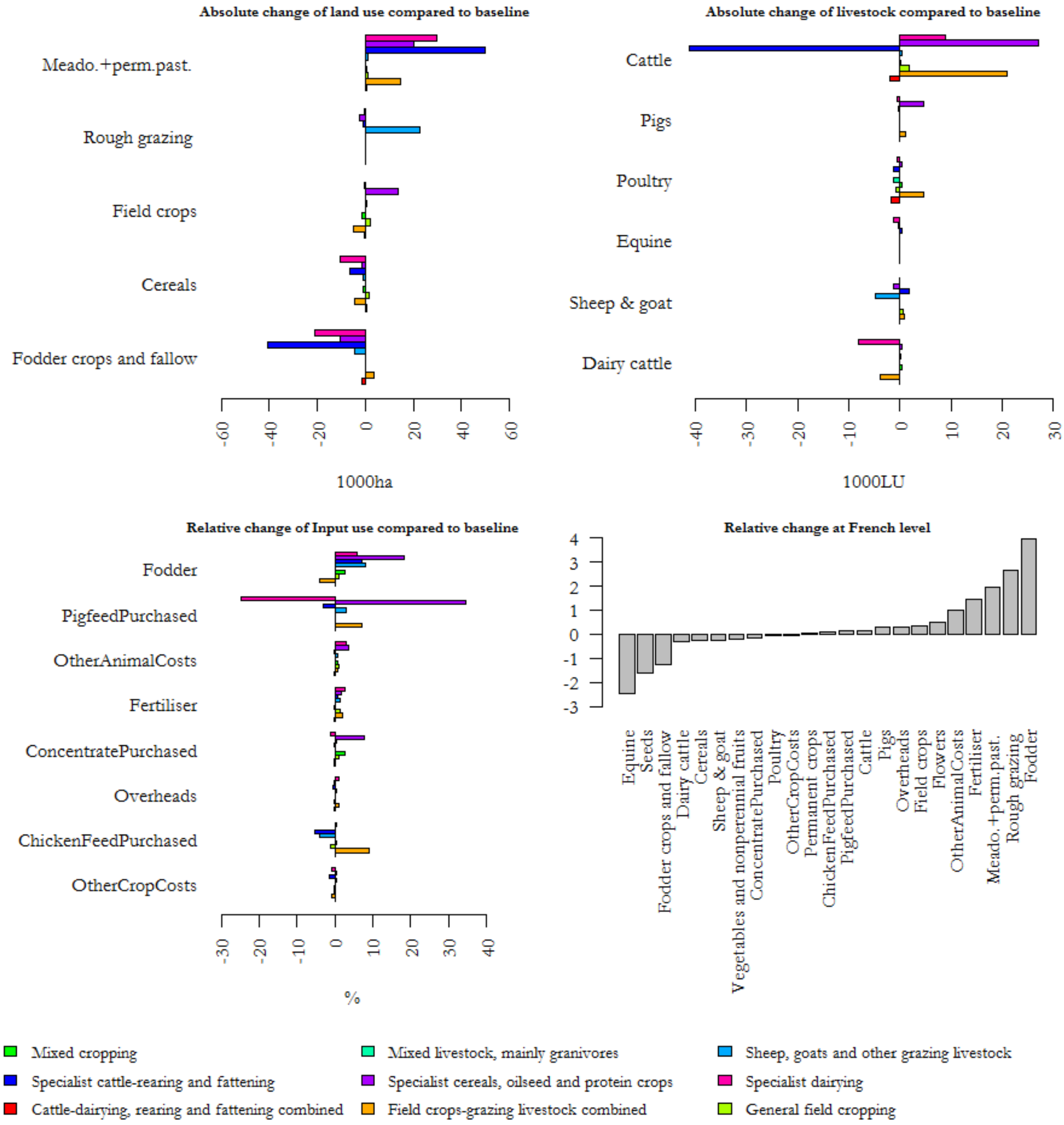


Figure 4-12. Impact of the introduction of a premium of 100€/ha for permanent grassland on French production.

4.5. Discussion

The opportunity cost for the maintenance of permanent grassland under the greening requirement of the CAP varies greatly between farm types and regions, from 5.9€/ha for specialist cattle-rearing and fattening in Languedoc-Roussillon to 240€/ha for specialist horticulture in Basse-Normandie. In this study, we propose to introduce a premium per hectare for permanent grassland based on the opportunity cost found in our simulation exercise. The European Commission (2011a), in its impact assessment, estimates the opportunity costs for the maintenance of permanent grassland at between 5€/ha and 620€/ha. If estimated for the potential eligible area, the average opportunity costs among farmers is lower, varying between 0€/ha and 99€/ha, with an average in France of 22€/ha. The European Commission assumes in its baseline scenario that all permanent grasslands are under threat. However, in practice, farmers might have no opportunity to convert permanent grassland due to agronomic constraints or feeding constraints. Furthermore, as mentioned in the introduction, part of the loss of permanent grassland can be attributed to a declarative artefact with no consequences for land cover. Farmers might declare permanent grassland as fallow land or temporary grassland in order to avoid future constraints on land use. The original data and the original assumption in the European Commission impact assessment tend to overestimate the opportunity costs.

The introduction of a regional premium for permanent grassland results in a national budget of about 180M€ - the equivalent of 20% of the VCS budget adopted in France for the livestock sector. The introduction of a national premium at 100€/ha for permanent grassland significantly increases the national budget to 720M€, representing about 78% of the VCS budget for the livestock sector. In such a scenario, the permanent grassland area increases by about 1% compared to 2009, a gain of 77 235ha. In both cases, the profitability of the livestock sector is the most positively impacted, whilst permanent grassland area is, at the minimum, equal to the 2009 level.

Our results show that changes in land allocation to the profit of permanent grassland lead to a reduction in fodder crops (temporary grassland, fodder maize), fallow land and cereals, in a smaller proportion. The changes in land allocations are in line with studies investigating the opposite effect, meaning the conversion of permanent grassland to arable land. Bouty et al. (2014) studied the conversion of permanent grassland in the south Niort plain and they found that in 80% of cases, farmers converted permanent grassland to temporary grassland, maize, wheat and sunflowers. Faïq et al. (2013) reconstructed the crop sequence patterns between 2009 and 2010 in France using graphical land-parcel registration declarations. They estimate a loss of 96 000 ha of permanent grassland, replaced by temporary grassland and fallow land.

The changes in land allocation translate to a change in livestock production. The introduction of a premium for permanent grassland indirectly subsidizes the grazing livestock sectors. Accordingly, we observe a diversification phenomenon. Farm types that do not specialize in cattle production, such as specialist dairy farming, specialist cereals, oilseed and proteins crops and, field crops/grazing livestock combined increase the cattle production. Specialist cattle rearing and fattening and, sheep and goats and other grazing livestock decrease cattle and, sheep and goat production. The overall increase in cattle leads to an increase in purchased fodder and fertilizer use. Consequently, the increase in permanent grassland does not fully compensate for the loss of fodder production. If fertilizers are traded on the international market, the fodder market is more local as transport costs are relatively high. A small increase in demand could significantly affect prices. Consequently, an increase in cattle production, especially for specialist cereals, oilseeds and proteins crops, might become unprofitable. This result illustrates the limitations of the model since prices are exogenous.

In this study, we investigate the impact of the maintenance of permanent grassland as a standalone policy. Nevertheless, in practice, the greening requirement is accompanied by two other measures: crop diversification and ecological focus areas. Fallow land can be declared as an ecological focus area. Consequently, farmers had an incentive prior to the reform and afterwards to declare permanent pasture as fallow land while, in reality, not changing the land cover. The introduction of a premium in our policy simulation might overestimate the conversion of fallow land to permanent grassland.

Another limitation of our model is that it is a bounded production possibility set to observed production possibility sets. For the maintenance of permanent grassland, policy makers intend to slow down the loss of permanent grassland, so a bounded production possibility set is theoretically not a problem. From a policy perspective, the introduction of a premium for permanent grassland has to be defined within quantitative limits in order to remain compliant with the Word Trade Organization 'blue box' criteria[22]. We could imagine determining this quantitative limit by multiplying the amount of permanent grassland for the reference year by the premium level, as is currently done in the context of the VCS scheme.

4.6. Conclusion

Scientists across the world advocate linking subsides for the provision of public goods (Balmann et al., 2010), and more integrated crop and livestock systems (Naylor et al., 2005; Lemaire et al., 2014). The introduction of a premium per hectare for permanent grassland would achieve both objectives. A premium of 100€/ha for permanent grassland for all farmers in France would, as a minimum, maintain permanent grassland at the 2009 level and would enhance the provision of environmental goods. However, a differentiated premium for permanent grassland for different farm types and regions would divide the overall budget by ten from 720M€ to 72€M€. A differentiated payment would be paid to farmers with the highest opportunity cost for permanent grassland and would avoid farmers who would grow permanent grassland independently of the policy context to perceive such payment. Hence, from a cost-benefit point of view, we can wondered, if the argument of insuring the same level playing among farmers, is still valid.

Finally, our results also show that a premium for permanent grassland would increase farm production diversification by increasing cattle production for every farm type and so strengthen the link, at farm level, between crop and livestock production. Such a policy would match current budget expenditure under the VCS scheme introduced in the CAP reform and could be compliant with the World Trade Organization rules.

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[22] Direct payments under production limiting programmes (often referred to as “Blue Box” measures) are exempt from commitments if such payments are made on fixed areas and yield or a fixed number of livestock.

Chapter 5. Counter cyclical capacity payment for set-aside land under price uncertainty: the case of French arable farmers in the Centre region

Abstract

This study presents a Counter Cyclical Capacity Payment (CCCP) for set-aside land and determines its impact on arable farm income variability and land use change in the Centre region in France. In light of the debate around the effectiveness of the Ecological Focus Area requirement within the greening package, we suggest a CCCP which could play two roles: mitigate farm income variability and enhance the provision of environmental services at the lowest cost. To capture output price uncertainty and price a CCCP, we apply a Copula model based on the joint distribution of the three most common commodities in the region: wheat, barley and rapeseed. Then using a Monte-Carlo setting, we generate the probability distribution of the three commodity prices and the CCCP. A farm-type regional model simulates activity changes for each stochastic price and CCCP generated. The results show that by pooling commodity price risk under one policy instrument and linking it to set-aside, we could achieve a higher level of set-aside at farm and regional level compared to the current requirement, while at the same time decreasing production in times of low commodity prices and reducing farm income volatility.

5.1. Introduction

Instability is inherent in agricultural markets and policy interventions for stabilising market prices have been common across the world (FAO et al., 2011; Galtier, 2013). The common explanations for agricultural price volatility are the natural dependence of agricultural production on its environment, such as weather and pests; the inelasticity of aggregate food demand; and the relatively low supply elasticity in the short term given the natural life cycle of crops. Galtier (2013) distinguishes two non-exclusive strategies to manage price instability: it can either be reduced, or its effects can be buffered using market-based instruments or through public interventions. The European Union (EU) has chosen to provide a safety-net to farmer by granting a direct decoupled payment in the form of a lump-sum. The United States (US) has chosen a market-based approach where payments are made when price or revenue fall below a their respective established reference level[23]. Meanwhile, the provision of environmental goods has been recognised as part of farming activities. In the EU, among other measures, farmers must ensure that at least 5% of their arable land is set aside as an "ecological focus area[24]". In the US, the Conservation Reserve Program provides payment to set aside erodible and environmentally sensitive land and to implement resource-conserving practices for at least 10 years. In this paper, we introduce the notion of a capacity payment and suggest considering set-aside land as a reserve agricultural capacity. The rationale underpinning reserve agricultural capacity is that in times of low commodity prices farmers will receive an incentive to withdraw land from production and vice-versa. In this configuration, set-aside land could play a role beyond the provision of environmental goods by mitigating farm income volatility and even price volatility for processors or consumers of agricultural commodities.

Historically, set-aside policy was associated with payments coupled to production. The abolition of coupled support has been accompanied by a decrease in fallow area and an increase in farmers' exposure to price risk. In the US, until the 1996 Fair Act, the government controlled production via the Acreage Reduction Programme (Gardner, 2002). In times of production surplus and coupled production payments, farmers participating in the government programme had to withdraw a certain percentage of their arable land. Set-aside policy[25] was fully abolished in 1996, as price stabilisation and policy support moved away from production towards market-based instruments or farm income support. Similar trends were observed in Europe where price support linked to production level led to a costly build-up of stocks. In 1992, the EU introduced direct payments to compensate cuts in price support and compulsory set-aside. Progressively, the EU has decoupled income support from production, achieving full decoupling in 2008. Furthermore,

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[23] Three types of support can be distinguished: Price Loss Coverage payment, Agriculture Risk Coverage payment, and Marketing Assistance Loan. All programs are triggered when price or revenue falls below the established reference levels. For more information see (Shields, 2014).

[24] Areas considered as ecological focus areas are defined in the European regulation (European Parliament and Council of the European Union, 2013a), but final implementation is left to Member States' decision. However, ecological focus areas should consist of areas directly affecting biodiversity, such as land lying fallow, landscape features, terraces, buffer strips, afforested areas and agro-forestry areas, or indirectly affecting biodiversity through the reduced use of inputs on the farm, such as areas covered by catch crops and winter green cover.

[25] In this article we consider set-aside policy in the broad senses consisting of payments to farmers for the purpose of fallowing parts of their land, or a compulsory obligation to fallow part of their land.

in light of the surge in commodity price in 2007-2008 and concerns relating to food security, under the agreement of the European Commission and a qualified majority of member states the rate of set-aside was altered and set to 0%. Finally, during the Health check of the Common Agricultural Policy (CAP) compulsory set-aside were abolished in 2008 (Morris et al., 2011). Today, risk management policy instruments, such as counter-cyclical programs and crop insurance programs, represent the greatest budget share (47 % see UMR SMART-LERECO and Cordier 2014) under the US agricultural policy. In Europe, most of the CAP budget (77% see UMR SMART-LERECO and Cordier 2014) is allocated to farm income support. The recent commodity price surged in 2007-2008 and 2010-2011 and this has reignited policy debates around volatility and risk management, for instance the G20 agenda in 2011 specifically tried to address food security.

While agricultural support shifting from production-linked subsidies to income support or risk management programmes, environmental concerns and the role of farming activities entered the policy arena (OECD, 2011a; OECD, 2011b). Voluntary or compulsory set-aside policies[26] have been re-introduced for environmental purposes in different countries, such as the land retirement program in the US (Stubbs, 2014), the introduction of "environmental set-aside" through the ecological focus area measure under the greening of the CAP in the EU (European Parliament and Council of the European Union, 2013a) or "the Grain for Green" programme in China (Uchida, Xu and Rozelle, 2005). Set-aside lands are recognised for their positive environmental impact. They increase carbon sequestration (Sperow, 2016) and biodiversity (Van Buskirk and Willi, 2004; Toivonen, Herzon and Helenius, 2013). Nevertheless, the effectiveness of set-aside policy has been questioned. First, current set-aside programs do not take into account the large heterogeneity in terms of landscape, production, and current erosion and biodiversity status (Boellstorff and Benito, 2005; Tscharntke, Batáry and Dormann, 2011). Second, the environmental gain from set-aside may be offset by other agricultural policy programmes (Goodwin and Smith, 2003). Third, on a global level set-aside policy might increase agricultural commodity price and could therefore lead to overall agricultural intensification. Pelikan, Britz and Hertel (2015) quantify the economic and environmental impact of devoting 7% of arable land to ecological focus areas in the EU. They show that for each additional hectare of land which the EU sets aside, land-based greenhouse gas emissions in the rest of world will increase by about 21 tonnes CO2 equivalent. While set-aside policy can be viewed through an environmental lens, we suggest also looking at set-aside land in terms of agricultural capacity.

