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Impact of EU biofuel policies on the French arable sector: A micro-level analysis using global market and farm-based supply models

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Summary – This paper aims to ex-ante assess the micro-economic impacts of current EU biofuel policies on the French arable sector using an agricultural supply model (ASMMA) coupled with a computable general equilibrium model (MIRAGE-BioF). The application of this modelling framework confirms that biofuel policies would significantly affect the EU agricultural market, with price increase by 2020 as high as +40% in the case of rapeseed compared with a status quo at 2008 level. This would strongly impact land use and production of first-generation feedstock crops in France (rapeseed, cereals and sugar beets). The highest percentage increase would be in land dedicated to rapeseed (+50%), likely to occur in regions with a low initial rapeseed land share. This increase would boost farm income of most arable farms (+10% on average); however, the environment would face increase pressure from agricultural production with more use of pesticide (+5%) and increase in N₂O emissions (+2.5%).

Keywords: biofuels, policy analysis, agricultural supply model, arable crops, France

Impacts de la politique de biocarburants de l'UE sur le secteur des cultures arables en France : analyse microéconomique combinant modèle d'offre agricole et modèle du commerce mondial

Résumé – Ce papier vise à évaluer les impacts micro-économiques des politiques de biocarburants de l'UE sur le secteur des cultures arables en France en utilisant un modèle d'offre agricole (ASMMA) combiné à un modèle d'équilibre général calculable (MIRAGE-BioF). L'application de ce cadre de modélisation confirme l'influence significative des politiques de biocarburants sur le marché agricole de l'UE, avec une augmentation du prix des matières premières pouvant atteindre +40% dans le cas du colza. Les répercussions sur l'utilisation des terres et la production des cultures énergétiques en France seraient conséquentes (colza, céréales et betteraves à sucre). La plus forte augmentation concernerait les superficies de colza (+50%), principalement dans les régions où cette culture s'est jusqu'ici moins développée. Les revenus de la plupart des exploitations de grandes cultures seraient positivement affectés (+10% en moyenne), mais s'accompagneraient d'une pression accrue sur l'environnement par l'usage des pesticides (+5%) et des émissions de N₂O (+2,5%).

Mots-clés : biocarburants, analyse des politiques, modèle d'offre agricole, cultures arables, France

JEL Classification: Q12, Q16, Q42

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1. Introduction

Over the last decade, biofuel production has grown rapidly worldwide as a consequence of ambitious public policies, in particular towards ethanol in the US and biodiesel in the European Union. Motivated by concerns for more energy independence, climate change mitigation and agricultural sector conversion, governments have supported substantial incorporation targets through subsidization and incorporation targets of biofuels in fossil fuels. In 2009, production of bioethanol represented worldwide 37.9 Mtoe and biodiesel 13.9 Mtoe to compare with 8.4 Mtoe and 0.7 Mtoe respectively in 2000 (US EIA Energy database). This rapid expansion is explained mainly by government policies, even though fossil fuel prices could also have played a major role in the case of ethanol (Babcock, 2011). More recently, the increasing popularity of biofuels as a green alternative to fossil energy has nevertheless come under criticism, and the policies promoting their use have been called into question (Pimentel and Patzek, 2005; OECD, 2008; De Santi *et al.*, 2008).

While positive impacts, such as the reduction in CO₂ fossil fuel emissions have long been expected for a certain number of crops (Scharlermann and Laurance, 2008; Bureau *et al.*, 2010), the indirect impacts on land-use change, food price increase, fertiliser costs, and environmental externalities have progressively emerged as substantial issues. Indeed, several studies have questioned the capacity of biofuel energy to reduce global warming, mainly if the indirect effects from land-use change or intensification are accounted for (Searchinger *et al.*, 2008; Fargione *et al.*, 2008). Other studies accused biofuels of being one of the prominent causes of what soon was referred to as a food crisis (Rosegrant, 2008; FAO, 2008; Ivanic and Martin, 2008; Keyzer *et al.*, 2008). In addition, some have pointed out that biofuels would be responsible for the increase in the input prices for the meat and agricultural processing industries as well as for the rise in the demand for land, leading to higher land rent values and in turn affecting production costs (Elobeid and Hart, 2007; Hill *et al.*, 2006; Tokgoz *et al.*, 2007; Tangermann, 2008). Moreover, biofuel production is held responsible for some other serious negative effects in local environment, such as increasing pesticide use, reducing biodiversity, and using large amounts of water (Woli, 2010). For example, Erisman *et al.* (2010) found that biofuel expansion accelerates the nitrogen cycle through increased fertiliser use resulting in losses to the environment and additional emissions of oxidized nitrogen.

In order to address these concerns, several government agencies have already conducted large scale impact assessment for their own policy-making processes (US EPA, European Commission, and ADEME for France) using an increasing number of models (see Fonseca *et al.*, 2010; Prins *et al.*, 2010; Witzke *et al.*, 2010). In the

European Union (EU), models used have been agricultural partial (CAPRI¹) or general equilibrium models (MIRAGE-BioF²), which provides a sector or an economy-wide outlook; however, the understanding of the detailed local impacts remains scarce, as these models cannot enter a finer geographical scale than the regional level (NUTS 2).

We propose with this paper to bridge this gap for the case of France by linking the general equilibrium model MIRAGE-BioF and the farm-based supply model ASMMA³ to assess the impacts of the current EU biofuel policies on the French arable sector at a detailed scale. The general equilibrium model makes it possible to capture the links between agricultural and non-agricultural sectors – in particular the energy sectors in the case of biofuels – as well as the competition for land between agricultural and other uses in the rest of the world. The farm-based supply model offers the most detailed disaggregation possible regarding farms, regions and products and an accurate representation of domestic agricultural policies. This framework allows us to better illustrate what the EU biofuel program implies for France thanks to various ASMMA economic and environmental indicators such as land use, supply, input use, agricultural income, and certain environmental externalities (nitrous oxide (N₂O) emissions, pesticide use) at farm, regional and national levels.

The paper is structured as follows: in section 2, an overview of the EU and French biofuel context is provided. In section 3, the modelling framework is exposed. In section 4, the considered scenarii are explained in detail and their results are presented and discussed in section 5. In section 6, the sensitivity of supply model outcomes to a parameter of interest is examined. In section 7, we conclude on the relevance of this type of modelling framework and stress the value added of our results in comparison with other studies.

2. The EU biofuel program and its French declination: an overview

Various motivations have been driving the EU biofuel policy and led to the deployment of public supports for the sector. According to OECD (2008), the main reasons are, by order of increasing importance, the need to (i) promote technological development and innovation, (ii) provide opportunities for employment and regional development, especially in rural areas, (iii) enhance the security of energy supply, and most importantly, (iv) reduce GHG emissions. To achieve these objectives several policy instruments have been adopted at the European and Member State levels: mandatory blending or use targets, tax exemptions, trade measures, and budgetary support as well as measures to stimulate productivity and efficiency improvements.

2.1. The EU framework for biofuel program

Incorporation targets are the core of EU renewable fuel policy. The European Commission has set an objective of 5.75% of biofuels in EU transportation fuel by

¹ CAPRI: Common Agricultural Policy Regional Impact Analysis (Britz and Witzke, 2008).

² MIRAGE: Modelling International Relationships in Applied General Equilibrium.

³ ASMMA: Agricultural Supply Model for Micro-economic policy Analysis.

2010 for all Member States (Council and Parliament Directive 2003/30/EC). This target was raised up to a 10% target of renewable energy in fuel transportation by 2020 with the EU Renewable Energy Directive adopted in April 2009 (Council and Parliament Directive 2009/28/EC). Each Member State is responsible for designing national measures in order to reach this objective. The target is in addition subject to sustainability criteria of production, in particular with respect to land used for growing bio-energy crops, and should conform to fuel quality standards defined by the Fuel Quality Directive (Council and Parliament Directive 2009/30/EC).

This policy encouraged a significant reallocation of EU cropland to the production of biofuels. Indeed, the EU market for biofuels is significantly protected. First, import tariffs protect domestic biofuels produced from more competitive foreign producers. This is in particular the case of ethanol, for which the EU currently applies an MFN (Most-Favoured-Nation) tariff of €0.192 per litre on un-denatured ethanol, and €0.102 per litre on denatured ethanol (EU TARIQ database). In the case of biodiesel, tariff levels are lower (6.5%), but the Fuel Quality Directive imposes some blending constraints that restrict the use of soybean and palm oil based biodiesel. Additionally, prohibitive duties have been imposed on US and Canada biodiesel exports to the EU in 2009 and 2010, respectively, as a countervailing measure to the US blending subsidies favouring the North American biodiesel refineries. Last, EU sustainability criteria entered into force in 2010 now restrict the use of biofuel in the mandate to those having been certified as sustainable, with respect to production process and land use change.

The EU has also used several budgetary tools to support the deployment of bioenergy in the context of the Common Agricultural Policy (CAP). Production of non-food crops on land receiving the CAP set-aside premium began in 1993, and has largely involved crops for liquid fuel production. In addition, an energy crop aid of €45 per hectare was introduced in 2004. These policies remained effective until 2008.

Finally, a set of efficiency-enhancing measures has been adopted in order to stimulate research and technological development, promote investment in production capacity, and secure agreements with vehicle manufacturers, as well as facilitate the establishment of distribution networks and retail points for biofuels. For a more detailed description of EU biofuel policies see Fonseca *et al.*, 2010; Bureau *et al.*, 2010; Wiesenthal *et al.*, 2009; Ryan *et al.*, 2006.

All these policy instruments, along with the effects of high oil and agricultural feedstock prices, have made it possible for the EU biofuel sector to get established and grow. Several experts have agreed that without the current set of policy instruments, the increase in biofuel production would certainly have been much more limited (FAO, 2008).

However, the EU program has become recently controversial within both academic and policy circles. It is being argued that these support policies have put undue pressure on national budgets (Kutas and Lindberg, 2007) and also on grain and oilseed markets, thereby driving up international food prices and affecting human welfare (Msangi *et al.*, 2007; Gerber *et al.*, 2009). These supports have also been accused of market distortions by favouring domestic production and hampering international trade (FAO, 2008).

In response to these numerous critiques, the EU marginally amended its policy, with the abolishment of subsidies for energy crops with the November 2008 CAP Health Check, as well as a slight inflexion in the formulation of the biofuel mandates (the finally adopted directive focused on renewable energy mandates rather than biofuel blending mandates only, thereby leaving some doors open for more flexible biofuel targets). Several European Member States have also reduced their tax exemptions and credits on first-generation biofuels (Bureau *et al.*, 2010).

2.2. France: an ambitious program for biodiesel deployment

The Renewable Energy Directive set a framework in accordance to which each Member States had to design its own support policy to reach the mandatory target. Currently, 17 Member States offer fuel tax exemption or reductions on low blends of biodiesel and ethanol, and three more for biodiesel blends only, according to the provision of the Energy Tax Directive (Council and Parliament Directive 2003/96/EC).

France has been an early promoter of use of crops to produce biofuels. As soon as 1997, significant tax exemptions have been adopted to support production of ethanol (0.50 euros per liter) and biodiesel (0.38 euros per liter). These levels of support remained high until the year 2006, where some progressive phasing out was set up until 2012, in exchange of a more stringent incorporation program. Until 2005, however, the success of the deployment indeed remained limited, with a production of 190 million liters of ethanol and ETBE (Ethyl Tert-Butyl Ether) and 300 million liters of biodiesel only.

In 2005, France announced an ambitious program of incorporation of biofuel of 7% up to 2010, whereas the EU requirement was only 5.75%, a level France ambitioned to reach as soon as 2008. This policy was implemented by imposing to fuel retailers a substantial tax in the case where they would not respect the incorporation objective set by the French government. The result of these measures was very effective: in an interval of five years, from 2005 to 2010, the production of biofuels jumped from 490 million liters to 4.9 billion liters, 72% of it being biodiesel (French Parliament, 2010). The development of biodiesel in France was particularly based on the processing of large amount of rapeseed, whose cropped area was more than doubled between 1990 and 2010, to reach around 1.5 million ha currently, i.e. around 11% of the French harvested area according to EUROSTAT. However, the slowdown of biofuel growth in the last two years did not allow attaining the objective pursued, although the final incorporation rate for 2010, 6.3%, finally exceeded EU set targets.

The cost of this policy was nevertheless not negligible. In spite of the phasing out of tax exemptions (from 25 cents in 2006 to 8 cents in 2011 for biodiesel, and from 33 cents to 14 cents for ethanol), the public tax losses remained high, amounting to 650 million euros in 2010 and were estimated at some 480 million in 2011, according to the French Parliament.

Considering the cost incurred, it appears particularly important to better assess the various impact of the biofuel policy on the French arable sector, from an economic perspective, on one side, but also from an environmental perspective on the other side.

3. Modelling Framework

We conduct our analysis by combining a micro and a macro-level model describing agricultural activities. The combinations of models for agricultural issues have been regularly employed to depict the economy's consumption side.

The idea behind this combination is to substitute the representative consumer by more disaggregated households (Emini *et al.*, 2005; Hérault, 2005). However, only a few papers deal with the coupling of macro models and micro behavioural models to provide a clear picture of the production side. Among the most well-known approaches, Britz *et al.* (2012) link within the CAPRI modelling framework a farm-type optimization model to a partial equilibrium EU model to analyze the impacts of the CAP Health Check reform. Deppermann *et al.* (2010) link the European Simulation Model (ESIM) and the FARMIS model to assess the effects of EU Policy liberalization both at the sectoral level and at the farm group level for the German agricultural sector. Louhichi *et al.* (2010) link the partial equilibrium EU model CAPRI and the bio-economic farm model FSSIM to analyze the impact of trade liberalization on arable farms in Midi-Pyrénées (France). Kirschke *et al.* (1998) combine a computable general equilibrium (CGE) model and a farm linear programming model to analyze the impact of the EU agricultural policy on different disaggregation levels. Brockmeier and Urban (2008) apply a CGE model (GTAP) and a farm positive mathematical programming model (FARMIS) to analyze the impact of the WTO negotiation on the global, national and farm levels. Binfield *et al.* (2006) use the FAPRI's world, EU and Ireland models and a farm linear programming model to analyze the impact of trade liberation on the Irish dairy sector.

In most of these studies (except for Britz *et al.*, 2012 and Deppermann *et al.*, 2010⁴), two steps are involved: first, outputs from the micro model (e.g., elasticities) are used to calibrate the macro model and provide a microeconomic basis for aggregate behaviour (i.e., a bottom-up approach). Second, the model with a higher aggregation level delivers endogenously calculated macroeconomic variables (e.g., prices) to the lower level aggregation model to be used as input (i.e., a top-down approach). The bottom-up and top-down approaches are run separately and only once without any iterative process (Peichl, 2009).