Capacity payments have emerged in the electricity sector as a mechanism to stabilise investment in generating electricity capacity (De Vries, 2007). Given the risk averse nature of investors, the high volatility of electricity prices, the capital intensive nature of generation and the long lead time for new facilities, governments have implemented capacity mechanisms to promote investment in power plants and avoid blackout. Similar to the electricity market, the agricultural commodity market exhibits high volatility with an

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inelastic demand. Furthermore, assuming risk averse farmers, we suggest considering set-aside land as a reserve agricultural capacity.

Theoretically, farmers already receive direct payments decoupled from production and, consequently, they should not have any incentive to produce and their decisions should be market driven. Mary (2013) examines the distortive effect of two types of decoupled payments: the Counter Cyclical Payment (CCP) in place in the US and the Single Farm Payment (SFP) in place in the EU. The author shows that both types of payment are not truly decoupled. However SFP creates the opposite incentive in terms of decision - whichever effect is the greater will drive the impact on production. CCP is found to have a significant impact but is relatively small in terms of output. This is in line with former literature indicating that CCP may induce risk-reducing incentives to produce (Antón and Le Mouël, 2004). Given, the current call for a risk management tool and the environmental benefits of set-aside land we investigate the possibility of a "Counter Cyclical Capacity Payment" (CCCP) for fallow land.

A CCCP for fallow land can theoretically fulfil two objectives. First, in times of low agricultural commodity prices, fallow land would be attractive since the CCCP payment would be relatively high compared to the agricultural commodity price. In that sense, its countercyclical nature would involve the farmer income in risk mitigation without dampening responsiveness to market price signals while providing environmental goods at the lowest opportunity cost. However, in case of long term price decline, a CCCP would have no impact on farm income, only structural changes of the agricultural sector could restore farm income. A CCCP should take into account several commodity prices into account in order to mitigate farm income volatility, meaning that payment should be triggered by multiple, sometimes correlated sources of risks, such as low wheat and barley prices resulting in an decrease of income. Section 5.2 describes the methodology used to derive the probability distribution of commodity prices, taking into account dependence between them, and then briefly discusses how we model farmers' behaviour. Section 5.3 presents the results. Finally, section 5.4 discusses the main findings, the limitations and section 5.5 concludes.

5.2. Methodology

In order to design an effective CCCP that pools the risks from different commodity prices, we need to define the degree of risk exposure for farmers for each commodity. To do so, section 5.2.1 uses the Farm Accountancy Data Network (FADN) to define the average land use during the period 1995-2009. Then, analysis of risk management policy should take account of the origin of price volatility and reproduce its main features, such as the degree of correlation between commodity prices or tail dependence or the variance of each commodity price. Section 5.2.2 generates the stochastic prices used later in a farm-type regional model. The joint multivariate distribution is estimated using a Copula approach and using a Monte-Carlo setting we generate the probability distribution for each commodity price and the CCCP. Finally, section 5.2.3 describes the farm-type regional model that we run for each stochastic price and CCCP generated. This procedure allows us to derive probability distributions for each variable defined by the farm-type regional model.

5.2.1. Case study: specialist arable famers in the Centre region in France.

Data on specialist cereals, oilseed and protein crop farms in the Centre region, covering the period 1995-2009, were obtained from the FADN. Holdings were selected to take part in the survey on the basis of a sampling plan. The sampling plan provides a representative dataset along three dimensions: region, economic size and type of farming. An individual weight is defined for each holding corresponding to the number of holdings sampled divided by the number of farms they intend to represent. FADN data is an unbalanced panel dataset and provides a unique identification number for each farmer survey, allowing us to track farmers over time. However, the number of farmers varies over time with a minimum of 138 farmers in 2009 and a maximum of 227 farmers in 2000 (for a full description of the structure of FADN data see Chapter 4, Section 4.3.1).

Regarding land use in the reference period, common wheat, rapeseed and barley are the dominant crops and represent about 66% of the Utilised Agricultural Area (UAA) during the period 1995-2009, followed by fallow land representing between 5.4 % and 12.4 % of the UAA (see Table 5-1). However, no clear time trends are observed regarding land allocation, particularly for fallow land.

Table 5-1. Main land use in the Centre region for specialist arable farmers during the period 1995-2009.

Main crops representing 96% of the UAA on average	Mean (% of UAA)	Min (% of UAA)	Max (% of UAA)	SD (% of UAA)
Common wheat	39.83	35.88	44.18	2.49
Rapeseed	14.81	7.97	19.05	3.09
Barley	11.49	7.97	14.76	1.93
Fallow land	7.94	5.42	12.37	1.82
Grain maize	7.92	6.40	9.47	0.95
Sunflowers	5.34	3.40	9.83	1.63
Dry pulses	4.35	1.57	7.96	1.99
Durum wheat	4.26	1.32	7.79	1.90

5.2.2. Price uncertainty and CCCP payment for fallow land

In order to model price uncertainty, it is important to design a realistic Monte Carlo experiment. We take into account the price distribution for the three most dominant crops: common wheat, rapeseed and barley, since they represent about 66% of the UAA for specialist arable farmers in the Centre region. Not only do we simulated different prices, but we also account for possible interactions. Hence, we build and index price using the joint price distribution for the three commodities, from which we derive a CCCP perfectly inversely correlated to the index price. Although yield uncertainty is a relevant variable for arable farmers, we assume that farmers face no yield uncertainty. Given that crop prices are not perfectly correlated, taking into account the most dominant crops allows us to provide a more efficient coverage than developing a specific policy for each commodity. Consequently, the CCCP for fallow land pools all farm price risk into a single policy that will help to mitigate farm income volatility and, additionally, may generate environmental benefits.

In the literature, copula models have been used extensively to design the current commodity programs in the US (Ahmed and Goodwin, 2015; Zhu, Ghosh and Goodwin, 2008; Goodwin and Hungerford, 2015). The strength of a "copula" function is to link, the univariate marginal probability distributions for one or more random variables (here our three dominant crop price distributions) to their joint multivariate probability distribution. Hence, a copula is a multivariate probability distribution for which the marginal probability distribution of each variable is uniform. Let us consider the marginal probability distribution $F_w(p_w), F_b(p_b), F_r(p_r)$, where p_w, p_b, and p_r are respectively the prices of common wheat, barley and rapeseed. Sklar theorem (1959) states that a unique copula *C* in the unit hypercube $[0,1]^3$ with uniform $U[0,1]$ marginal distribution is associated with the joint distribution $F(p_w, p_b, p_r)$ such as:

$$F(p_w, p_b, p_r) = C(F_w(p_w), F_b(p_b), F_r(p_r);\ \theta) \tag{5.1}$$

where θ is a vector parameter of the copula, reflecting the dependence structure among the marginal distributions. Consequently, a copula approach first allows us to specify the univariate distribution for each random variable independently. They may or may not belong to the same parametric family. Then the copula model defines the degree and the structure of the dependence between our variables.

The first step is to estimate the marginal distributions for wheat, barley and rapeseed. We use the average observed regional price for these three commodities during the period 1995-2009 in the FADN dataset. We use the Maximum Likelihood Estimators (MLE) to fit several probability distributions[27]. For reasons of parsimony, we just report the relevant results. However, the full results are available in the Appendix V. Based on the Akaike (AIC), Bayesian (BIC) information criteria and Chi-Square statistical test, we found the following marginal distribution:

$$F_w(p_w) = logLogistic\ (0; 119{,}37; 10{,}15) \tag{5.2}$$

$$F_b(p_b) = Pearson5(37{,}03; 4209{,}60) \tag{5.3}$$

$$F_r(p_r) = Pearson5(27{,}47; 5861{,}60) \tag{5.4}$$

The second step is to estimate the degree and the dependence structure among commodity prices. The two most common families of copulas are elliptical copulas, such as the Gaussian and *t* copulas, and Archimedean copulas, such as Clayton and Gumbel copulas. A full evaluation of appropriate copulas is beyond the scope of this study. Instead, we fit several copulas using MLE and rely on the information criterion (AIC and BIC) (for further information on this topic see Goodwin and Hungerford 2015; Woodard

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[27] For the estimation of the marginal distributions and the copula model we used the software @Risk developed by Palisade.

et al. 2011). Table 5-2 shows the goodness of fit for the different estimated copulas. The BIC and the average log-likelihood are the highest for the *t*-copula. However, the Gaussian performs better according to the AIC.

Table 5-2. Goodness of fit of the different copulas.

Copulas type	**AIC**	**BIC**	**Average log-likelihood**
Gaussian	-17.82	-17.88	0.87
t	-17.66	-18.83	0.99
Clayton with all variables reversed	-15.34	-14.94	0.59
Gumbel	-8.99	-8.59	0.38
Gumbel with all variables reversed	-8.01	-7.61	0.34
Frank	-5.04	-4.64	0.24
Clayton	-1.48	-1.08	0.13

A Gaussian copula assumes linear correlation and zero dependence in the tails of the distributions, while a *t*-copula allows dependence in the tails but imposes symmetry between them. In our case, we are studying the prices in the Centre region. Hence, we can expect that the external forces influencing prices, such as weather or pests are common to the three marginal distributions. In other words, it is likely that if bad weather has impacted wheat price, it also has impacted barley price. This phenomenon is called tail dependence. Hence we opt for a *t*-copula. Table 5-3 shows the dependence structure for our marginal distributions implied by the *t*-Copula.

Table 5-3. Dependence structure implied by the t-Copula.

Type: t-copula	**Wheat**	**Barley**	**Rape seed**
Wheat	1		
Barley	0.89	1	
Rape seed	0.34	0.09	1

The Index price is a linear weighted average of wheat, barley and rapeseed price and has the following formula:

$$Index\ Price = \frac{(p_w \times 40 + \ p_b \times 15 + p_r \times 11)}{(40 + 15 + 11)} \tag{5.5}$$

where the weight 40, 15 and 11 are respectively the observed mean of land allocation for each crop (see Table 5-1). Our simulation model is based on 2000 iterations and uses a Latin Hypercube sampling method. We then obtain the following Index price distribution in Figure 5-1.

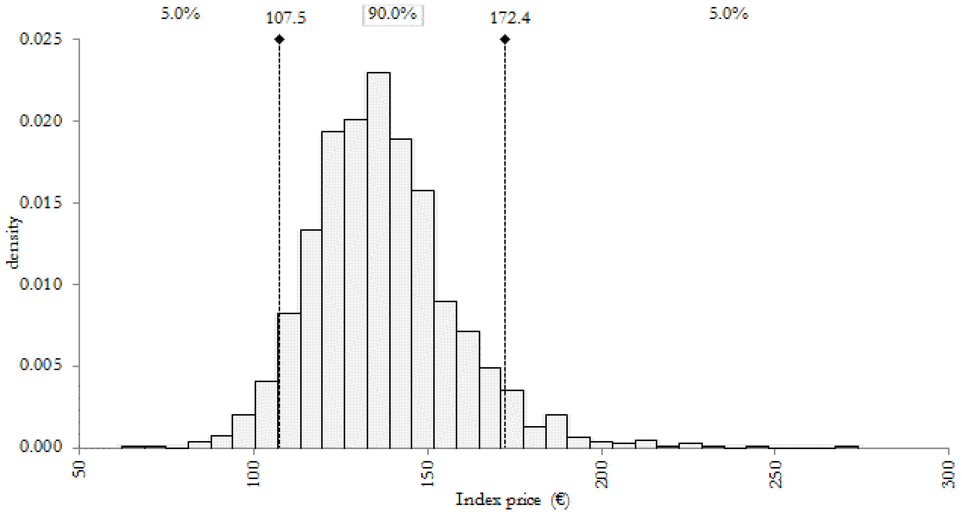

Figure 5-1.Index price distribution.

From the index price distribution we wish to build a CCCP perfectly inversely correlated to the index price, where the minimum value of the index price corresponds to the maximum value of the CCCP and the maximum value of the index price corresponds to the minimum value of the CCCP. We assume that the minimum value for the CCCP is zero. As regards the maximum, we assume a value of 500€/ha. This is obtained using the formula (5.6)[28]. Figure 5-2 shows the obtained distribution for the CCCP.

$$CCCP = -2.5 \times Index\ Price + 674 \tag{5.6}$$

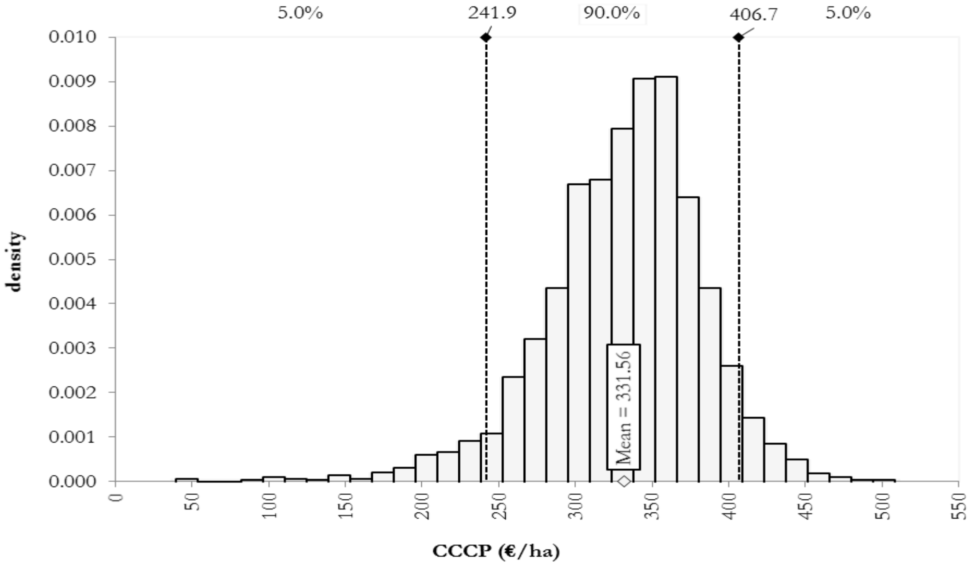

Figure 5-2. Distribution of the CCCP

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[28] We estimate a linear equation $y = ax + b$ based on two points: (MaxIndexPrice ; MinCCCP) and (MinIndexPrice ; MaxCCPP) which gives (270;0) and (69.6;500). $a = -\frac{500}{270-69.6} \cong -2.5\ and\ b \cong 674$

The mean for the CCCP is about 332€/ha. This is in line with the impact assessment by the European Commission (European Commission, 2011b) who estimate that 14% of farmers have an opportunity cost for an ecological focus area of between €200 and €400/ha but acknowledge that it varies greatly from farm to farm.

5.2.3. Modelling farmers' behaviour

In this section, we describe the model used for policy analysis. We assume that farmers decide upon their land use, know their selling prices and the amount of CCCP they will receive. These prices are derived from the Monte Carlo experiments. However, the model does not draw a distinction between future prices and stock market prices. Implicitly, we therefore assume that at the time farmers determine their land use, they protect themselves and fix their selling prices using future markets or forward contracts.