In this study, we use a similar approach based on linking the global markets-orientated general equilibrium model MIRAGE-BioF (Valin *et al.*, 2010) and the microeconomic supply model ASMMA specific to French agriculture. First, ASMMA delivers a set of elasticities to calibrate the MIRAGE-BioF macro model (see table B.5 in the appendix for an overview of MIRAGE supply elasticity matrix). Second, the MIRAGE-BioF is used to estimate new prices under the simulated EU biofuel policies. Third, ASMMA uses the estimated prices to simulate the responses to price shocks of all individual arable farms in the French FADN sample. In addition, in order to improve consistency between the two models, their baselines and policy scenarii were

⁴ In Britz *et al.* (2012) and Deppermann *et al.* (2010), the bottom-up and top-down approaches are iteratively run for certain number of iterations (i.e. iterative exchange of variables between the micro and the macro models until convergence is achieved).

streamlined. Because we are particularly interested in the micro-economic impacts of EU biofuels, this paper only presents the methodology and results of the ASMMA supply model. A more detailed description of the MIRAGE-BioF model is provided in the appendix, and relies on works from Bouët *et al.* (2010), as well as Laborde and Valin (2012) which analyze the impact of EU biofuel mandates in other regions of the world.

3.1. Description of the ASMMA supply model

ASMMA (Agricultural Supply Model for Microeconomic Policy Analysis) is a supply model developed to analyze the potential impacts of policy and market changes on the sustainability of the French agricultural sector. It consists of a non-linear optimization model refined at the farm level, with possibilities of exchange of production factors and production rights across farms. It simultaneously solves a set of microeconomic farm models reproducing the behaviour of individual representative farms for the French agricultural sector. In order to get good representativeness of the French farming systems, all the individual arable farms in the Farm Accountancy Data Network (FADN) sample have been modelled. The use of this farm level modelling approach permits a finer and integrated analysis, capturing the wide heterogeneity of French farms while avoiding aggregation bias (Buysse *et al.*, 2007).

ASMMA is referred to as a static-comparative Positive Mathematical Programming (PMP) agricultural and bioenergy model. Proposed by Howitt (1995a), PMP is a generic and fully automated procedure developed to accurately calibrate programming models and overcome the normative character of traditional mathematical programming (MP) models.

The core structure of ASMMA was designed: 1.) to help define the activities by culture or by rotation; 2.) to explicitly represent technology and 3.) to smooth the integration of engineering data or results from bio-physical models needed to assess the environmental effects of production.

In terms of policy representation, ASMMA is able to simulate a broad range of agricultural and environmental policy instruments. The principal ones are the Common Agricultural Policy (CAP) support regime included in the Common Market Organisation (CMOs) regulations such as the compensation payments which are added to the gross margin and embedded in the model objective function and the obligatory set-aside and the quota based policies which are taken into account as additional constraints. The other group of policies modelled in ASMMA is related to the cross-compliance regulations which aim at sustaining various agro-environmental conditions that must be respected to avoid reduced farm support payment under the CAP reform of 2003. Cross-compliance regulations are taken into account mainly by additional constraints while in some cases binary variables are needed to transform the model into a Mixed Integer Non-Linear Programming (MINLP) model.

3.2. ASMMA mathematical structure

ASMMA uses a model template to ensure a uniform handling of all the farm models and their results. That is to say, all the microeconomic farm models are structurally

identical: they have the same equations and variables but the set of parameters depends on farm data. This model template is an extension of the Farming System Simulator's template (Louhichi *et al.*, 2010) developed within the SEAMLESS project (Van Ittersum *et al.*, 2008).

The objective function of ASMMA maximizes the agricultural surplus at given prices and subsidies, subject to constraints on resources and policy restrictions. The general mathematical formulation of ASMMA is as follows:

$$\pi_x = \text{Max} \sum_{f=1}^F w_f \left[gm'_f x_f - d'_f x_f - \frac{x'_f Q_f x_f}{2} \right]$$

S.t. $A_f x_f \leq b_f$

$x_f \geq 0$

where π is the agricultural surplus defined as the summation of the weighted farm income of FADN sample farms; the weights w_f are determined from the relative share of the farm in the NUTS 2 region, f indexes the farm from 1 to F, gm_f is the $(n \times 1)$ vector of the gross margin of activities, x_f is the $(n \times 1)$ vector of the simulated levels of the agricultural activities, d_f is the $(n \times 1)$ vector of the linear part of the activities' implicit cost function, Q_f is an $(n \times n)$ symmetric, positive (semi-) matrix of the activities' implicit cost function, A_f is a $(n \times m)$ matrix of technical coefficients, and b_f is a $(m \times 1)$ vector of available resources and upper bounds to the policy constraints.

The gross margin (gm) is defined as total revenues including sales from agricultural products and compensation payments (subsidies) minus observed accounting costs of production activities. The accounting costs include costs for fertilisers, crop protection and seeds. Q and d are the parameters of the implicit cost function used to calibrate the model to the observed situation. This function makes it possible to capture the risk aversion, the unspecified constraints, and the non-observed costs (due to heterogeneous land quality, limited management and machinery capacity). In principle, any non-linear convex cost function with the required properties can reproduce the base year solution. For simplicity, and lacking strong arguments for other type of functions, a quadratic cost function is usually employed.

Several PMP approaches have been developed to derive the parameters of the implicit cost functions. However, as the number of observations is usually not enough to allow for the traditional econometric estimation ("an ill-posed" problem), most of the proposed approaches go without any type of estimation by setting all off-diagonal elements of Q to zero and calculating the remaining parameters using *ad hoc* assumptions (see Heckelei, 1997 for a discussion). In order to reduce the arbitrary behaviour of the model and estimate more reliable cost functions covering all the parameters, two innovative PMP approaches based on multiple observations and more robust estimation methods have been proposed: (i) the Maximum entropy (ME)-PMP approach suggested by Paris and Howitt (1998) and extended by Heckelei and Britz (2000) and (ii) the Ordinary least square (OLS)-PMP approach proposed by Paris and Arfini (2000) and extended by Arfini and Donatti (2008).

In this analysis, we follow Heckelei and Britz (2000) approach as it allows for the easy and flexible use of prior information such as price elasticities. This approach makes it possible to estimate a full matrix for all the observed activities in each farm. However, it lacks the representation of farm behaviour with respect to activities that are unobserved during the base year period, commonly referred to as a self-selection problem. This leads to two issues. First, the cost function must accommodate true zeroes. Second, for simulation, the parameters of the cost function need to be estimated for all the activities and all the farms in the sample. To overcome this self-selection problem, Paris and Arfini (2000) suggest estimating an overall cost function (frontier cost) for the entire farm sample; each farm being therefore characterized by the same cost function and an error vector which reflects the distance of the farm from the cost frontier. This means that all the farms are assumed to face similar technical, economic and environmental conditions. This assumption cannot, nevertheless, be adopted in our case due to the large heterogeneity across farms in each region. To cope with this self-selection problem we have adopted the following *ad hoc* modelling decisions: the gross revenue of the non-observed activities is equal to the regional average gross revenue and the cost function parameters are equal to the largest cost function parameters within the region. That is, we assume that if a farm did not cultivate a crop during the base year, this is only because of its high costs and low profitability. More explanations on the calibration process are supplied in the appendix.

3.3. Environmental indicators

In order to evaluate the environmental impacts and stimulate the development of more environmentally-friendly farming practices, two farm level indicators are computed in ASMMA: Pesticide use and N₂O emissions. Pesticide use is measured by the Treatment Frequency Index (TFI) which indicates the intensity of pesticide application. The TFI is expressed on the standard dose of active substance per hectare needed for one treatment against the pest in question. The standard dose allows aggregating different biologically actives and reflects the direct effect on target organisms as well as the indirect impact on ecosystems, which results from changes in the quantities and species found in the food chain (Gravesen, 2003).

In order to compute pesticide use at the farm level, expressed per hectare of usable farmland, the following equation is used:

$$\text{Pesticide use}_f = \sum_{i,T} (AD_{i,T} / SD_{i,T}) x_{i,f} / \sum_i x_{i,f}$$

where *f* indexes representative farms, *i* indexes agricultural activities, *T* indexes treatment types, *AD* is average applied dose by hectare of each crop and region, *SD* standard dose by hectare of each crop and region, and *x* is agricultural activity levels. Data on applied and standard doses (i.e., *AD* and *AS*) is based on information provided in Guichard *et al.* (2010).

Regarding N₂O emissions, in ASMMA the main sources of emissions taken into consideration are: mineral fertiliser application, nitrogen-fixing crops and atmospheric deposition. The other sources of agricultural greenhouse gas emission are excluded because only arable farms are modelled. To compute N₂O emissions, we follow the IPCC (Intergovernmental Panel on Climate Change) methodology (IPCC, 1996,

2006), which suggests a linear relationship between N₂O emission and the three sources of emissions. The main reasons for choosing this method are its easiness of implementation and lower data requirement. However, there is a growing body of evidence indicating a nonlinear, exponential response of direct N₂O emission to N input (for more discussion see Kima *et al.*, 2012).

The following equation is used to compute N₂O emissions:

$$N_2O_f = \sum_i \left[a_{i,N,f} x_{i,f} + x_{i,f} Ndep + a_{i,N,f} x_{i,f} (1 - Nfix) \right] cd cf$$

where N₂O is nitrous oxide emissions from mineral fertiliser application, nitrogen-fixing crops and atmospheric deposition (in MtCO₂eq), f indexes representative farms, i indexes agricultural activities, a is mineral N fertiliser applied for each crop (in tonnes/ha), x is agricultural activity levels, Ndep is atmospheric N deposition (in tonnes/ha), Nfix is biological N fixation of crops (75% for pulses), cd is the nitrous oxide emission factor (the default IPCC emission factor of 0.019 kg N₂O per kg N was adopted) and cf the conversion factor for N₂O into CO₂eq (the 1996 IPCC-GWP coefficient of 310 was retained).

4. Empirical application

In this study, the agricultural supply model ASMMA is used to simulate the consequences of EU biofuel policies, in particular the implementation of current National Renewable Energy Action Plans (NREAP), on the French arable sector. To run ASMMA, three types of data are required: farm data, input coefficients and policy data.

Farm data: a sample of individual farms representative of the arable farming system was gleaned from the French FADN data source as well as their corresponding data such as available farm land, farm representativeness coefficients and the output coefficient of the observed crops (e.g., price, yield, historical reference land for EU payments and the observed area). These data were used in the ASMMA model for the calculation of gross margin, the definition of constraints' right-hand side (RHS) value and the calibration process. The selected sample contains 2,534 arable farms, belonging to the 13, 14 and 81 OTEX subgroups, covering around 109,556 farms nationwide (table 1).

Input coefficients: ASMMA uses information available in FADN. This data source only provides total costs and total input use per input category, without indicating the input use (and unit costs) of each (crop and animal) output. To overcome this lack of information, we have used the Generalized Maximum Entropy (GME) method to estimate input coefficients, using FADN data completed by information from the Cropping Practices Survey Data⁵ (Agreste, 2006) to set support points of the estimated parameters (Louhichi *et al.*, 2012).

⁵ The Cropping Practices Survey Data "Enquêtes pratiques culturales" is a survey and database that contains information on the current production practices for major filed crops in France, such as tillage practices, previous crops, sowing and fertiliser, as well as pesticide use, irrigation and, harvesting, taking into account the heterogeneity in terms of soil type. Carried out by the SSP (Service de la statistique et de la prospective; Ministère de l'Agriculture et de la Pêche) every four years since 1986. In 2006, this survey covered around 11 arable crops localized in 18,000 fields located in 21 administrative regions (Agreste, 2006).

Table 1. Number and area of arable farms in the French FADN sample (2006)

| OTEX 13-14-81 | Sample farms | Farms represented | Total area (1000 ha) |
|----------------------------|--------------|-------------------|----------------------|
| Ile-de-France | 144 | 3 447 | 533 |
| Champagne-Ardenne | 208 | 8 483 | 1 086 |
| Picardie | 242 | 9 071 | 1 052 |
| Haute-Normandie | 110 | 4 980 | 441 |
| Centre | 277 | 12 856 | 1 567 |
| Basse-Normandie | 53 | 2 985 | 196 |
| Bourgogne | 145 | 6 165 | 780 |
| Nord-Pas-de-Calais | 215 | 7 655 | 430 |
| Lorraine | 147 | 4 566 | 483 |
| Alsace | 89 | 2 853 | 159 |
| Franche-Comté | 58 | 1 575 | 142 |
| Pays de la Loire | 92 | 5 458 | 388 |
| Bretagne | 82 | 4 613 | 171 |
| Poitou-Charentes | 125 | 7 518 | 799 |
| Aquitaine | 138 | 7 060 | 320 |
| Midi-Pyrénées | 181 | 10 340 | 706 |
| Limousin | 6 | 519 | 34 |
| Rhône-Alpes | 82 | 4 566 | 254 |
| Auvergne | 66 | 2 724 | 174 |
| Languedoc-Roussillon | 31 | 1 145 | 75 |
| Provence-Alpes-Côte d'Azur | 43 | 1 377 | 62 |
| Total | 2 534 | 109 956 | 9 853 |

Source: FADN database (2006)

Policy data: we collected the data focusing on EU compensation payments for each crop. These payments are financed by the EU and administered by the ministry or department of agriculture of each Member State. Modelling the regional specific implementation of the compensation payment under 2003 CAP reform requires four pieces of information: the way the payment was given (i.e., per activity level, per historical yield, and per unit of main output), the amount of the payment (i.e., basic premium per ha, slaughtered animal or tonne of product), the likely options envisaged by each Member State to apply the decoupling system (i.e., partial or full decoupling) and the regional ceiling of premiums. The decoupled part of the payment is based on the historical reference land and the total amount of subsidies received over the years 2000-2002. The coupled and the decoupled payment of each activity were used to calculate the gross margin per ha of activity. A cut factor was calculated endogenously, which defines how much the premium has to be reduced in order to fit under the regional premium ceiling.

4.1. Model calibration

The base year information for which the model was calibrated stems from the year 2006. In term of policy representation, the 2003 CAP reform (the so-called Fischler Reform) as implemented in 2006 constitutes the base year policy. The most important measures of the Fischler CAP Reform are the adoption of decoupled direct payment, the introduction of a modulation system, and the enforcement of agri-environment schemes. In the French arable sector, this reform is based on the application of the historic single payment scheme, the adoption of partial decoupling (up to 25% of hectare payments remaining coupled) and the implementation of a 5% modulation rate.