We use a similar farm-type regional model to the model discussed in Chapter 4 (for a detailed explanation, please refer to Chapter 4, Section 4.3.2) where the objective is to maximize the profit for arable land in the Centre region π . This gives, for a given iteration, (the model is run for 2000 iterations using price distributions obtained from the Monte Carlo simulation):

$$\underset{y,c,x}{Max}\ \pi = \sum_f W_f \,.\left(\sum_k P_k.\, y_{f,k} - \sum_j D_j \,.\, c_{f,j} + \sum_i \text{CCCP}.\, x_{f,\text{fallow land}} + DS_f\right) \tag{5.7}$$

S.t.

$$Y_k = \sum_f W_f \,.\, y_{f,k} \tag{5.8}$$

$$X_i = \sum_f W_f \,.\, x_{f,i} \tag{5.9}$$

$$C_j = \sum_f W_f \,.\, c_{f,j} \tag{5.10}$$

$$\sum_t \lambda_t\, \widehat{Y_{t,k}} \geq Y_k \tag{5.11}$$

$$\sum_t \lambda_t\, \widehat{X_{t,i}} \leq X_i \tag{5.12}$$

$$\sum_t \lambda_t\, \widehat{C_{t,j}} \leq C_j \tag{5.13}$$

$$\sum_t \lambda_t = 1 \tag{5.14}$$

$$y_{f,k} - \sum_t \delta_{f,t}\, \widehat{y_{f,k}} - \sum_{peer} \beta_{f,peer}\, \widehat{y_{peer,k}}/\theta_f = 0 \tag{5.15}$$

$$x_{f,i} - \sum_t \delta_{f,t}\, \widehat{x_{f,i}} - \sum_{peer} \beta_{f,peer}\, \widehat{x_{peer,i}}/\theta_f = 0 \tag{5.16}$$

$$c_{f,j} - \sum_{t} \delta_{f,t}\, \widehat{c_{f,j}} - \sum_{peer} \beta_{f,peer}\, \widehat{c_{peer,j}}/\theta_f = 0 \tag{5.17}$$

$$\sum_{t} \delta_{f,t} + \sum_{peer} \beta_{f,peer} = 1 \tag{5.18}$$

$$\sum_{i} x_{f,i} \leq maxUAA_f \tag{5.19}$$

where i corresponds to crop acreage.

$\delta_{f,t}, \beta_{f,peer}, c_{f,j}, x_{f,i}$ and $y_{f,k} \geq 0$

where f indexes the farm, k the outputs of the farmers, j the different categories of input costs and i the different inputs used by the farmers. W_f is the weight for each farmer in the sample. $y_{f,k}$ is a column vector of production quantities, $x_{f,i}$ is a column for the vector of input activities and $c_{f,k}$ is a column vector of input costs. P_k is the price derived from the Monte Carlo simulation for wheat, barley and rapeseed and the average outprice observed in 2009 for all the other crops. D_j is the index price of the different input cost categories in 2009. *CCCP* is the counter cycle payment for fallow land which is dependent on the wheat, barley and rapeseed prices. Finally, DS_f is the sum of the decoupled payment and rural development subsidies received by a farmer in 2009.

Three sets of constraints (5.8, 5.9, 5.10) ensure that the farm-type regional endogenous variables, Y_k the produce quantities, X_i the input activities and C_j the input costs, are partitioned according to the weight for each farmer. Four sets of constraints (5.11, 5.12, 5.13, 5.14) illustrate the historical activities mixed approach proposed by McCarl in 1981. Where *t* indexes the different years from 1995 to 2009, $\widehat{Y_{t,k}}$, $\widehat{X_{t,i}}$, and $\widehat{C_{t,j}}$ are the historical farm-type regional observations for production quantities, input activities, and input costs, respectively, and are exogenous to the model. However, contrary to Chapter 4, this set of constraints is transformed in terms of inequality where we assume strong disposability. In other words, an increase or decrease in fallow land does not always lead to a change in other land use at farm-type regional level. The last set of constraints (5.15, 5.16, 5.17, 5.18, 5.19) ensures that farm-level solutions are themselves a linear weighted average of their historical and/or peer activity mix. Where $\widehat{y_{f,k}}$, $\widehat{x_{f,i}}$ and $\widehat{c_{f,j}}$ are, respectively, the historical farm observations for production quantities, input activities, and input costs and are exogenous to the model. $\widehat{y_{peer,k}}$, $\widehat{x_{peer,i}}$ and $\widehat{c_{peer,j}}$ are the historical peer observations for production quantities, input activities, and input costs. Respectively, and are exogenous to the model. θ_f is the efficiency score for each individual farmer and its value lies between 0 and 1.

5.3. Results

In this section, we compare two scenarios. As mentioned previously, the model does not draw a distinction between future prices and spot market prices. Therefore, at the beginning of the campaign farmers fix their selling prices and determine their land use based on them In the first scenario "No CCCP", no obligation to set aside arable land is implemented. Farmers are free to choose land allocation given the market conditions. The model from (5.7) to (5.19) is run for 2000 iterations taking into account the dependence structure between our three commodity prices (see Section 5.2.2) and the CCCP in equation (5.7) is equal to zero. The second scenario "With CCCP" differs only from the first scenario in the implementation of a CCCP for fallow land. In other words, farmers have a financial incentive to set aside part of their arable land. The lower the price for wheat, barley and rapeseed, the higher the CCCP.

Figure 5-3 shows the difference in income distribution at regional (Figure 5-3.A) and farm level (Figure 5-3.B). Here, we are not interested in the absolute change in income, since in the scenario "With CCCP" income will be inflated by the subsidy. Instead, we investigate the impact of a CCCP on the variance in the income distribution. At regional level, the percentage change in income varies between plus and minus 50 % for both scenarios. Nevertheless, we observed a standard deviation (SD) of 18.9% for regional income when a CCCP is in place, compared to 21.6% in the absence of a CCCP. The difference is more pronounced at farm level. Figure 5-3.B shows the distribution of the SD for the percentage change in farm income. Clearly, the implementation of a CCCP decreases the volatility of farm income. The average SD drops from 47% to 35% with a CCCP.

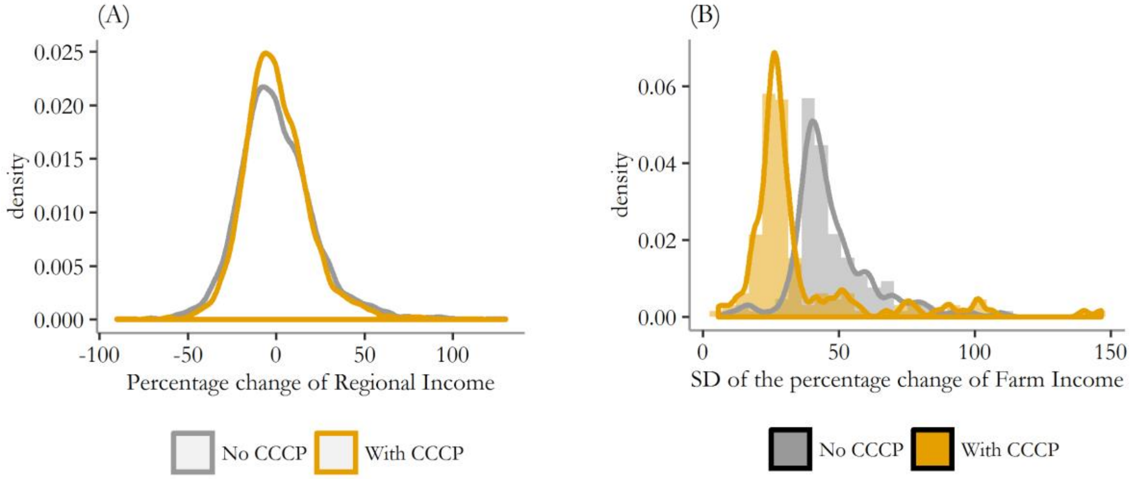

Figure 5-3. Income distribution at regional and farm level.

In theory, a countercyclical payment based on wheat, barley and rapeseed prices and linked to fallow land should limit over-production in times of low commodity prices. We expect, on average, a decrease in land allocated to these commodities and an increase in fallow land. However, equation (5.19) binds the total UAA at farm level to the maximum historical value. The observed change to UAA at farm level in the FADN data could be due to several factors: structural change to the farm, small errors in the recording of areas, land abonnement. However, we did not observe significant trends in the change to UAA, since for all farmers, the average maximum increase in UAA is about 4.6% at farm level. In other words, farmers can to slightly extend or adjust their UAA and set aside part of their land leading to an overall increase in fallow land and UAA at farm and regional level.

Table 5-4 shows land allocation for both scenarios and the percentage change in the mean when a CCCP is implemented compared to no CCCP. As expected, the highest increase is observed for fallow land (70%), corresponding to an average addition of 50 431ha set-aside. The land allocated to rapeseed and barley decreased by about 20 000ha, while we observed a small increase for common wheat. The total UAA, at a regional increase of 3%, corresponded to an addition of about 30 000 ha. The area for maize, sunflowers and dry pulses increased by about 12 500 ha overall, while areas allocated to other cereals and industrial crops, durum wheat and summer cereals decreased by 12 000 ha in total. Looking at the difference in SD between the two scenarios, the SD of rapeseed, grain maize, durum wheat and sunflowers increase the most, while the SD for common wheat increase slightly relative to its mean and the one for barley even decrease. These results indicate that common wheat and barley are the two crops the least substitutable with fallow land and so the most resilient to price changes. Results regarding minor crops (below 10 000ha in average area) might be misleading. Their percentage changes seem important, but looking at the absolute mean value and the SD, we observe that the SD deviation for those crops is relatively high. We do not consider these results in our interpretation. This phenomenon highlights one of the model's weakness and strengths. The weakness is that it relies on dependence on peers, as already reported in Chapter 2. If the chosen peer strongly differs from a given farm, the changes might be overestimated or underestimated. The less dominant crops, such as "other industrial crops", have a higher chance of this type of overestimation or underestimation, since the number of peers growing such crops is likely to be low. Actually, other approaches that parametrically estimate farmers' responses also become less precise with a lower number of observations. Therefore, it is a positive aspect of the model and how it is implemented here that standard deviations on the outcome are reported, which is not common in agricultural policy simulation models.

Table 5-4. Land use with and without CCCP.

Land use	Scenarios	% change	Mean (ha)	Median (ha)	Max (ha)	Min (ha)	SD (ha)
UAA	With CCCP	3%	1 181 240	1 181 286	1 185 369	1 143 697	1 858
	No CCCP		1 151 087	1 147 658	1 182 046	1 130 561	12 132
Common wheat	With CCCP	0%	455 297	455 800	467 206	410 360	3 147
	No CCCP		453 196	453 933	467 206	410 360	2 819
Rapeseed	With CCCP	-9%	179 728	175 348	223 985	165 041	10 378
	No CCCP		197 817	195 855	223 985	165 041	8 230
Barley	With CCCP	-2%	148 207	148 624	170 769	119 025	2 004
	No CCCP		150 707	148 624	170 769	119 025	4 305
Fallow land	With CCCP	70%	122 529	116 448	129 832	62 654	7 352
	No CCCP		72 098	70 638	114 760	62 654	4 282
Grain maize	With CCCP	3%	84 729	85 891	109 373	73 928	2 598
	No CCCP		82 227	82 628	109 373	73 928	1 185
Durum wheat	With CCCP	-11%	54 909	58 937	89 972	32 564	6 193
	No CCCP		61 980	59 958	89 972	32 564	4 609
Sunflowers	With CCCP	8%	54 707	53 724	59 607	39 278	3 361
	No CCCP		50 786	50 584	58 028	39 278	1 782
Dry pulses	With CCCP	20%	36 386	38 788	49 474	18 127	5 079
	No CCCP		30 281	31 471	49 474	18 127	4 557
Other cereals	With CCCP	-16%	7 903	9 040	20 071	6 404	1 344
	No CCCP		9 436	9 040	20 071	8 189	935
Sugar beet	With CCCP	-8%	8 157	8 596	11 612	7 374	684
	No CCCP		8 902	8 596	12 114	7 795	522
Other industrial crops	With CCCP	-27%	6 409	5 886	9 799	166	992
	No CCCP		8 729	8 765	12 453	166	1 168
Potatoes	With CCCP	-15%	3 345	3 169	5 071	2 018	450
	No CCCP		3 951	3 836	5 465	2 018	372
Oats	With CCCP	-4%	3 201	3 209	6 118	1 482	146
	No CCCP		3 343	3 262	6 118	1 482	183
Meadow+permanent pasture	With CCCP	-3%	3 199	3 368	4 473	992	358
	No CCCP		3 293	2 963	6 526	992	563
Rye	With CCCP	-11%	2 648	2 688	7 567	1 337	197
	No CCCP		2 987	3 011	7 567	1 337	292
Fresh vegetables	With CCCP	7%	2 575	2 594	5 014	1 413	111
	No CCCP		2 405	2 503	5 014	1 413	322
Rough grazing	With CCCP	12%	1 762	1 683	4 796	327	237
	No CCCP		1 577	1 683	4 796	327	226
Summer cereals mixed	With CCCP	-55%	732	569	8 922	169	450
	No CCCP		1 640	1 158	8 922	231	815
Temporary grass	With CCCP	-24%	996	925	2 991	143	221
	No CCCP		1 318	1 285	2 991	143	289
Other seeds	With CCCP	-27%	801	722	2 962	344	183
	No CCCP		1 098	1 018	2 962	344	310
Other	With CCCP	34%	982	1 157	2 278	221	293
	No CCCP		732	695	4 205	9	188

Figure 5-4 shows the share of the main crops in the UAA for both scenarios. It is interesting to note that despite an increase in absolute terms (Table 5.1) for areas of common wheat, its relative share in the UAA decreases, meaning that its increase in area is less than proportional to the increase in UAA. For common wheat, barley, rapeseed and durum wheat we observed a decrease in the share of UAA when a CCCP is implemented. In the absence of CCCP, fallow land represents about 6% of the UAA and increases to 10% when a CCCP is implemented. The increase in areas for dry pulses, sunflowers and grain maize reflects a relatively small increase in their respective share of UAA.

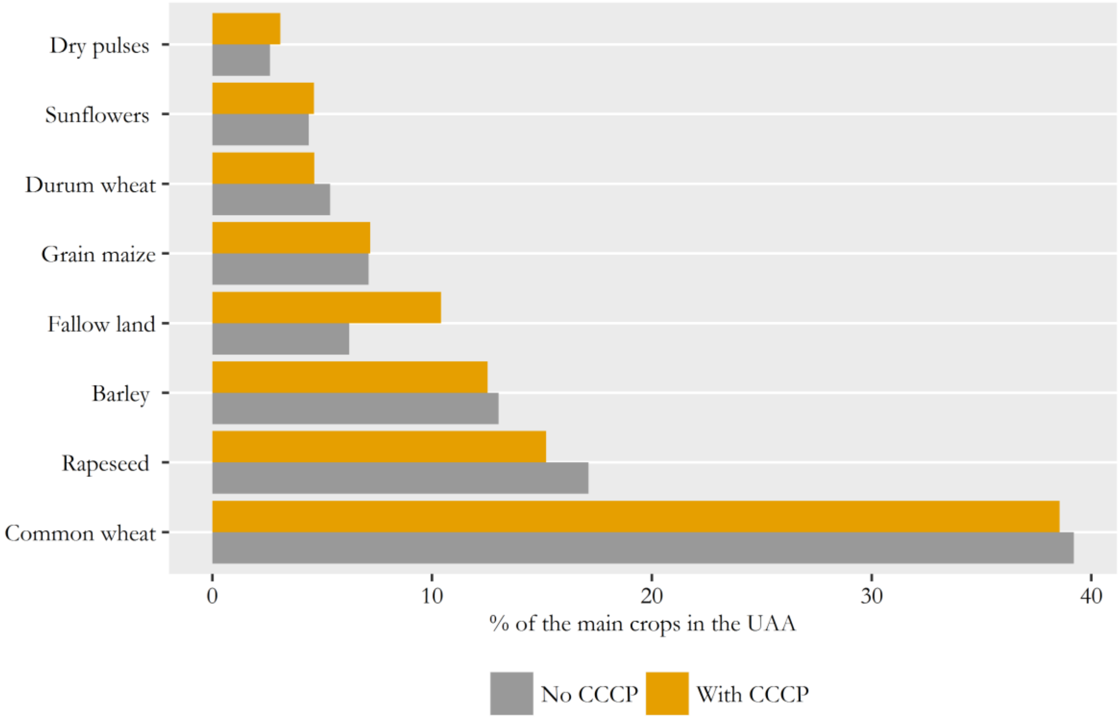

Figure 5-4. Share of the main crops in the UAA for the scenarios "No CCCP" and "With CCCP".

The post-2013 CAP requires that 5% of arable land is covered with an “ecological focus area”. For practical reasons (mostly data availability), we assume that only fallow land (including voluntary set-aside) is counted towards this goal. Then, we investigate three different minimum thresholds. First, we look at the number of compliant farmers with 5% of fallow land. Second, the post-2013 CAP establishes the full greening provision for a minimum of 7% in ecological focus area (which may be implemented in 2017), so the second minimum threshold for fallow land is set at 7%. Finally, we investigate a threshold of 10% for fallow land. Figure 5-5 shows the distribution of the share of compliant farmers for the three minimum levels of fallow land, with and without CCCP. For a minimum requirement of 5% of fallow land, in the presence of a CCCP, 82% of farmers are compliant against 57% in the absence of a CCCP. In the case of a minimum requirement of 7%, 72% of farmers comply when they receive a CCCP, against 38% without it. The gap in terms of the number of compliant farmers is smaller (10 points) with a CCCP than without a CCCP (19 points). However, for a minimum level of 7% and 10% with a CCCP, the distribution of compliant farmers is bimodal. A bimodal distribution suggests that there are threshold effects in the implementation of fallow land, which is also illustrated in Figure 5-6.

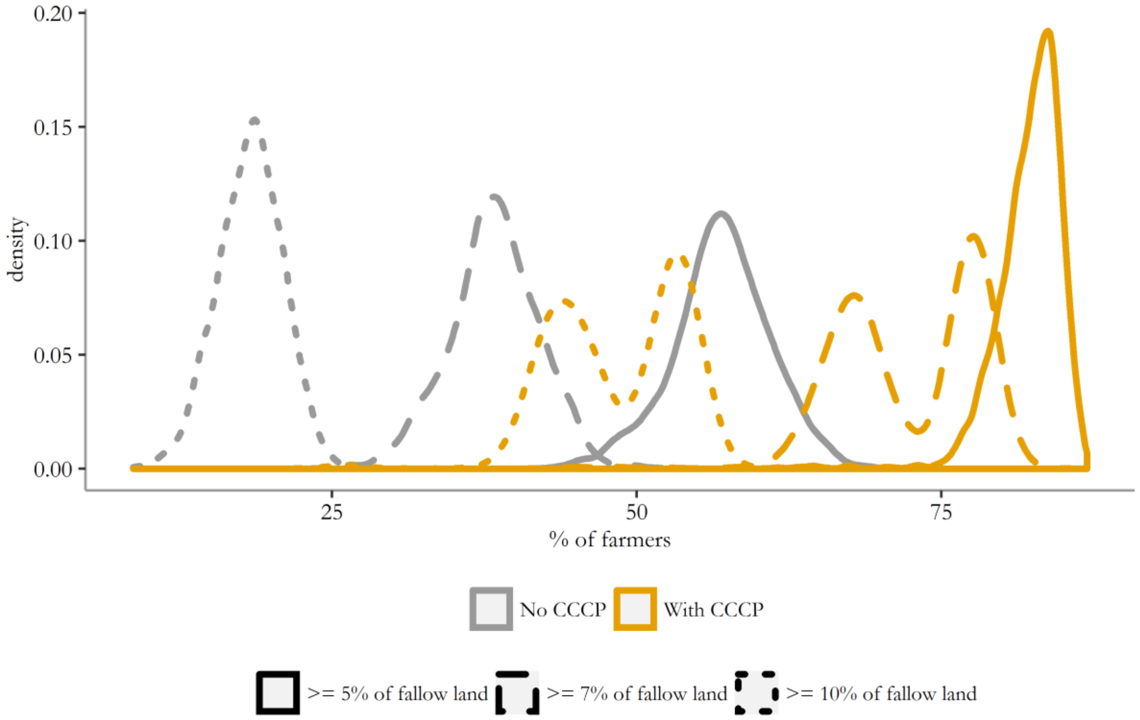

Figure 5-5. Probability distributions for the share of farmers complying with three different minimum levels of fallow land under the different Monte Carlo generated prices and CCCP.

Figure 5-6 shows the relationship between the number of compliant farmers for different levels of greening requirement and the level of the CCCP. Each circle on the graph represents one Monte Carlo simulation, i.e. a generated set of prices and CCCP. In the case of a 5% requirement, the number of compliant farmers increases almost linearly with an increase in the CCCP. As commodity prices fall and CCCP increases, the number of farmers setting aside land gradually increases. In the case of a 7% requirement, and even more so for a 10% requirement, we can distinguish a threshold effect in the outcomes of the price-CCCP scenarios. There are few settings where there are between 75% and 80% of the farmers complying with the 7% set-aside requirement and there are two groups of farmers (plotted in grey and black), 65% and 45% of the farmers for 7% and 10% greening requirements, respectively, who would be compliant if the CCCP was around 300€/ha. However, to convince 75% and 55% of the farmers to comply with the 7% and 10% greening requirements, the CCCP would need to be around 370€/ha. Consequently farmers respond non-linearly to CCCP.

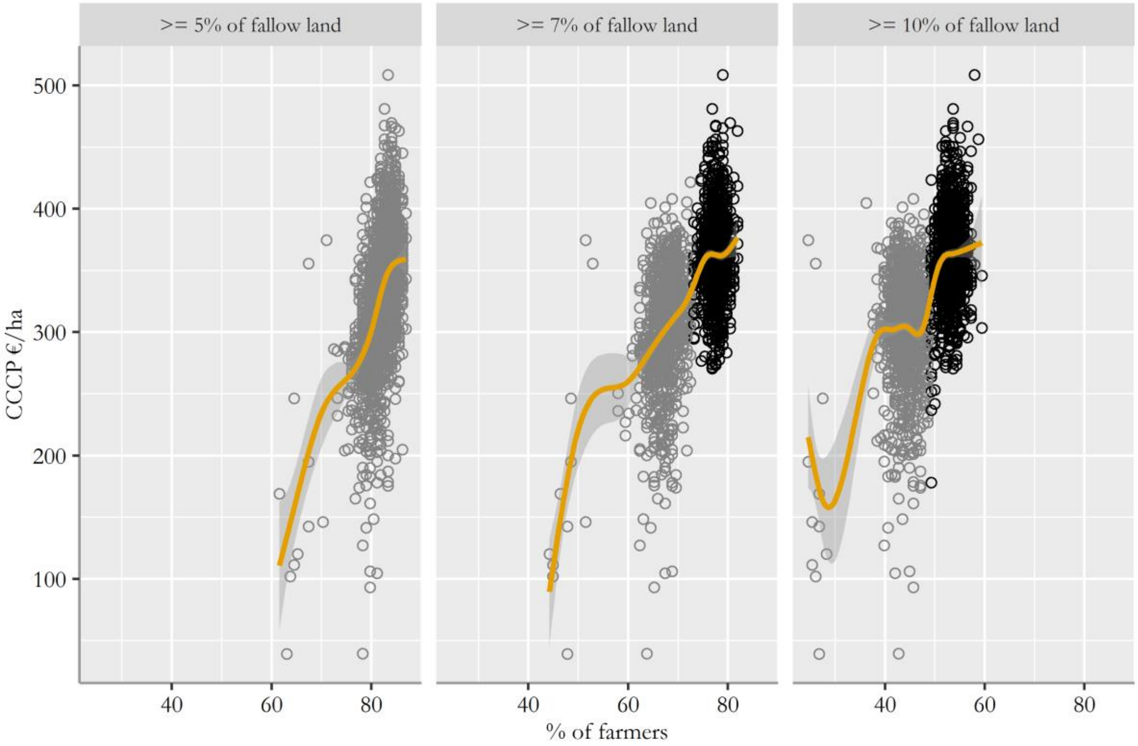

Figure 5-6. Relationship between the level of CCCP received and the number of compliant farmers.

5.4. Discussion

The objective of this research was to determine whether a CCCP, similar to capacity payments implemented in the electrical sector, could mitigate farm income risk and provide environmental benefits. The results show that by pooling commodity price risk under one policy instrument and linking it to set-aside, we could achieve a higher level of set-aside at farm and regional level compared to the current requirement, while at the same time decreasing production in times of low commodity prices and reducing farm income volatility.

These results are in line with Dörschner and Musshoff (2013) who found that in the case of an agro-environmental measure leading to a decrease in income risks, risk aversion will, in turn, increase the acceptance of such a measure. Though, our simulation exercise looks at the impact of a CCCP on farm income volatility, it does not consider risk behaviour of farmers. In the context of mathematical programming models, risk is often model using linear mean-variance under maximisation of expected utility. In order to recover risk coefficients, often models are calibrated to the observed farmer behaviour and regional price distributions are used (Gómez-Limón, Arriaza and Riesgo, 2003). A major drawback of such approach is it assumes that behaviour differing from the optimum under profit maximisation is purely imputable to risk. More recently, Petsakos and Rozakis (2015) proposed a non-linear mean-variance model that they calibrate using PMP based procedure. Yet, the authors acknowledge that the obtained results might lead to negative profit per hectare indicating mystification of the underlying distributions. Furthermore, due to the introduction of non-linearities such approach could be computationally challenging to calibrate. Hence, the integration of risk in agricultural policy model remains a path to explore in future research.

Another limitation of our approach is that prices are not simulated endogenously and so impacts on the supply side is not fully taken into account. More specifically, one of the main challenge of climate policy is to defeat the "Green paradox"(Sinn, 2008). In our case, the green paradox infers that an increase of set-aside in Europe might lead to an agricultural intensification in the rest of the world which could eventually lead to a more problems globally than before. Hence, in future research it would be critical to take into account market feedbacks in order to assess the environmental impact of policies (Fölster and Nyström, 2010). For instance, we could run our model for the entire EU and link it to a general or partial equilibrium model. An interesting point would be to compare the current EFA requirement to a CCCP. Indeed a CCCP will not alleviate pressure on set-aside in times of high commodity price and it is likely that set-aside land will be low. Nevertheless, Pelikan et al. (2015) show that a mandatory minimum level of set-aside, without taking into account commodity prices, may intensify production in the rest of the world. We can wonder whether policy makers value the production location for positive and/or negative externalities. Here, although a CCCP does not alleviate pressure on set-aside when prices are high, it does partially reduce pressure on the agricultural commodity market. Besides, the past milk crises have led the EU to offer a premium per liter of milk non-produced during a period of 3 months given the fall in milk price (European Comission, 2016). The system that offers a premium for production cuts is conceptually similar to the propose CCCP. Here, we propose a first step in the calculation and the assessment of such policy instruments.

Assuming that farms will set aside the least profitable land, one could argue that a mandatory requirement for fallow land will ensure a perennial supply of ecological benefits at a fixed location. Although there is legitimate concern, the current policy does not prevent rotations, and contrary evidence on the impact of set-aside management and rotational effects exist. On the one hand, some authors (Van Buskirk and Willi, 2004) conclude that short rotations enhance biodiversity; on the other hand, others (Kovács-Hostyánszki and Báldi, 2012) find a positive correlation between set-aside age and farm land biodiversity. Promoting set-aside in locations where it likely increases ecological benefits would require linking policy incentives to a spatial location that reports the current ecological status (Maes et al., 2012).

The results also illustrate the difficulty for policy-makers in designing policy instruments that fit all objectives. Despite a relatively homogenous sample in a given region, farmers' responses to CCCP exhibit threshold effects. From a policy point of view, the simulated model implements a CCCP that is linearly dependant on the Index price (see equation (5.6)). We could take into account such an effect and impose non-linearity. However, it is likely that the observed threshold effects differ between geographical areas, farm management practices and in time. Hence, such a tailored CCCP could be impractical in real life. Another question is: knowing that for around 300€/ha , 65% and 45% of farmers comply with the 7% and the 10% requirement, is it worth trying to convince the remaining farmers and what is the cost-benefit? Furthermore, from an environmental point of view, the pressure on biodiversity might be different depending on the landscape context (Tscharntke et al., 2011; Tzilivakis et al., 2016; Pe'er et al., 2014). If European policy makers intend to enhance biodiversity via the first pillar of the CAP, the more uniform the policy mechanism is, the less efficient it gets. Such results highlight the need to develop methodologies that take into account farmers' heterogeneity. Recently, the European Commission reviewed the impact of greening measures after one year of implementation (European Commission, 2016). Regarding the ecological focus area measure, they used the CAPRI (Common Agricultural Policy Regionalised Impact) model (Britz et al., 2014), a comparative-static, farm-type regional model. Such an approach does not take into account the farm context specificity, leading to aggregation bias and over or under estimations of the impacts. Our approach addresses this issue by partitioning regional solutions from farm-level solutions and ensuring they represent historical or/and peer activity mix.

Although our modelling approach takes farmers' heterogeneity into account, historical behaviours may not reflect future behaviour. Any price development beyond historical observations cannot be captured by our model. To address this issue, one possibility would be to extend the historical observations by appending synthetic observations. Several options to generate synthetic observations are feasible. Chen and Onal (2012) simulate synthetic crop mix based on a set price for acreage elasticity and elasticity lagged acreages, all estimated using the historical supply responses. However, such an approach still relies on past observations. Another possibility would be to simulate land-use response using a detailed bio-economic model and then estimate land-use elasticity taking into account past observations and simulated observations. Another limitation of our study is the number of commodity prices taken into account. If a CCCP were designed by policymakers, potentially all output prices could be taken into account and other data sources could be used to derive more realistic probability distributions.

5.5. Conclusion

A price risk management instrument could be combined with the provision of positive externalities. A CCCP promotes the building of an agricultural production capacity, mitigates farm income risk and provides environmental benefits. In the EU, in the long term, results show that a CCCP could potentially surpass the current ecological focus area measure implemented in the post-2013 CAP, with 10% of set-aside land out of total UAA at farm level. In the US, CCCP could be an alternative to both the crop insurance program and the conservation reserve program. In doing so, it would address the criticism that government support has crowded out the insurance market and that the interaction between programs might have offset the benefits of the conservation program. Although our study does not investigate the price effects of a CCCP, the wide adoption of such a policy would certainly reduce pressure on commodity prices leading to greater stability and would help towards building a long term agricultural generation capacity.