To evaluate the performance of the calibrated model we ran some simulation experiments based on isolated 10% increases of single product prices and calculated the aggregated national percentage change in area related to the price change. Table 2

Table 2. Comparison with other studies of own price supply elasticity in France (2006)

| Crop | Land share | Prior | Our estimate | Guyomard <i>et al.</i> (1996) | Heckelei and Britz (2000) |
|------------|------------|-------|--------------|-------------------------------|---------------------------|
| Soft Wheat | 0.33 | 0.80 | 0.64 | 0.72 | 1.32 |
| Corn | 0.14 | 1.17 | 0.95 | 1.63 | 0.65 |
| Barley | 0.11 | 1.48 | 1.35 | 0.35 | 2.65 |
| Rapeseed | 0.06 | 1.15 | 1.15 | 0.42 | 1.46 |
| Sunflower | 0.05 | 1.46 | 1.34 | 0.22 | 1.13 |
| Soya | 0.00 | 2.82 | 1.99 | 3.70 | 1.86 |

Table 3. Definition of base year, baseline (i.e. reference run) and policy scenario

| | Base year [2006] | Baseline [2020] | NAP [2020] |
|-------------------------|--|---|---|
| Exogenous assumptions | 2006 yield | - Yield trend - Inflation rate of 1.9 % per year | |
| EU Compensation payment | - Partial decoupling - Historic Single Payment Scheme - Premiums for growing energy crops (45€/ha) | - Full decoupling - Regional Single Payment Scheme - Abolishment of premiums for energy crops | |
| Obligation set-aside | Set-aside is fixed to 10% of total farm area | Set-aside is fixed to 5% of total farm area | |
| Modulation | 5% | 10% | |
| EU biofuel directive | | Base year incorporation level (1.7%) | 7.7% of incorporation made from first generation biofuels |
| Producer prices | 2006 prices | Four-year average prices (2006-2009) | Prices under new incorporation rate |

compares our point elasticity estimates (for 2006) as well as our priors with two estimates provided by Guyomard *et al.* (1996) and Heckelei and Britz (2000). Guyomard *et al.* estimate a model with seven outputs and three inputs based on a restricted profit function, using annual data for France. Heckelei and Britz estimate a model similar to ours, but they use a cross-section dataset of French regions instead of French farms as is our case (the dataset is also different: 1994 in Heckelei and Britz and 2006 in this investigation).

Interestingly, the elasticities estimated for France in the present study fall between the results of Guyomard *et al.* and Heckelei and Britz for most crops (for sunflower, our elasticities are higher, and for soft wheat lower). Generally speaking, our elasticities are lower than Guyomard *et al.* for the major crops (i.e., soft wheat and corn which have high land shares) and higher for all the minor ones, except for soya (1.99 vs. 3.70). The comparison with elasticities provided by Heckelei and Britz remains non-conclusive: our elasticities are lower for three of the crops and higher for the other three. For the crop with the largest land share, soft wheat, all three studies are mostly in agreement because they estimate low elasticities, which is consistent with the literature. However, one should not forget that the theoretical structure of the three underlying models as well as the employed dataset differ between the three sets of estimates, thereby limiting their comparability.

4.2. Baseline scenario construction

The baseline scenario is interpreted as a projection over time covering the most probable future development in term of technological, structural and market changes. It represents the reference for the interpretation and analysis of the selected policy scenarii. In our case study, a continuation of the CAP (including Health Check decisions adopted in November 2008) up to 2020, taken as the time horizon for running simulations, is the principal policy assumption operating in the baseline scenario. Compared to the base year, the main change, in terms of CAP representation, is the adoption of full decoupling, the transition to the regionalised Single Payment Scheme (SPS), the abolishment of energy crop premiums (45€/ha), the increase in modulation rates from 5% to 10% and the decrease in set-aside rate from 10 to 5% (table 3)⁶.

Regarding the EU biofuel directive, we assume a moderate biofuel policy with a stabilization of incorporation at 2006 levels to fit the MIRAGE-BioF model scenario. Trade policies are supposed unchanged.

In terms of technological and market change, three exogenous assumptions are adopted: (i) an assumed inflation rate of 1.9 per cent per year; (ii) an adjustment of baseline prices using four-year average prices (2006-2009) to take into account price

⁶ The set-aside assumption reproduces the observed policy change with the decrease from 10% to 0% adopted in 2008, followed by the objective of 5% initially announced for the Post-2013 CAP. Note that the most recent proposals for CAP reform scenario now discuss an increase to 7% of land set-aside after 2013.

fluctuation during the food crisis period⁷; and (iii) a yield trend to reflect technical progress coming from CAPRI trend module (Britz and Witzke, 2011). Since the CAPRI yield trend is not explicitly defined at farm level but rather at the NUTS 2 level, the same trend is imposed on all farms belonging to the same NUTS 2 region (Appendix table A.1). All the other parameters are assumed to remain unchanged up to 2020 (no change in input costs and in farm resource endowments as well as in farm representativeness coefficients).

The other modelling assumptions that have been made are:

The exchanges of production factors and production rights between farms are not allowed (i.e. land, labour and quota markets are assumed missing).

Structural change is not taken into account, i.e. total farm area is assumed constant; no farm exit/entry neither re-specialization.

Only current production activities are considered.

The sugar reform decided in February 2006 is not implemented. The sugar beet quota is set to observed sugar beet production in the base year, whereas A, B and C sugar beet prices are substituted by observed mixed sugar beet prices.

EU biofuels consumption is kept at the 2006 level of a 1.7% share in the mix of biofuels and fossil fuels (5.7 Mtoe in the base year).

Assumptions on trade policy are status quo concerning tariffs on ethanol and the anti-dumping and countervailing measures against US biodiesel are considered in place.

4.3. Layout and implementation of policy scenarii

Three policy scenarii are implemented and compared to the baseline.

The central scenario is based on the current EU biofuel mandate as defined by the 2009 Renewable Energy Directive. In this scenario (referred to here as “NAP”) we consider that National (Renewable Energy) Action Plans lead to the incorporation of 27.5 Mtoe from first generation biofuels in EU transportation by 2020, with a 70% share of biodiesel and a 30% share of ethanol. Out of the targeted 10% of renewable fuel, this represents a share of 7.7% of renewable fuel made from first generation biofuels, the rest achieved through the use of second generation biofuels as well as electric cars and biogas (Laborde and Valin, 2012).

In this scenario, EU biodiesel production reaches 17.3 Mtoe of biodiesel and ethanol 5.3 Mtoe. The rest of bioenergy need is imported mostly from Brazil for ethanol (2.9 Mtoe) and from Indonesia, Malaysia and Argentina for biodiesel (1.8 Mtoe).

This central scenario is completed by two other scenarii aimed at disentangling the composition effect between ethanol and biodiesel impact:

⁷ We opted for this assumption instead of price projection because most of the available price projection takes into account the current biofuel policies which constitute one of the simulated policy scenarii in this paper.

Pure biodiesel scenario: a scenario of 7.7 percent fully based on the addition of biodiesel alone (“BIOD”), most of it coming from domestic EU production, whereas imports account to 3.5 Mtoe.

Pure ethanol scenario: a scenario where the same target is reached through an increase in ethanol consumption («ETHA»), a large part of it coming from domestic EU production, whereas imports account to 8.8 Mtoe (Brazil for the largest part).

These scenarii are simulated within the global market model (MIRAGE-BioF) and the resulting prices are fed into the supply model (ASMMA) in order to predict their impacts on the French arable sector.

5. Results and discussion

The impacts of the simulated scenarii are represented by a set of structural (land use), economic (farm income, agricultural surplus) and environmental indicators (pesticide use, N₂O emission). They have been computed at different scales ranging from the farm to the national level. In order to render the results easily understandable and comparable across scenarii and regions, all impacts were measured as percentage changes in comparison to the baseline (i.e., reference run). In our analysis, particular attention is given to the central scenario (i.e., current EU biofuel policies), especially in terms of its impacts on oilseed production, as rapeseed and, to a lesser extent, sunflower, are the most common feedstocks for biodiesel in Europe. In addition, given that the CAP Health Check abolished subsidies for energy crops, no distinction can be made between production for food and energy purposes.

Table 4. Comparison of a few quantitative assessments related to EU biofuel policies

| Reference | Model type | Scenario | EU Feedstock ^a | World price impact | | |
|--|-------------------------|------------------------|---------------------------|--------------------|------------------|-------------|
| | | | | Oilseeds | Cereals | Sugar crops |
| Britz and Leip, 2008 ^b | PE (CAPRI) | 10% EU | 2/3 oilseeds, 1/3 cereals | 32% | 13% | na |
| Banse <i>et al.</i> , 2008 | CGE (LEITAP) | 10% EU | oilseeds | 8% | 7% | 2% |
| Britz and Hertel, 2011 | CGE (GTAP) & PE (CAPRI) | 10% EU | oilseeds | 48% | 3% | 2% |
| Hertel <i>et al.</i> , 2008 ^b | CGE (GTAP) | 15 bln gn US +6.25% EU | Initial shares | 62% ^c | 23% ^c | na |
| Taheripour <i>et al.</i> , 2010 | CGE (GTAP) | 15 bln gn US +6.25% EU | Initial shares | 27% | 6% | 8% |
| DG AGRI, 2007 ^b | PE (ESIM) | +3.1% EU | | 8-10% | 3-6% | na |

a As interpreted from the paper materials

b As reported in Fonseca *et al.*, 2010

c EU prices according to Fonseca *et al.*, 2010.

5.1. Impacts on arable crop prices

The main finding from the application of the global model MIRAGE-BioF is that current EU biofuel policies (i.e., current mandates) lead to a high percentage increase in oilseed prices in Europe, confirming results from the literature (see table 4 for an overview). Indeed, we find that in the case of the NAP scenario, rapeseed price increase by 43% when compared with the 2006 level, as the market is already tense in the initial situation. A same situation is observed for sunflower whose price rise by 20%. Although these increases can appear very high, one can observe that recent price fluctuations are not inconsistent with such variations. Several previous assessments found similar magnitude of effects of the EU policy on world prices (Britz and Hertel, 2011, Taheripour *et al.*, 2010). Article reporting domestic EU prices show even higher levels of price increase (Hertel *et al.*, 2008 cited by Fonseca *et al.*, 2010). Whereas annual price for rapeseed oil was in 2006 793 USD per ton, it was 1013 USD on average in 2010 and 1423 USD in mid-2011, according to FAO. Moreover, these mandates contribute to an increase in the prices of cereal products (+6% for corn and +7% for wheat), as the competition for land leads to an overall decrease in cereal production (table 5). Results are however much more exacerbated for cereals with the ethanol scenario, where these corn and wheat levels reach 12% and 14% increase, respectively. Sugar beet, which is significantly used for ethanol processing in our scenario, becomes more expensive, with a +31% price rise.

Table 5. Impact of simulated scenarii on arable crop prices at EU and world levels (% change to reference run)

| | NAP | | BIOD | | ETHA | |
|-------------|------|-------|------|-------|-------|-------|
| | EU | World | EU | World | EU | World |
| Wheat | 6.8 | 2.7 | 2.7 | 1.3 | 14.2 | 5.0 |
| Corn | 5.9 | 1.1 | 3.4 | 0.8 | 12.6 | 2.1 |
| Sunflower | 20.3 | 15.8 | 30.3 | 25.1 | 5.2 | 3.1 |
| Rapeseed | 43.3 | 22.0 | 60.2 | 32.3 | 5.3 | 2.5 |
| Sugar crops | 11.8 | 3.2 | 3.9 | 1.2 | 31.4 | 9.1 |
| Soybeans | 7.7 | 4.5 | 12.1 | 7.7 | 1.2 | 0.5 |
| All crops | 6.10 | 2.46 | 3.68 | 2.36 | 11.23 | 3.40 |

Source: MIRAGE-BioF results

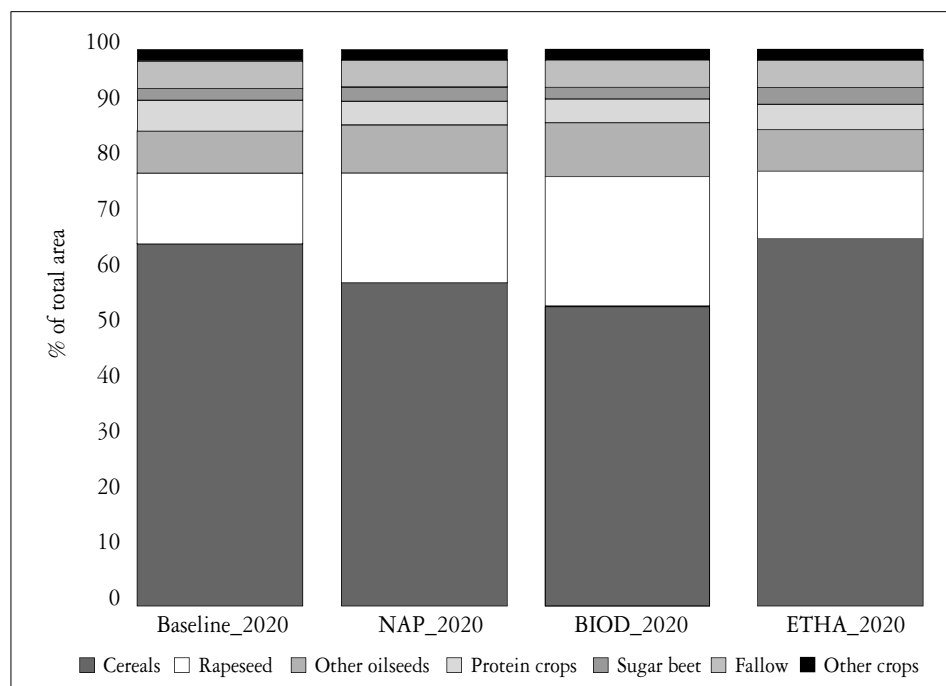
5.2. Impacts on land use and supply

As a consequence, the effect of the three policy scenarii on the French arable crop sectors show in the ASMMA model a significant increase in the production of biofuel feedstock crops such as oil crops, sugar beet and wheat, while the production of other arable crops falls in almost all regions and scenarii.

As expected, the implementation of the central scenario (i.e., current targets) would lead, as shown in figure 1, to a large increase in oilseed area to the detriment of cereals, protein crops and, to a lesser extent, crops for other industrial uses. The most important increase would be in rapeseed area, its share in total arable land expanding

from 13% (around 1.25 million hectares), in the baseline, up to 19% (1.9 million hectares) under the NAP scenario. Sunflower area would rise as well, by around 14%, responding to the 20% price increase provoked by this policy scenario. Sugar beet area would grow by around 16% but this is of minor importance when measured in absolute terms. However, cereal crops, mainly wheat and barley, would be strongly affected and their acreage would decline by 11%, despite the increase in their prices. This is owing to the high competitiveness of rapeseed and sunflower under this scenario, in comparison to other crops.

Figure 1. Land-use change in the French arable crop sector under simulated policy scenari



The pure biodiesel scenario (BIOD) would put more pressure on land use and induce an expansion of oilseed production following the growing demand for biodiesel. The shares of rapeseed and sunflower in total arable land would expand even more than in the central scenario, reaching 23% and 9%, respectively. This expansion would be at the expense of cereals (notably barley) and protein crop areas which would fall by around 17% and 22%, respectively.

Under the pure ethanol scenario (ETHA), the change in land use would be relatively slight in spite of the increase in prices of ethanol feedstock crops (around 14% for wheat, 12% for corn and 31% for sugar beet). The main percentage change would appear in the area dedicated to sugar beet, reaching the 40%. The increase in wheat area would be relatively small (around 6%); however, measured in absolute terms, it would be significant (about 236 thousands hectares) due to its large initial share in the total area (figure 2).