Chapter 6. Conclusions and Policy recommendations

6.1. Research objectives and conclusions

The last reform of the Common Agricultural Policy (CAP) has introduced three new greening measures - crop diversification, permanent grassland and Ecological Focus Area (EFA)– with which farmers must comply in order to receive their full allocation of direct payments. The introduction of the greening measures poses new challenges for agricultural policy modellers. Measures are farm specific and are designed to change the land allocation at farm level. Consequently, any ex-ante assessment should be able to take into account farm-level specificity and should tackle the following modelling challenges: self-selection bias, substitution patterns, aggregation bias and uncertainty. Besides the introduction of the greening requirements, farmers can also receive coupled payment support. Indeed, the post 2013 CAP has reintroduced support coupled to agricultural production, representing 4.1% of the total budget for direct support in the EU. We suggest that coupled support could instead be linked to the provision of environmental services that underpin a more environmentally friendly production model and achieve similar objectives to current greening requirements. We propose two types of alternative coupled payment linked to environmental services: a premium per hectare for permanent grassland and a Counter Cyclical Capacity Payment (CCCP) for set-aside land. Hence, the dissertation evaluates the impact of the greening requirements at farm level, compares the greening requirements to alternative policy instruments while, at the same time, developing a non-parametric mathematical programming model to tackle the different modelling challenges.

Chapter 2 addresses the crop diversification measure. By its nature, this measure forces some farmers to adopt a new crop. Traditionally, in agricultural policy models, the newly adopted crop is the crop with the lowest opportunity cost at regional level. Such an approach implicitly smoothens farmers' heterogeneity by assuming that the opportunity cost for each crop is the same for all. Instead, we introduce the notion of 'mimicking peer behaviour' where the main assumption is that a farmer is likely to do the same as his peers. We show that if the intention of the crop diversification measure is to deter monoculture, the policy is effective. However, at landscape level, the measure has limited impact on crop diversity since adopted crops are also dominant crops in the landscape. The results also show the limitations of such a methodological approach. In fact, the key element is the selection of peers. Can a farmer have several peers? Which variables are taken into account and what is their weight in the selection of peer farmers? In chapter 2, non-compliant farmers adopt the production choices of their peers. Only one peer can be selected for each farmer, based on four variables: crop area, total farm area, number of crops and geographical distance, where the latter is a discriminant variable ensuring the selection of a single peer. However, if the model minimises the difference between the selected peer and the associated farmer, it does not indicate to what extent they are alike. For instance, the selected peer could have a rare crop configuration. Hence, peer selection is driven by the dimensions of our problem and the underlying heterogeneity of our dataset.

In order to assess the capability of models to reproduce the substitution patterns observed in reality, chapter 3 tests the ability of two modelling approaches given data heterogeneity and input uncertainty. The parametric approach is a standard econometric model where we estimate a cubic production function. The non-parametric approach is an inverse DEA model. Here, it is important to stress that an inverse DEA model is not used in the context of productivity analysis, but as a method to select peer Decision Making Units (DMUs) based on input and output variables. Indeed, distance functions provide the conceptual underpinning of efficiency measurement and allow one to describe a multi-input multi-output production function leaving the behavioural objective undefined. In that sense, DEA is just a mathematical programming model used to compute input and output radial distances. Compared to chapter 2, each DMU has multiple peers and management is implicitly taken into account by preserving efficiency scores. However, in chapter 3 we assume profit maximisation behaviour for the selection of peers when price changes. Hence, DMUs fully or partially adopt their own production technology or that of their peers to maximise their profit. The results show the importance of using panel data, or robust grouping technics, in order to maximise homogeneity in the sample. The models' performance is negatively affected by an increase in heterogeneity and they tend to overestimate change if there is a high level of heterogeneity. Both modelling approaches remain consistent when uncertainty is introduced. However, they underestimate change when it prevails. In terms of substitution pattern, the inverse DEA model outperforms the parametric approach and performs well with a small sample size. The parametric approach performs poorly given that in the most favourable situation we have generated a panel dataset of 1000 observations with different prices and free of any measurement or sampling bias. This quantity of data is far beyond the real world policy simulation, where, typically, less than 20 observations per farm are available and the amount of price variation is limited.

Chapter 2 introduces a non-parametric approach to tackle the self-selection problem and simulates land-use change based on a "pure" mimicking of peer behaviour. Chapter 3 further elaborates this approach assuming multiple peers per DMU and profit maximisation behaviour. Additionally, chapter 3 provides evidence that when the underlying data-generating process exhibits non-linearity and threshold effects, the non-parametric approach is superior to a Taylor polynomial approximation. This reflection has been considered in chapter 4 where we seek to simulate the impact of the maintenance of permanent grassland on farmers' activity changes using FADN data. The problem is that the amount of information per farm is insufficient to transpose the inverse DEA model from chapter 3 onto chapter 4. Indeed, in the case of a panel specification for the inverse DEA model, peer farmers are past observations for the farmer under consideration. The number of observations per farm is smaller, along with the number of peers. This would result in a strong inelasticity of input and output to prices or policy changes. One solution is to augment the number of possible peers by taking into account farmers in the same region and with the same farm type. Here, the drawback is that under profit maximisation, the chosen activity mix is the one for the most profitable peer. This phenomenon is known as the "extreme specialization problem" (Baker and McCarl, 1982; Buysse et al., 2007). To remedy this problem, Önal and McCarl (1991) show that by stacking the individual optimal solutions (for instance a farm model) we obtain the optimal solution for an aggregate model (for instance a farm-type regional model). Hence, we developed a farm-type regional model that is constrained by the farm-type regional historical activities mix, but also partitions the farm-type regional solution into individual solutions that are themselves a convex combination of the individual and/or peer historical activities. Such an approach enables us to tackle the problem of self-selection, to ensure a good representation of substitution patterns and finally to avoid aggregation bias.

Regarding the maintenance of the permanent grassland measure under the greening package, we study the case of France. France is an interesting country to study, since agricultural land covers about 43% of the French territory (Farm Structure Survey, 2010) and was the highest among the EU-27 in 2010. Results highlight the importance of taking into account farm diversity. Indeed, to maintain the ratio of permanent grassland at the 2009 level, the opportunity cost varies greatly between farm types and regions, from 5.9€/ha for specialist cattle-rearing and fattening in Languedoc-Roussillon to 240€/ha for specialist horticulture in Basse-Normandie. Chapter 4 also demonstrates that the introduction of a premium of 100€/ha for permanent grassland would increase permanent grassland area by about 1% compared to the 2009 level. Furthermore, the introduction of such a premium would represent only 78% of the current Voluntary Coupled Support (VCS) budget for the livestock sector, would benefit the same targeted sectors under the current VCS, would promote the provision of permanent grassland and strengthen the link at farm level between crop and livestock production.

Finally, chapter 5 presents a CCCP for set-aside and analyses its impact on arable farmers' income variability and land-use changes in the Centre region in France. In the light of the debate around the effectiveness of the Ecological Focus Area requirement within the greening package, we suggest a CCCP which could play two roles: mitigate farm income variability and enhance the provision of environmental services at the lowest cost. To capture output price uncertainty and the price of the CCCP, we apply a Copula model based on the joint distribution of prices over the past 10 years for the three most common commodities: wheat, barley and rapeseed. Then, using a Monte-Carlo setting, we generate the probability distribution for each commodity price and the CCCP. This is the same farm-type regional model that, in chapter 4, simulates activity change for each stochastic price and the CCCP generated. In order to account for price uncertainty, we assume that farmers decide upon their land use, know their selling prices and the amount of CCCP they will receive. However, the model does not draw a distinction between future prices and stock market prices. We therefore assume that when farmers determine their land allocation, they protect themselves and fix their selling prices using future markets or forward contracts. The results show that by pooling commodity price risk under one policy instrument and linking it to set-aside, we could achieve a higher level of set-aside at farm and regional level compared to the current requirement, while at the same time decreasing production surplus in times of low commodity prices and reducing farm income volatility.

6.2. Policy recommendations

According to the European regulation No 1306/2013 (European Parliament and Council of the European Union, 2013b), the European Commission should monitor and evaluate the performance of the CAP in relation to the following three objectives:

"(a) viable food production, with a focus on agricultural income, agricultural productivity and price stability;

(b) sustainable management of natural resources and climate action, with a focus on greenhouse gas emissions, biodiversity, soil and water;

(c) balanced territorial development, with a focus on rural employment, growth and poverty in rural areas."

The greening measures are intended to contribute to objective (b), although they may impact on all objectives. In this dissertation, we contribute to the objective (a) and (b) in analysing the potential impact of the greening measures on land-use change and farm income. We show that the current policy design might have limited effects and impacts might vary widely between farmers and regions. A successful greening package should take into account several factors. Beside the specific results of each chapter discussed in section 6.1, each chapter has been confronted with at least one of the following issue: determining the minim baseline level, whether or not to account for interaction among policy instruments, and to which extent current available data are sufficient to conduct a robust assessment.

First, the success of a policy measure can only be assessed given a point of reference. Yet, under the current legislation, the minimum baseline is not clearly stated. Farmers might decide not to comply with the greening package. For simplification, in chapter 2 we assume that all farmers want to comply. In chapter 4, given that the costs of maintaining permanent grassland differ across farmers, but are unknown to the authority, we determine farm-type regional opportunity costs, implicitly assuming that within a group some farmers will compensate for others. Such approach is in line with the choice made by Member States to maintain the ratio of permanent grassland to agricultural area at best at regional level. By imposing a ratio at regional level and not at farm level, the minimum baseline level differ across farmers and it is dependant of the decision made by other farmers. Additionally, the current design of the policy does not sanction farmers who have the most environmentally harmful practices, but those who historically received the highest level of direct payment for their eligible land. In the case of permanent grassland, farmers with a historically large area of permanent pasture are now the most constrained in terms of land allocation compared to those who converted permanent pasture into arable land ahead of the reform. Hence, we suggest that the integration of environmental concerns into pillar I of the CAP should also clearly define the rationale under which it operates. The greening of pillar I could apply the "Polluter-Pays-Principle", in which case a baseline indicator should be defined at farm level. For instance, for the crop diversification measure, three crops on a large farm have a different impact on biodiversity and the landscape than three crops on a small farm (Pe'er et al., 2014). For the maintenance of permanent grassland, the current requirement does not influence management practices, but instead freezes the geo-location of permanent grassland to where it was historically observed and not where it is the most beneficial. For EFA, the current logic does not ensure the deliverance of ecosystem services. For instance, nitrogen-fixing crops are considered as EFA, although their ecological interest in mitigating nitrogen and phosphorus losses or improving biodiversity greatly depends on management practices (Williams et al., 2014). The greening of pillar I could also apply the "Provider-Gets-Principle". However, in this case payments should be made in accordance with the environmental value produced and the individual opportunity costs of the measure. Such an approach would fit under the rationale of pillar II of the CAP, which leaves flexibility to MS and their regions to translate European objectives into specific regional objectives. However, from a budgetary point of view, MS are reluctant to transfer further funds from pillar I to pillar II, since the pillar II budget is co-financed by MS. A possible option to reconcile both approaches would be to reinforce and extend cross-compliance policy and introduce coupled payments linked to the production of environmental services. Cross-compliance policy could establish the minimum baseline level applicable to all arable land. However, the effectiveness of cross-compliance policy largely depends on the effectiveness of the control and sanction systems. The introduction of voluntary payments coupled to environmental goods would go beyond cross-compliance policy and could potentially target management systems that deliver environmental services.

Second, policy makers should take into account the interaction between policy instruments and impacts beyond the EU. This dissertation does not simulate possible interactions, but rather look at possible budget transfer from the VCS to payment for permanent grassland. The EU intends to address climate change, in order to measure the impact of any policy instruments on climate, impact indicators should take into account impacts on third countries (Pelikan et al., 2015). The positive impact from one policy instrument might be offset by another. In that sense, the re-introduction of support coupled to production is a major step back. We argue that coupled support should be linked to the provision of environmental benefits. Coupled payments for permanent grassland will not only increase areas under permanent grassland but they would incentivize farmers to change their management practices and they would indirectly target farmers currently considered under the VCS. Additionally, some policy instruments might exhibit synergy effects. Several authors suggest that the risk attitude of farmers might partially explain the adoption of environmentally friendly practices (Vollenweider, Di Falco and O'Donoghue, 2011; Till Dörschner and Musshoff, 2013; Finger and Buchmann, 2015). A counter cyclical payment linked to more environmentally friendly practices would explicitly take into account the risk attitude of farmers, while the provision of environmental goods would be achieved at the lowest cost and negative environmental impacts on third countries would be minimised.

Third, the reform of the CAP has also introduced a new monitoring and evaluation system (European Commission, 2015b), the goal being to assess the performance of the CAP and its main instruments. Chapter 3 illustrates the impact of sample size on the predicting performance of ex-ante policy models. It shows that a reduction in sample size hampers the performance of the models. Additionally, the development of Positive Mathematical Programming (PMP) has been partially motivated to remediate to the data intensive nature of econometric technics, yet PMP suffers from other limitation such as self-selection bias in order to model the impact of greening measures. If new objectives such as environmental objectives are integrated into the CAP, it goes without saying that we need to extend the data collection. For instance, the European Commission recently published a review of greening measures after one year (European Commission, 2016). They used two different data sources, the Farm Structure Survey and the FADN data. Regarding the crop diversification measure, they stressed that the selection of crops might differ from the regulation as some crops are not listed or are, in some cases, bundled together in the dataset. Policy makers have two choices; they can develop policy instruments taking into account the current data availability or they can extend the current dataset in order to allow for a robust assessment of the policy. However, they cannot ask for a robust evaluation framework without the required underlying data. Beyond the findings of this dissertation, we believe that today, farmers capture valuable data through the multiple sensors on their equipment that would be beneficial for researchers and policy makers. Most machinery suppliers provide services to improve farmers' efficiency based on this data. However, the European legislation does not address the issue of property rights for the data. So far, private companies have gained a privileged position with unique insights into farmers' decision behaviour. In the US, the Agricultural Data Coalition has created the first farmers' data repository cooperative where farmers can store and control their information. In France, the biggest agricultural cooperative InVivo is seeking to build a big agri-data business model. It is just the right time for the European regulators to create the appropriate framework to ensure privacy of information and partnerships with the private sector in order to link current public datasets to site-specific private datasets (Antle, Capalbo and Houston, 2015; Michener and Jones, 2012; Horlings and Marsden, 2011; Zaks and Kucharik, 2011).

6.3. Future research

This dissertation evaluates the greening measures individually and assumes that all farmers are affected. However, in reality, not all farmers are concerned by the greening measures, for example small farmers and organic farmers. Additionally, interactions between the different policy instruments within the CAP are not taken into account. Interactions between policy instruments might play a major role in the deliverance of ecosystem services. In the US, Goodwin and Smith (2003) show that while the Conservation Reserve Programme contributed to erosion reduction, approximately half of this reduction has been offset by an increase in erosion resulting from the income-supporting federal programs. Miao et al. (2016) shows that incorporating crop insurance subsidies into the design of the Conservation Reserve Programme, would significantly increase the efficiency of the programme and the area enrolled. Such findings show the existence of trade-offs and synergies between the delivery of environmental and agricultural goods (Kirchner et al., 2015; Bryan and David, 2013). More research could be done in order to evaluate the overall impact of the CAP and assess to what extent the impact of a given policy instrument is offset by another.

Additionally results suggest that one-size-fits-all measures might hamper the effectiveness of the policy. For instance the opportunity costs of maintaining permanent grassland varies greatly between farmers and regions. Bateman et al. (2013) shows that spatially targeted objectives increase the net value of land to the society. If additionally the provision of public good were taken into account (where economic value can be estimated), they show that a gain in public goods will overcompensate the lost in farm income in some locations. These results highlights one limitation of our proposed approach. Indeed, in this dissertation we do not measure the impact on the environment such as greenhouse gas emission or biodiversity, nor attribute to them an economic value. Nevertheless, the literature shows that accounting for multi-criteria could lead to the identification of policy measures with synergy effects between economic and environmental performances (Mouysset et al., 2015; Mouysset, 2014; Mouysset, Doyen and Jiguet, 2014; Ay et al., 2014). One possible options would be to integrate multi-criteria in order to identify synergies and tradeoffs (Ay et al., 2014).

Building on the aforementioned improvements, a next step could be to determine prices endogenously by linking our model to a general or partial equilibrium model. Indeed, extensification of the European agricultural systems to account for the provision of public good might lead to an intensification of the agricultural system in other parts of the world. The problem becomes even more complex depending if the location of positive or negative externalities matter to the society and if different societies value the produced positive or negative externalities differently. For instance, do Europeans value equally a loss of biodiversity in Europe and in Brazil and vice versa.

In this dissertation, we introduce the notion of a capacity payment and suggest considering set-aside land as a reserve agricultural capacity. The rationale underpinning reserve agricultural capacity is that in times of low commodity prices farmers would receive an incentive to withdraw land from production and vice-versa. In this configuration, set-aside land could play a role beyond the provision of environmental goods by mitigating farm income volatility. However, this dissertation is just a first step that illustrates possible interactions between the delivery of environmental and agricultural goods. Further research would need to be conducted that takes into account yield and price risks. Furthermore, we assume that farmers are risk neutral. Evidence in the literature shows that farmers tend to be risk averse (Finger and Buchmann, 2015). Accounting for risk preferences might help to better understand farmers' decisions and design more effective policy instruments. The proposed policy instruments (CCCP and premium of permanent grassland) are largely inspired by the greening package logic, although other options exist. Pirard (2012) investigates the different market-based instruments for ecosystem services. He distinguishes five categories: direct market for environmental products (e.g. genetic resources), tradable permits (e.g. emission quota in the EU), reverse auctions (e.g. Conservation Reserve Program in the US), Coasean type agreements (e.g. The Vittel payments for ecosystem services (Perrot-maître, 2006)), regulatory price signals (e.g. Agro-environmental measures in the EU) and voluntary price signals (e.g. labels and certifications). Payments for ecosystem services might belong to one or several categories. However, payment design is context specific and its efficiency can only be assessed if the context is documented in a systematic way. Multidisciplinary research plays a key role in reported policy outcomes in an environmental, economic, social and political context from micro level to macro level. Regarding, the greening package within the CAP, efficient policy instruments still need to be invented.

Finally, the development of mathematical programming models for ex-ante impact assessment is, by definition, an approximate reconstruction of the reality that today integrates complex phenomena from biological to social systems and from micro to macro level. A multitude of approaches coexist between and within disciplines. One of the main challenges for modellers is to assess to what extent the developed model represents the relevant policy drivers. The problem becomes even more complex in policy modelling since natural experiments cannot be conducted. If partial validation has been conducted against historical data and expert screening, model output validation should not solely rely on a peer-review process and traditional "historical matching" but also on the development of protocols (Jakeman and Letcher, 2003). Indeed, ex-ante mathematical programming is often a mixture between causal relationships within the systems and observed associations. In the case of a pure causal model, the model is refuted if a causal relationship does not make sense, even though model outputs match the observed data. In the case of pure non-causal models, model outputs must match the observed data for the model to be considered valid. This difference in paradigm illustrates the complexity in determining model validity. Recently, the Nobel Laureate Daniel Kahneman has sent an open email to researchers in psychology working on social priming in order to create a replication ring to check each other's results (Kahneman, 2012). The priming effect infers that exposure to socially relevant stimuli can facilitate, or prime, a host response, often without people's intention or awareness. If the advice of Kahneman to create a replicating ring to check each other's results is valid for every discipline, I also argue that researchers could be themselves subject to the priming effect for two reasons. First, "negative results" or "dull results" are often not published, thereby skewing the scientific literature. Second, model validation is bound to be a relative, semiformal, and conversational process (Barlas and Carpenter, 1990). Hence, model validation exercises are rarely published and it is often assumed that if a large number of papers use a similar methodology, the methodology must be valid. However, researchers should systematically accompany model development with model validation results. Furthermore, validation methodology should be further researched and validation exercises revealing negative or dull performance of the model should be better appreciated by the scientific community and funding agencies.

6.4. Concluding remarks

"Capital in the Twenty-First Century" from the economist Thomas Piketty was published in 2013 and since then it has generated a lot of ink flow from economists, journalists and policy makers (Avent, 2014; Góes, 2016; Milanovic, 2014; Piketty, 2014). Beyond the focus of the book on wealth and income inequality, the success of Thomas Piketty relaunched the debate around natural capital (Mace et al., 2015; Maseyk et al., 2016; Barbier, 2014). One of the main critics of Piketty's theory was that he did not account for the depreciation of natural capital in appraising wealth. Accounting for natural capital and formalising its link with the provision of environmental services is a challenging task. In fact, natural capital is the stock giving rise to ecosystem services (Maseyk et al., 2016). The United Nations and the World Bank have started to address the issue of natural capital (UNU-IHDP and UNEP, 2014; WAVES, 2015) and have adjusted income indicators to account for agricultural land, for instance. This dissertation introduces the notion of agricultural capacity. Agricultural land can be considered as a natural capital stock providing agricultural output and ecosystem services that are valued by people. Hence, the formalisation of such an approach by policy makers would help to design more transparent policy instruments, taking into account the existing trade-off or synergy between agricultural capacity, agricultural production and ecosystem services.

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Appendixes

Appendix I. GAMS code for the specification of the DGP

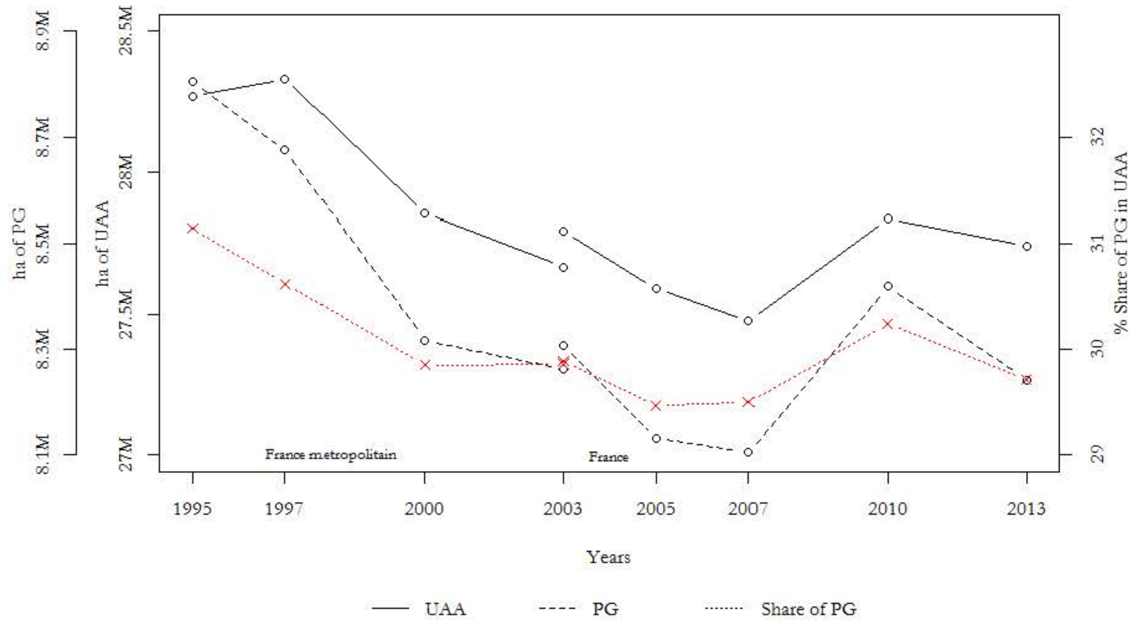
```
*----------------------------------------------------------------------*
*              Define Bioeconomic model to generate data
*
*----------------------------------------------------------------------*
Set
j              Observations "Decision Making Unit"      /dmu1 * dmu1000/
i              Inputs (feeds)                         /input1 * input3/
o              Output                                         /output1/
sRequirement   Feed requirements             /capacity, energy, protein/
d              Scenario with endogenous error term                /d1*d4/
e              Scenario with exogenous error term                 /e1*e4/
;
Table pFeedcontent(i,sRequirement)  Feed characteristics
           capacity         energy           protein
input1     - 0.2             0.2              0.7
input2     - 0.4             0.7              0.5
input3     - 0.4             0.5              0.6
;
Parameters
Pbasicrequirement(j,sRequirement)         Feed requirements for each DMU
Pconversionefficiency(j,sRequirement)            Conversion coefficients
po(j,o)                                             Initial output price
pi(j,i)                                             Initial input prices
pin(j,i)                                                New input prices
pon(j,o)                                               New output prices
disturbancebasicrequirement(j,sRequirement)        Endogenous error term
error(i,j,e)                                        Exogenous error term
disturbance(j,d)
;

Pbasicrequirement(j,'capacity') =  -2.5;
Pconversionefficiency(j,'capacity') = -0.2 ;

Pbasicrequirement(j,'energy') =  1.36;
Pconversionefficiency(j,'energy') =  0.3 ;

Pbasicrequirement(j,'protein') =  1.4;
Pconversionefficiency(j,'protein') =  0.4 ;


*initial input and output prices *
po(j,o) = uniform(20,21) ;
pi(j,'input1')=uniform(3,4);
pi(j,'input2')=uniform(1,2);
pi(j,'input3')=uniform(0.5,2.5);

* option to change input and output prices *
option seed = 123 ;
pon(j,o)=po(j,o);
pin(j,'input1')=uniform(3,4);
pin(j,'input2')=uniform(1,2);
pin(j,'input3')=uniform(0.5,2.5);


* disturbance term with four possible standard deviations *
disturbance(j,'d1')   = 0;
```

```
disturbance(j,'d2')  = normal(0,0.05 );
disturbance(j,'d3')  = normal(0,0.15 );
disturbance(j,'d4')  = normal(0,0.2 );

* Added error term after simulation with four possible standard deviations
*
error(i,j,'e1')=0;
error(i,j,'e2')=normal(0,0.05);
error(i,j,'e3')=normal(0,0.15);
error(i,j,'e4')=normal(0,0.3);


Parameters
*parameters used to store results
x(i,j,d,e)       Initial dataset of inputs used for the estimation of the
                 RLR model and the Inverse DEA model
y(o,j,d,e)       Initial dataset of outputs used for the estimation of
                 the RLR model and the Inverse DEA model
xbio(i,j,d)      New dataset of inputs under the new market conditions
                 used to compare with the RLR model and the Inverse DEA
                 model
ybio(o,j,d)      New dataset of output under the new market conditions
                 used to compare with the RLR model adnd the Inverse DEA
                 model
profit(j)        Initial profit
profitbio(j)     New profit
addedError(i,j,e)Error term x*e
;

Positive variables
vinputuse(j,i)        Inputs generated X
voutputproduction(j,o) Output generated Y
;
Variable
vZ                    Profit
;
Equations
Eqprofit                   Profit definition with initial input and
                           output prices
EqprofitNew                Profit definition with new input and output
                           prices
Eqfeeding(j,sRequirement)  Feeding constraints
;

Eqprofit..       vZ =e= sum(j, sum(o, voutputproduction(j,o) *po(j,o) )
- sum(i, vinputuse(j,i) * pi(j,i) )) ;

EqprofitNew..    vZ =e= sum(j, sum(o, voutputproduction(j,o) *pon(j,o) )
- sum(i, vinputuse(j,i) * pin(j,i) )) ;

Eqfeeding(j,sRequirement)..
      sum(i,vinputuse(j,i)*pFeedcontent(i,sRequirement))=g=
disturbancebasicrequirement(j,sRequirement)*Pbasicrequirement(j,sRequir
ement)+Pbasicrequirement(j,sRequirement)+Pconversionefficiency(j,sRequi
rement)*sqr(sum(o,voutputproduction(j,o)));

*model equation with initial input and output prices
Model Bioeconomic /Eqprofit,Eqfeeding/;
```

```
*model equation with new input and output prices (however we only change
input prices)
Model Bioeconomic2 /EqprofitNew, Eqfeeding/;

*--------------------------------------------------------------------*
*Run and Store results in a GDX file for each combination of disturbance
*and error terms
*--------------------------------------------------------------------*
*Import dataset
$GDXIN startingValDGP.gdx

Parameters
xDGP(i,j,d,e)       starting value
yDGP(o,j,d,e)       starting value
xbioDGP(i,j,d)      starting value
ybioDGP(o,j,d)      starting value
;

$load xDGP=x, yDGP=y, ybioDGP=ybio, xbioDGP=xbio

$GDXin

Set
Mod/bioeconomic,bioeconomic2/

Parameter
M(d,Mod) model status
S(d,Mod) model solve statement
;
loop((d),

disturbancebasicrequirement(j,'capacity')=disturbance(j,d) ;

Solve bioeconomic maximising vZ using nlp ;

x(i,j,d,'e1')=vinputuse.l(j,i) ;
y(o,j,d,e)=voutputproduction.l(j,o);
                  M(d,'bioeconomic')=bioeconomic.modelstat ;
                  S(d,'bioeconomic')=bioeconomic.solvestat;

         loop(e,addederror(i,j,e)=vinputuse.l(j,i)*error(i,j,e););

x(i,j,d,'e2')=vinputuse.l(j,i)+addederror(i,j,'e2') ;
x(i,j,d,'e3')=vinputuse.l(j,i)+addederror(i,j,'e3') ;
x(i,j,d,'e4')=vinputuse.l(j,i)+addederror(i,j,'e4') ;
x(i,j,d,e) $(x(i,j,d,e)<0)=0 ;

Solve bioeconomic2 maximising vZ using nlp ;
*Store results of the new data set*
xbio(i,j,d)= vinputuse.l(j,i)   ;
ybio(o,j,d)= voutputproduction.l(j,o) ;

                  M(d,'bioeconomic2')=bioeconomic2.modelstat ;
                  S(d,'bioeconomic2')=bioeconomic2.solvestat;
*execute_unload 'startingValDGP.gdx' x,y,xbio,ybio;
execute_unload                                         'bioeconomic.gdx'
i,o,j,x,y,pi,po,xbio,ybio,pin,pon,d,e,M,S;
;);
```