Figure 2. Cropland change in the French arable crop sector under simulated policy scenarii

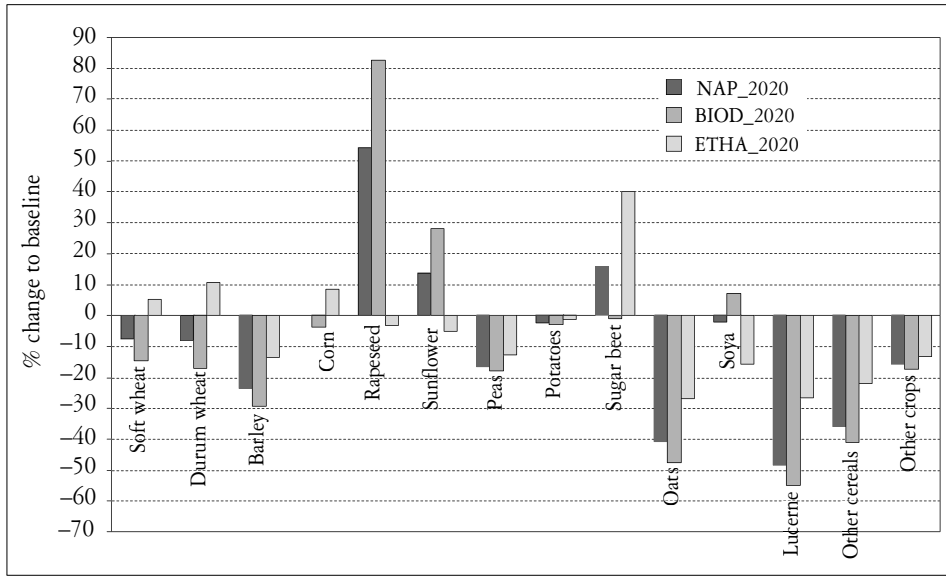
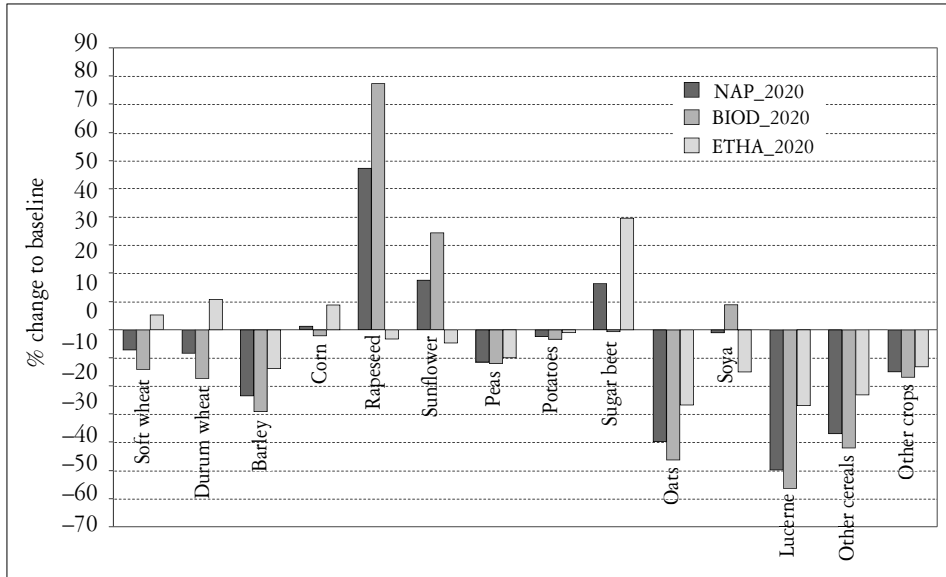


Figure 3. Production change in the French arable crop sector under simulated policy scenarii



Fallow land appears to be in both baseline and policy scenarii to the same lower bounds set by CAP set-aside policy (i.e., 5% of total land). This means that voluntary set-aside would not be profitable under these scenarii.

The effect of policy scenarii on supply (i.e., production level) follows the same tendency as land use involving an expansion in oilseed production under the NAP and

BIOD scenarii and a rise in sugar beet, corn and wheat production in the ETHA scenario. The main expansion would occur in rapeseed production for both food and energy purposes, where its value would increase from an initial value of 4.5 million tonnes, in the baseline, up to 7 millions of tonnes in the NAP scenario (around 57%) and 8.5 million tonnes in the BIOD scenario (around 87%). This increase in supply is explained more by land expansion rather than yield increase (i.e., intensification) given that only average current crop managements were included in ASMMA (i.e., transition towards more intensive production technique was not allowed). However, as the land expansion would occur mostly on regions with high productivity, the percentage increase in supply would be slightly higher than the one in land. Cereals production, mainly soft wheat and barley, would be largely affected by both central and pure biodiesel scenarii and their percentage decreases would exceed 9% in the first scenario and 15% in the second one (figure 3).

Table 6. Impact of simulated scenarii on rapeseed area at regional level

| OTEX 13-14-81 NUTS 2 regions | Total area (1 000 ha) | Share of rapeseed in total area (%) | | | % change of rapeseed area to baseline | |
|---------------------------------|--------------------------|-------------------------------------|---------------|----------------|--|----------------|
| | | Baseline [2020] | NAP [2020] | BIOD [2020] | NAP [2020] | BIOD [2020] |
| Ile-de-France | 533 | 17 | 24 | 28 | 46 | 69 |
| Champagne-Ardenne | 1 086 | 15 | 24 | 29 | 60 | 88 |
| Picardie | 1 052 | 10 | 16 | 19 | 52 | 84 |
| Haute-Normandie | 441 | 9 | 15 | 19 | 69 | 114 |
| Centre | 1 567 | 18 | 26 | 30 | 45 | 68 |
| Basse-Normandie | 196 | 12 | 20 | 24 | 69 | 107 |
| Bourgogne | 780 | 20 | 30 | 34 | 46 | 68 |
| Nord-Pas-de-Calais | 430 | 3 | 6 | 8 | 100 | 169 |
| Lorraine | 483 | 22 | 31 | 36 | 42 | 67 |
| Alsace | 159 | 1 | 2 | 3 | 101 | 175 |
| Franche-Comté | 142 | 14 | 23 | 27 | 63 | 96 |
| Pays de la Loire | 388 | 9 | 15 | 19 | 68 | 106 |
| Bretagne | 171 | 11 | 25 | 31 | 124 | 182 |
| Poitou-Charentes | 799 | 15 | 23 | 27 | 49 | 74 |
| Aquitaine | 320 | 4 | 8 | 10 | 90 | 134 |
| Midi-Pyrénées | 706 | 3 | 6 | 8 | 136 | 212 |
| Limousin | 34 | 15 | 28 | 34 | 88 | 125 |
| Rhône-Alpes | 254 | 8 | 11 | 13 | 48 | 72 |
| Auvergne | 174 | 7 | 11 | 13 | 52 | 76 |
| Languedoc-Roussillon | 75 | 3 | 6 | 8 | 134 | 211 |
| Alpes-Côte d'Azur | 62 | 1 | 2 | 2 | 74 | 121 |
| Total/Average | 9 853 | 12.7 | 19.6 | 23.2 | 54 | 83 |