Appendix II. French regions

Appendix III. Evolution of the permanent grassland area in France



Source: FSS eurostat tables ef_pograss and ef_lu_ofgrass

Appendix IV. Peers selection

For each farmers *f* present in the FADN in 2009, we use the DEA model under constant return to scale (Banker et al., 1984) to identify peer farmers and obtain the efficiency score of farmer in 2009. Each farmers are benchmarked against peer farmers belonging to the same farm type (TF8) and the same region (NUTS2) and present in the data between 1995 and 2009. Hence, the problem must be solved *F (1 x f)* times, once for each farmers.

$$Min_{\theta,\lambda_{peer}}\, \theta_f$$

$$\text{S.t.} \quad \sum_{peer} \lambda_{peer}\widehat{y_{peer,k}} - \widehat{y_{f,k}} \geq 0$$

$$\theta_f\widehat{x_{f,\imath}} - \sum_{peer} \lambda_{peer}\widehat{x_{peer,\imath}} \geq 0,$$

$$\theta_f\widehat{c_{f,\jmath}} - \sum_{peer} \lambda_{peer}\widehat{c_{peer,\jmath}} \geq 0,$$

$$\lambda_{peer} \geq 0$$

Indexes	**Description**
$\boldsymbol{f}$	Farmers under consideration. They are farmers present in the dataset in 2009.
$\boldsymbol{peer}$	Potential peer farmers. They are all farmers present in the dataset between 1995 and 2009 and belonging to the same NUTS2 region and the same TF8 group.
$\boldsymbol{k}$	Outputs
$\boldsymbol{i}$	Inputs
$\boldsymbol{j}$	Input costs

Parameters	Description
$\widehat{\boldsymbol{y_{peer,k}}}$	Observed outputs of peer farmers
$\widehat{\boldsymbol{y_{f,k}}}$	Observed outputs of the farmer under consideration
$\widehat{\boldsymbol{x_{peer,i}}}$	Observed inputs of peer farmers
$\widehat{\boldsymbol{x_{f,i}}}$	Observed inputs of the farmer under consideration
$\widehat{\boldsymbol{c_{peer,j}}}$	Observed input costs of peer farmers
$\widehat{\boldsymbol{c_{f,j}}}$	Observed input costs of the farmer under consideration

Variables	**Descriptions**
$\boldsymbol{\theta_f}$	Efficiency score of the farmer under consideration
$\boldsymbol{\lambda_{peer}}$	Vector of constants

Here, the problem takes the *f*-th farm and seeks to radially contract the input vector $\widehat{x_{f,\imath}}$ and the input costs vector $\widehat{c_{f,\jmath}}$ as much as possible, while still remaining within the production possibility set determined by the observed data points (farmers in the sample). The radial contraction of the input vector $\widehat{x_{f,\imath}}$ and the input costs vector $\widehat{c_{f,\jmath}}$ produces a projected point ($X \lambda$, $C \lambda$, $Y \lambda$). This project point is a linear combination of these observed data points referred as peer farmers. Then, we obtain a list of peer farmers defining the production possibility set and against which farmers in 2009 are benchmarked.

Appendix V. Fitting results of the marginal distributions for wheat, barley and rapeseed.

Table-Appendix V 1. Fitting results of the marginal distribution for wheat

	LogLogistic	**Pearson5**	**Lognorm**	**InvGauss**	**Gamma**	**Pearson6**	**Weibull**	**Triang**	**Uniform**	**Expon**	**Levy**
Method	MLE	MLE	MLE	MLE	MLE	MLE (Modified)	MLE	MLE	MLE (Bias Corrected)	MLE	MLE
Num. Est. Parameters	2	2	2	2	2	3	2	2	1	1	1
Fitted Parameter #1	beta	alpha	mu	mu	alpha	alpha1	alpha	M. likely	Max	beta	c
Fitted Value	119.37	31.45	123.43	123.59	27.36	120 423 445.40	4.39	122.28	217.28	123.59	119.41
Fitted Parameter #2	alpha	beta	sigma	lambda	beta	alpha2	beta	Max			
Fitted Value	10.15	3 755.58	23.03	3 534.63	4.52	31.45	134.32	216.80			
Fitted Parameter #3						beta					
Fitted Value						3.12E-05					
Akaike (AIC)	139.81	139.96	140.90	140.95	142.07	143.14	147.96	153.02	163.74	176.82	189.07
Bayesian (BIC)	140.22	140.37	141.32	141.37	142.49	143.08	148.37	153.43	164.14	177.22	189.47
Av. LogL	-4.49	-4.50	-4.53	-4.53	-4.57	-4.50	-4.77	-4.93	-5.38	-5.82	-6.23
Chi-Sq Statistic	0.40	0.40	1.20	1.20	1.20	0.40	3.60	15.60	19.60	15.60	8.40
A-D Statistic	0.23	0.32	0.39	0.40	0.49	0.32	1.08	1.90	3.15	4.74	6.41
K-S Statistic	0.09	0.13	0.14	0.14	0.15	0.13	0.21	0.34	0.44	0.54	0.57

Table-Appendix V 2. Fitting results of the marginal distribution for barley

	Pearson5	InvGauss	Lognorm	LogLogistic	Gamma	Pearson6	Weibull	Triang	BetaGeneral	Uniform	Expon	Levy
Method	MLE	MLE	MLE	MLE	MLE	MLE (Modified)	MLE	MLE	MLE (Approximate)	MLE (Bias Corrected)	MLE	MLE
Num. Est. Parameters	2	2	2	2	2	3	2	2	3	1	1	1
Fitted Parameter #1	alpha	mu	mu	beta	alpha	alpha1	alpha	M. likely	alpha1	Max	beta	c
Fitted Value	37.03	116.94	116.88	113.77	34.44	3.2E-05	5.45	116.14	5.21	182.18	116.94	113.69
Fitted Parameter #2	beta	lambda	sigma	alpha	beta	alpha2	beta	Max	alpha2			
Fitted Value	4 209.60	4 095.35	19.75	10.58	3.40	37.03	125.94	183.61	2.33			
Fitted Parameter #3						beta			Max			
Fitted Value						0.00			172.09			
Akaike (AIC)	135.94	136.42	136.43	136.56	137.04	139.12	141.05	148.24	148.35	158.46	175.16	187.49
Bayesian (BIC)	136.36	136.84	136.85	136.97	137.45	139.07	141.46	148.66	148.29	158.86	175.56	187.89
Av. LogL	-4.36	-4.38	-4.38	-4.39	-4.40	-4.36	-4.53	-4.77	-4.67	-5.21	-5.76	-6.17
Chi-Sq Statistic	1.20	1.20	1.20	1.20	1.20	1.20	1.20	12.40	2.80	12.40	15.60	12.40
A-D Statistic	0.40	0.44	0.44	0.39	0.49	0.40	0.79	2.42	1.39	3.84	4.87	6.49
K-S Statistic	0.20	0.21	0.21	0.18	0.22	0.20	0.26	0.39	0.31	0.50	0.54	0.59

Table-Appendix V 3. Fitting results of the marginal distribution for rapeseed

	Pearson5	**LogLogistic**	**InvGauss**	**Lognorm**	**Gamma**	**Pearson6**	**Weibull**	**Triang**	**Uniform**	**Expon**	**Levy**
Method	MLE	MLE	MLE	MLE	MLE	MLE (Modified)	MLE	MLE	MLE (Bias Corrected)	MLE	MLE
Num. Est. Parameters	2.00	2.00	2.00	2.00	2.00	3.00	2.00	2.00	1.00	1.00	1.00
Fitted Parameter #1	alpha	beta	mu	mu	alpha	alpha1	alpha	M. likely	Max	beta	c
Fitted Value	27.47	214.83	221.63	221.49	25.71	16 896 390.30	4.78	219.74	360.47	221.63	213.39
Fitted Parameter #2	beta	alpha	lambda	sigma	beta	alpha2	beta	Max			
Fitted Value	5 861.63	9.25	5 739.33	43.52	8.62	27.47	240.67	364.31			
Fitted Parameter #3						beta					
Fitted Value						0.00					
Akaike (AIC)	159.50	159.83	159.91	159.91	160.50	162.68	164.15	169.46	178.93	194.34	206.59
Bayesian (BIC)	159.91	160.25	160.32	160.33	160.92	162.62	164.57	169.87	179.33	194.74	206.99
Av. LogL	-5.15	-5.16	-5.16	-5.16	-5.18	-5.15	-5.31	-5.48	-5.89	-6.40	-6.81
Chi-Sq Statistic	0.40	0.40	1.20	1.20	1.20	0.40	2.80	3.60	15.60	15.60	10.00
A-D Statistic	0.29	0.25	0.33	0.33	0.38	0.29	0.72	1.81	3.20	4.58	6.26
K-S Statistic	0.13	0.11	0.15	0.14	0.16	0.13	0.19	0.32	0.44	0.51	0.57

Summary

Today, governments across the globe integrate environmental issues into policy by whether sponsoring environmental programs aimed at more environmentally friendly farming practices, and/or sanctioning farmers who fail to comply with a set of environmental rules. In the European Union; the Common Agricultural Policy (CAP) reflects this dichotomy between promoting and sanctioning with its two pillar structure. Pillar I is oriented towards production and withholds payments if farmers do not comply with a set of environmental rules, while Pillar II promotes sustainable rural development.

The latest CAP reform in 2013 introduced the greening of the direct payment systems under Pillar I. The "greening" refers to the introduction of three measures deemed beneficial for the environment and the climate with which farmers must comply in order to receive their full allocation of direct payments. The first measure is crop diversification and aims to tackle the issue of decreasing diversity in agricultural landscapes - in other words the presence of monocultures. The second measure is the maintenance of permanent grassland. Member States need to ensure that the ratio of permanent grassland area to total Utilized Agricultural Area does not fall by more than 5% compared to the reference level. Finally, the third measure ensures that famers dedicate 5% of arable land to Ecological Focus Areas (EFAs). EFAs cover a broad range of features from which set-aside land is a popular choice from Member States but also from farmers.

The introduction of the greening measures poses new challenges for agricultural policy modellers. Measures are farm specific and are designed to change the land allocation at farm level. Consequently, any ex-ante assessment should be able to simulate farmers' adoption of new crop, to correctly reproduce the substitution pattern, to correctly represent farmer heterogeneity and account for price uncertainty. Hence, the objective of this dissertation is to contribute to the impact assessment of the three greening measures. To reach this objectives and answer the abovementioned modelling challenges, we propose a non-parametric model. Furthermore, we compare the effectiveness of two measures - the maintenance of permanent grassland and the requirement for EFAs – to two alternative policy instruments – a premium payment for permanent grassland and a Counter Cyclical Capacity Payment (CCCP) for set-aside land.

To simulate the impact of the crop diversification measure, we develop a new modelling route based on mimicking behaviour. The crop diversification measure requires that modellers simulate the adoption of a new crop for a given farmer without having any cost information on the potential new crops for this given farmer. We develop a non-parametric mathematical programming model based on peer behaviour. In fact, to predict the reaction of a non-compliant farmer A to a newly imposed rule, we look at compliant farmer B and project the crop allocation of farmer B on farmer A. Here, we assume that farmer B is similar to farmer A and shares similar context, hence it is likely that farmer A come to the same conclusion than farmer B. To select farmer B, first we only look at compliant farmers. Then from this pool of farmers, we use four variables and choose the farmer that differs the least from farmer A according to the relative permanent

grassland area, the number of crops, the crops areas, and located as close as possible. Once farmer B is identified, we project his crop allocation onto the total arable area of farmer A in order to render him compliant with the crop diversification measure. We simulate the impact of this measure on Flemish farmers. This measure implicitly targets monoculture and it is indeed maize, the most dominant crop, which would see the largest reduction in area. In this sense, the mechanism is effective. However, the largest part of the 'freed' area was absorbed by other dominant crops, which reduces the overall crop diversification effect at landscape level. The measure has, in its present form, limited effect at landscape level.

As agricultural policies continue to evolve and integrate environmental and climatic concerns, agricultural policy models tend to incorporate more components of environmental models where biophysical relationships might play a role between environmental and economic outcomes. Non-linear phenomena such as threshold effects are frequent in biological systems which may respond to an incremental change with a sudden regime shift. Therefore we test the validity of two models - a non-parametric and a parametric model - in reproducing a data generating process where biophysical relationships hold. The parametric approach is a standard econometric model. The non-parametric approach is an inverse Data Envelopment model. In fact, the proposed non-parametric approach builds further on the premise of 'mimicking' behaviour, but assuming profit maximisation behaviour, and the possibility of multiple peers. Models are considered valid if we cannot distinguish output coming from the initial data generating process with the tested models. In general, the econometric model performs poorly as we have generated datasets of 1000 observations with different prices and free of any measurement or sampling bias. This amount of data is far beyond the real world policy simulation, where typically less than 20 observations per farm are available and the amount of price variation is limited. On the contrary, one of the main strengths of the non-parametric model is the ability to obtain reliable results for a small sample. Nevertheless, our results show the importance of using panel data or robust grouping technics in order to maximise homogeneity in the sample.

Based on our validation exercise, we further develop the non-parametric model to account for farmers heterogeneity and so aggregation bias. We propose a farm-type regional model using historical activity mixes that we extend using individual farm production frontier constraints defined by the historical activity mix for the observed farmers and their associated peers. Such an approach enables us to take full advantage of the information available and to model farmers' adoption while ensuring consistency between farm level results and regional level results.

First we simulate the opportunity costs at farm-type regional level for maintaining the ratio of permanent grassland at the 2009 level in France. The opportunity cost for the maintenance of permanent grassland varies greatly between farm types and regions, from 5.9€/ha for specialist cattle-rearing and fattening in Languedoc-Roussillon to 240€/ha for specialist horticulture in Basse-Normandie. In light of the partial recoupling of certain subsidy in the livestock sector under the Voluntary Coupled Support scheme, and in order to address farmer heterogeneity, we propose to study the option of a premium per hectare for permanent grassland. Increasing the competitiveness of permanent grassland would ultimately lead to a decrease in forage costs and would support the livestock sector per se. Results show that a premium of 100€/ha for permanent grassland for all farmers in France would, as a minimum, maintain permanent grassland at the 2009 level. Furthermore, a premium per hectare would increase diversification in farm production by increasing cattle production for every farm type and so strengthen the link, at farm level, between crop and livestock production. Such a policy would match current budget expenditure and would represent 78% (720M€) of the Voluntary Coupled Support scheme. However, a differentiated premium for permanent grassland for different farm types and regions would divide the overall budget by ten from 720M€ to 72M€. Hence, from a cost-benefit point of view, we can wondered, if the argument of insuring the same level playing among farmers, is still valid.

Second we introduce the notion of a capacity payment and suggest considering set-aside land as a reserve agricultural capacity. The rationale underpinning reserve agricultural capacity is that in times of low commodity prices farmers will receive an incentive to withdraw land from production and vice-versa. In this configuration, set-aside land could play a role beyond the provision of environmental goods by mitigating farm income volatility. In order to account for price uncertainty, we assume that farmers decide upon their land use, know their selling prices and the amount of CCCP they will receive. However, the model does not draw a distinction between future prices and stock market prices. We therefore assume that when farmers determine their land allocation, they protect themselves and fix their selling prices using future markets or forward contracts. The results show that by pooling commodity price risk under one policy instrument and linking it to set-aside, we could achieve a higher level of set-aside at farm and regional level compared to the current requirement, while at the same time decreasing production in times of low commodity prices and reducing farm income volatility.

The EU introduced the greening of the CAP to address climate change, but at the same time it has re-introduced support coupled to production classified by the OECD as environmentally harmful. We argue that coupled support should be linked to the provision of environmental benefits. Coupled payments for permanent grassland will not only increase areas under permanent grassland but they would incentivize farmers to change their management practices and they would indirectly target farmers currently considered under the Voluntary Coupled Support scheme. Additionally, some policy instruments might exhibit synergy effects. A counter cyclical payment linked to more environmentally friendly practices would explicitly take into account the risk attitude of farmers, while the provision of environmental goods would be achieved at the lowest cost. Accounting for natural capital and formalising its link with the provision of environmental services is a challenging task. Agricultural land can be considered as a natural capital stock providing agricultural output and ecosystem services that are valued by people. Hence, the formalisation of such an approach by policy makers would help to design more transparent policy instruments, taking into account the existing trade-off or synergy between agricultural capacity, agricultural production and ecosystem services.

Samenvatting

Vandaag de dag houden regeringen over heel de wereld rekening met milieu in hun landbouwbeleid. Ze doen dit enerzijds door het financieel ondersteunen van milieuvriendelijke landbouwpraktijken en anderzijds door het sanctioneren van landbouwers die niet voldoen aan een set van milieuvoorwaarden. In de Europese Unie is deze dichotomie tussen ondersteunen en sanctioneren zichtbaar in de twee pijlers van het Gemeenschappelijk Landbouwbeleid (GLB). De eerste pijler richt zich op productie en weerhoudt inkomenssteun aan landbouwers als ze niet voldoen aan bepaalde milieuvoorwaarden, terwijl de tweede pijler duurzame plattelandsontwikkeling ondersteunt.

Bij de laatste hervorming van het GLB in 2013 werd de vergroening van de rechtstreekse inkomenssteun onder de eerste pijler ingevoerd. De 'vergroening' verwijst naar de invoering van drie maatregelen die gunstig worden geacht voor het milieu en het klimaat. Landbouwers moeten aan deze maatregelen voldoen om recht te hebben op de volledige rechtstreekse inkomenssteun. De eerste maatregel, gewasdiversificatie, heeft als doel diversiteitsverlies in landbouwlandschappen een halt toe te roepen. Ze richt zich met andere woorden op het tegengaan van monoculturen. De tweede maatregel is het behoud van blijvend bestaand grasland. Lidstaten moeten er op toezien dat de verhouding van blijvend grasland op de totale oppervlakte cultuurgrond niet met meer dan 5% afneemt ten opzichte van het referentieniveau. Ten slotte eist de derde maatregel dat 5% van het bouwland van landbouwers als ecologisch aandachtsgebied (EAG) moet worden ingericht. Er bestaan verschillende mogelijkheden voor het inrichten van ecologisch aandachtsgebied, waarvan braakland de populairste keuze is.

De invoering van de vergroeningsmaatregelingen brengt nieuwe uitdagingen met zich mee voor het modelleren van landbouwbeleid. De maatregelen zijn bedrijfsspecifiek en gericht op het veranderen van landgebruik op het niveau van individuele boerderijen. Als gevolg daarvan moet een ex-ante beleidsbeoordeling in staat zijn de keuze van een landbouwer voor nieuwe gewassen te simuleren, het substitutiepatroon correct reproduceren, de heterogeniteit in de landbouwerspopulatie weergeven en prijsonzekerheid in rekening brengen. Daarom is het doel van dit proefschrift om bij dragen aan de impactbeoordeling van de drie vergroeningsmaatregelen. Om dit doel te verwezenlijken en te beantwoorden aan de bovengenoemde uitdagingen kiezen we voor een niet-parametrisch model. Voorts vergelijken we de effectiviteit van twee maatregelen - het behoud van bestaand grasland en de vereiste van ecologisch aandachtsgebied – met twee alternatieve beleidsinstrumenten: een premiumbetaling voor blijvend grasland en een contracyclische capaciteitsbetaling voor braakland.

Om de impact van de gewasdiversificatiemaatregel te simuleren ontwikkelen we een nieuwe modelleerbenadering gebaseerd op kopieergedrag. De gewasdiversificatiemaatregel vereist dat modelleerders de keuze van een nieuw gewas voor een bepaalde landbouwer voorspellen, zonder te beschikken over informatie over de kost van potentiële nieuwe gewassen voor diezelfde landbouwer. We ontwikkelen een niet-parametrisch mathematisch programmeermodel gebaseerd op peer-gedrag. Om de reactie van een landbouwer A, die niet aan de gewasdiversificatiemaatregel voldoet, op een nieuwe opgelegde beleidsmaatregel te voorspellen, kijken we naar het gedrag van een landbouwer B die wel aan de maatregel voldoet. Vervolgens projecteren we het teeltplan van landbouwer B op dat van landbouwer A. Hierbij veronderstellen we dat landbouwer B vergelijkbaar is met landbouwer A en in een gemeenschappelijke context handelt, waardoor het waarschijnlijk is dat landbouwer A tot dezelfde beslissing komt als landbouwer B. Om landbouwer B te selecteren starten we met landbouwers die aan de gewasdiversificatiemaatregel voldoen. Uit die groep selecteren we de landbouwer die op basis van vier variabelen het minst verschilt van landbouwer A: de relatieve oppervlakte blijvend grasland, het aantal gewassen, de oppervlakte toegekend aan deze gewassen en de locatie. Zodra landbouwer B wordt geïdentificeerd projecteren we zijn teeltplan op de totale oppervlakte bouwland van landbouwer A, zodanig dat deze ook voldoet aan de vereiste van gewasdiversificatie. We simuleren de impact van de gewasdiversificatiemaatregel op Vlaamse landbouwers. De maatregel heeft als doel monoculturen tegen te gaan. Het is inderdaad maïs, het dominante gewas in Vlaanderen, waarvoor we de grootste afname in oppervlakte waarnemen. In die optiek is de maatregel effectief. Het grootste deel van de vrijgekomen grond wordt echter ingenomen door andere dominante gewassen, wat er voor zorgt dat het effect van gewasdiversificatie op landschapsniveau wordt afgezwakt. De maatregel heeft, in zijn huidige vorm, een beperkt effect op landschapsniveau.

Aangezien landbouwbeleid continu evolueert en meer en meer milieu- en klimaataspecten in rekening brengt, worden componenten van milieumodellen in landbouwbeleidsmodellen geïntegreerd, in het bijzonder als biofysische relaties een link vormen tussen ecologische en economische effecten. Niet-lineaire fenomenen zoals drempeleffecten zijn veelvoorkomend in biologische systemen, waarbij een kleine verandering kan resulteren in een plotse regimeshift. Daarom testen we hoe goed twee modellen – een niet-parameterisch en een parametrisch model – het data-genererend proces reproduceren wanneer er biofysische relaties in het spel zijn. De parametrische aanpak omvat een standaard econometrisch model. De niet-parametrische aanpak bestaat uit een invers Data Envelopment model. De voorgestelde niet-parametrische aanpak bouwt voort op de aanname van 'kopieergedrag', maar veronderstelt aanvullend ook winst-maximaliserend gedrag en de mogelijkheid tot het hebben van meerdere peers. Modellen worden als geschikt beschouwd als we de output van het model niet kunnen onderscheiden van de output van het initieel data-generend proces. Het econometrisch model presteert slecht, hoewel we datasets gegeneerd hebben met 1000 observaties van verschillende prijzen, vrij van meetfouten en sampling bias. Deze hoeveelheid data gaat veel verder dan gebruikelijke beleidssimulaties, waarvoor er doorgaans minder dan 20 observaties per bedrijf beschikbaar zijn, met beperkte prijsvariatie. Daar staat tegenover dat niet-parametrische modellen als voordeel hebben dat je er zelfs met een kleine steekproef betrouwbare resultaten mee kan verkrijgen. Niettemin tonen onze resultaten aan dat het belangrijk is gebruik te maken van paneldata en robuuste clusteringtechnieken, om de homogeniteit van de steekproef te maximaliseren.

Voortgaand op onze validatieoefening hebben we het niet-parametrisch model verder verfijnd, zodat het rekening houdt met de heterogeniteit in de landbouwerspopulatie en aggregation bias. We stellen een bedrijfstype-specifiek regionaal model voor, gebruik makend van historische data over de activiteitenmix, die we aanvullen met individuele frontier beperkingen op de productie. Deze zijn gebaseerd op historische activiteitenmixen voor de geobserveerde landbouwers en hun geassocieerde peers. Deze aanpak laat toe om alle beschikbare informatie te benutten en om het aanpassingsgedrag van individuele boeren te modelleren, terwijl de consistentie tussen bedrijfsspecifieke en regionale resultaten wordt gevrijwaard.

Eerst simuleren we, op bedrijfstype-specifiek regionaal niveau, de opportuniteitskosten voor het behoud van blijvend grasland op het niveau van 2009 in Frankrijk. Deze opportuniteitskosten variëren sterk afhankelijk van de regio en het bedrijfstype, gaande van 5.9 €/ha voor gespecialiseerde opfok- en afmestbedrijven van rundvee in Languedoc-Rousillon tot 240€/ha voor gespecialiseerde tuinbouw in Basse-Normandie. Met het oogpunt op gedeeltelijke herkoppeling van subsidies in de veeteeltsector, deel uitmakend van het vrijwillige gekoppelde steunprogramma, en tegemoetkomend aan heterogeniteit in de landbouwerspopulatie, onderzoeken we de beleidsoptie van een premium per hectare blijvend grasland. Een verhoging van het concurrentievermogen van blijvend grasland zou uiteindelijk resulteren in een verlaging van voederkosten en een ondersteuning van de veeteeltsector op zich. De resultaten tonen aan dat een premium van 100€/ha voor blijvend grasland voor alle boeren in Frankrijk ervoor kan zorgen dat het blijvend grasland ten minste op het niveau van 2009 blijft. Bovendien zou een premium per hectare de diversificatie op bedrijfsniveau verhogen door de productie van vee te stimuleren voor elk bedrijfstype, waardoor de link tussen akkerbouw en veeteelt op het niveau van individuele bedrijven wordt versterkt. Een dergelijke beleid zou binnen de huidige budgettering passen en zou 78% (720M€) van het budget voor het vrijwillige gekoppelde steunprogramma vertegenwoordigen. Een gedifferentieerd premium voor blijvend grasland, afhankelijk van bedrijfstype en regio, zou het totale budget met een factor tien reduceren van 720M€ tot 72M€. We kunnen ons dus, vanuit het perspectief van kosten en baten, afvragen of het argument van een 'gelijk speelveld' voor alle landbouwers wel opgaat.

Vervolgens introduceren we het concept van een capaciteitsbetaling en stellen we voor dat braakland kan worden beschouwd als reserve landbouwcapaciteit. Het idee hierachter is dat landbouwers in tijden van lage verkoopprijzen een prikkel krijgen om grond uit productie te halen, en vice-versa in het geval van hoge verkoopprijzen. In die configuratie zou braakland niet alleen een rol spelen in de voorziening van milieugoederen, maar ook in het afvlakken van inkomensvolatiliteit. Om rekening te houden met prijsonzekerheid, gaan we ervan uit dat landbouwers kennis hebben van hun verkoopprijzen en de hoeveelheid capaciteitsbetaling die ze zullen ontvangen wanneer ze beslissen over hun landgebruik. Het model houdt echter geen rekening met het onderscheid tussen future prijzen en beursprijzen. Daarom nemen we aan dat landbouwers zichzelf beschermen bij hun beslissing over landgebruik, door hun verkoopprijzen vast te pinnen doormiddel van future markten of termijncontracten. Onze resultaten tonen aan dat, door de prijsrisico's te bundelen in één beleidsinstrument en deze te linken met braakland, we een grotere oppervlakte met braakland verkrijgen dan wat vereist is door het huidige beleid. Tegelijkertijd vermindert de productie in geval van lage verkoopprijzen, waardoor de inkomensvolatiliteit afneemt.

De EU voerde de vergroening van het GLB in om klimaatverandering aan te pakken, maar tegelijkertijd zorgde ze voor de herinvoering van steun gekoppeld aan productie, wat door de OESO als milieuonvriendelijk wordt beschouwd. We stellen dat gekoppelde steun gelinkt moet zijn met de verschaffing van milieugoederen. Gekoppelde steun voor blijvend grasland zou niet enkel de totale oppervlakte blijvend grasland verhogen, maar de landbouwers ook een prikkel geven om hun beheerspraktijken te veranderen. Daarnaast zou het een indirect effect hebben op landbouwers die momenteel onder het vrijwillige gekoppelde steunprogramma vallen. Bovendien vertonen bepaalde beleidsinstrumenten sterke synergie-effecten. Een contracyclische betaling gekoppeld aan milieuvriendelijke praktijken zou het gedrag van landbouwers ten aanzien van risico's in rekening brengen, terwijl de voorziening van milieugoederen zou worden verkregen aan de laagste kost. Het in rekening brengen van natuurlijk kapitaal en het formaliseren van de link met de voorziening van milieugoederen vormt een uitdaging. Landbouwgrond kan worden beschouwd als een voorraad natuurlijk kapitaal die landbouwproducten verschaft en ecosysteemdiensten verstrekt die door mensen worden gewaardeerd. De formalisering van een dergelijke aanpak door beleidsmakers kan ervoor zorgen dat er meer transparante beleidsinstrumenten worden ontwikkeld, rekening houdend met de bestaande trade-offs en synergiën tussen landbouwcapaciteit, landbouwproductie en ecosysteemdiensten.

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Working Papers	B.E.T.I Dupeux and J. Buysse . Parametric versus non-parametric approaches for policy modelling: a validation exercise in a controlled environment. B.E.T.I Dupeux and J. Buysse . Greening and the maintenance of Permanent grassland : an analysis of farm activity changes in France. B.E.T.I Dupeux and J. Buysse . Counter cyclical capacity payment for set-aside land under price uncertainty: the case of French arable farmers in the Centre region.
Conference Papers	B.E.T.I Dupeux, J. Brusselaers and J. Buysse. Welfare analysis of organic dairy certification: a graphical assessment. *Paper prepared for presentation at the ICAE 2015 Congress 'Agriculture in an interconnected world',* August 8 to 14, 2015, Milan, Italy. L. Mahy, B.E.T.I Dupeux, and J. Buysse. Validation of a non-parametric farm level crop choice simulation method. *Paper prepared for presentation at the ICAE 2015 Congress 'Agriculture in an interconnected world',* August 8 to 14, 2015, Milan, Italy. B.E.T.I Dupeux and J. Buysse. Parametric versus non-parametric simulation. *Paper prepared for presentation at the EAAE 2014 Congress 'Agri-Food and Rural Innovations for Healthier Societies'*, August 26 to 29, 2014, Ljubljana, Slovenia. B.E.T.I Dupeux and J. Buysse. Inverse Efficiency Simulation. *Paper prepared for presentation at the 11th International Conference on Data Envelopment Analysis (DEA2013)*, June 27 to 30, 2013, Samsun, Turkey. B.E.T.I Dupeux and J. Buysse. Does the CAP enslave the fittest? *Paper prepared for presentation at the 133rd EAAE Seminar,* June 14 to 16, 2013, Mediterranean Agronomic Institute of Chania, Greece.
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