Source: ASMMA results

Table 7. Impact of simulated scenarii on share of farms at regional level cultivating rapeseed

| OTEX 13-14-81 NUTS 2 regions | Farms represented | Percentage of farms producing rapeseed (%) | | | |
|---------------------------------|----------------------|--|---------------|----------------|----------------|
| | | Baseline [2020] | NAP [2020] | BIOD [2020] | ETHA [2020] |
| Ile-de-France | 3 447 | 79 | 82 | 93 | 79 |
| Champagne-Ardenne | 8 483 | 80 | 85 | 88 | 80 |
| Picardie | 9 071 | 65 | 89 | 93 | 66 |
| Haute-Normandie | 4 980 | 78 | 85 | 90 | 77 |
| Centre | 12 856 | 81 | 81 | 82 | 81 |
| Basse-Normandie | 2 985 | 96 | 96 | 100 | 92 |
| Bourgogne | 6 165 | 84 | 88 | 90 | 84 |
| Nord-Pas-de-Calais | 7 655 | 80 | 91 | 93 | 78 |
| Lorraine | 4 566 | 99 | 100 | 100 | 99 |
| Alsace | 2 853 | 6 | 16 | 49 | 6 |
| Franche-Comté | 1 575 | 90 | 100 | 100 | 91 |
| Pays de la Loire | 5 458 | 55 | 67 | 81 | 55 |
| Bretagne | 4 613 | 78 | 86 | 88 | 79 |
| Poitou-Charentes | 7 518 | 68 | 78 | 80 | 68 |
| Aquitaine | 7 060 | 15 | 21 | 28 | 17 |
| Midi-Pyrénées | 10 340 | 46 | 55 | 64 | 43 |
| Limousin | 519 | 100 | 100 | 100 | 100 |
| Rhône-Alpes | 4 566 | 49 | 63 | 63 | 51 |
| Auvergne | 2 724 | 44 | 54 | 54 | 44 |
| Languedoc-Roussillon | 1 145 | 15 | 46 | 52 | 15 |
| Provence-Alpes-Côte d'Azur | 1 377 | 9 | 17 | 25 | 9 |
| Total/Average | 109 956 | 63 | 71 | 77 | 63 |

Source: ASMMA results

The supply response of ethanol feedstock crops to the ETHA scenario remains relatively minor compared to the responses of biodiesel feedstock crops to the NAP and BIOD scenarii. Apart from sugar beet production which would rise by around 40% at the expense of oilseeds and protein crops, wheat and corn productions would grow by only 6% and 9%, respectively. This small increase is explained for wheat by its high land share in the reference run (around 40% of total land) and for corn by the slight increase of its price (around 12%). The high percentage increase in sugar beet production is driven by price change and would concern only sugar beet for energy purpose, as sugar beet production for food use is restricted by the production quota.

All the trends in land use and supply changes revealed at the national level under simulated scenarii remain apparent at the regional and farm levels, i.e. an increase in oilseed area in the NAP and BIOD scenarii, and a rise in sugar beet, wheat and corn areas under the ETHA scenario. The expansion of rapeseed would occur in all the

Table 8. Impact of pure ethanol scenario on wheat and sugar beet areas at regional level

| OTEX 13-14-81 NUTS 2 regions | Total area (1 000 ha) | Share of wheat in total area (%) | | | Share of sugar beet in total area (%) | | |
|---------------------------------|--------------------------|-------------------------------------|----------------|------------|--|----------------|------------|
| | | Baseline {2020} | ETHA {2020} | Dev (%) | Baseline {2020} | ETHA {2020} | Dev (%) |
| Ile-de-France | 533 | 47 | 49 | 6 | 4 | 5 | 35 |
| Champagne-Ardenne | 1 086 | 33 | 35 | 6 | 3 | 6 | 102 |
| Picardie | 1 052 | 49 | 51 | 4 | 8 | 9 | 6 |
| Haute-Normandie | 441 | 53 | 55 | 4 | 4 | 5 | 41 |
| Centre | 1 567 | 46 | 48 | 6 | 1 | 1 | 48 |
| Basse-Normandie | 196 | 50 | 51 | 3 | 2 | 7 | 263 |
| Bourgogne | 780 | 36 | 40 | 10 | 0 | 1 | 296 |
| Nord-Pas-de-Calais | 430 | 50 | 53 | 4 | 8 | 10 | 24 |
| Lorraine | 483 | 37 | 40 | 7 | 0 | 0 | 9 |
| Alsace | 159 | 17 | 18 | 6 | 3 | 3 | 5 |
| Franche-Comté | 142 | 34 | 37 | 8 | 0 | 1 | 86 |
| Pays de la Loire | 388 | 48 | 50 | 5 | 0 | 0 | 46 |
| Bretagne | 171 | 44 | 46 | 6 | 0 | 0 | 0 |
| Poitou-Charentes | 799 | 40 | 43 | 8 | 0 | 0 | 0 |
| Aquitaine | 320 | 14 | 15 | 4 | 0 | 0 | 0 |
| Midi-Pyrénées | 706 | 38 | 41 | 6 | 0 | 0 | 0 |
| Limousin | 34 | 43 | 47 | 10 | 0 | 0 | 0 |
| Rhône-Alpes | 254 | 29 | 31 | 6 | 0 | 0 | 0 |
| Auvergne | 174 | 43 | 44 | 2 | 0 | 1 | 252 |
| Languedoc-Roussillon | 75 | 47 | 49 | 4 | 0 | 0 | 0 |
| Alpes-Côte d'Azur | 62 | 58 | 60 | 4 | 0 | 0 | 0 |
| Total/Average | 9 853 | 41 | 44 | 6 | 2 | 3 | 40 |

Source: ASMMA results

arable farms even those with lower profitability and its area would increase, between the baseline and policy scenario, by more than 20% in the majority of farms. However, a detailed analysis of the central scenario results shows significant differences across regions⁸, confirming results reported in Guindé *et al.*, 2008: the largest percentage increases in rapeseed areas would occur in regions where initial shares are small (table 6). That is, regions with largest share of rapeseed in the reference run react less rapidly to a price increase triggered by the NAP scenario, in comparison to the other ones. For example, in the Centre, Bourgogne and Lorraine regions, where rapeseed area exceeds 18% of total cropland, the percentage increases are modest, in comparison to regions with a very small initial rapeseed share (less than 10%). The latter would

⁸ The region of Corse is excluded from this study due to missing data.

respond significantly to an increase in the price of rapeseed but this response is slight in absolute terms. The main reason of this response is that most of the farms in regions with a high initial rapeseed share produce already rapeseed; sometimes with a large land share, therefore, increasing the rapeseed area above will be more costly due to rising marginal costs with production. On the contrary, in the regions with a small initial share, the increase in rapeseed area is attributed to land use change in farms already producing rapeseed but also in the other ones since new farms started producing rapeseed⁹ (table 7). Under the BIOD scenario, these regional differences fade away and the rapeseed area would double in almost all regions.

The other common regional result is that in all regions, except Bourgogne and Lorraine, the area devoted to rapeseed under the central scenario would not exceed a quarter of the total acreage. This is equivalent to a four-year rotation for rapeseed, which seems acceptable from an agronomic point of view. However, under the BIOD scenario, rapeseed would occupy more than a quarter of total areas in almost half of the regions, and more than 30% in some cases. This expansion could be unsuitable from an agronomic point of view as it could lead to an increase in negative environmental externalities, mainly in term of pesticide use.

Farms responses to the pure ethanol scenario are quite similar across regions. A relatively small increase in wheat land, ranging from 2 to 10% in most of the regions, is projected. This increase would however be quite significant in absolute terms, as the share of wheat in the total area is shown to exceed 30% in all the regions, except in the cases of Alsace and Aquitaine. For sugar beet, the change in land use would be relatively significant following the high price increase, mainly in the major sugar beet production areas such as Champagne-Ardenne, Centre and Normandie. As shown in table 8, wheat response to price increase is projected to be relatively minor for these regions to the benefit of sugar beet, which means that sugar beet geared towards ethanol becomes more profitable in light of these new prices.

5.3. Economic and environmental impacts

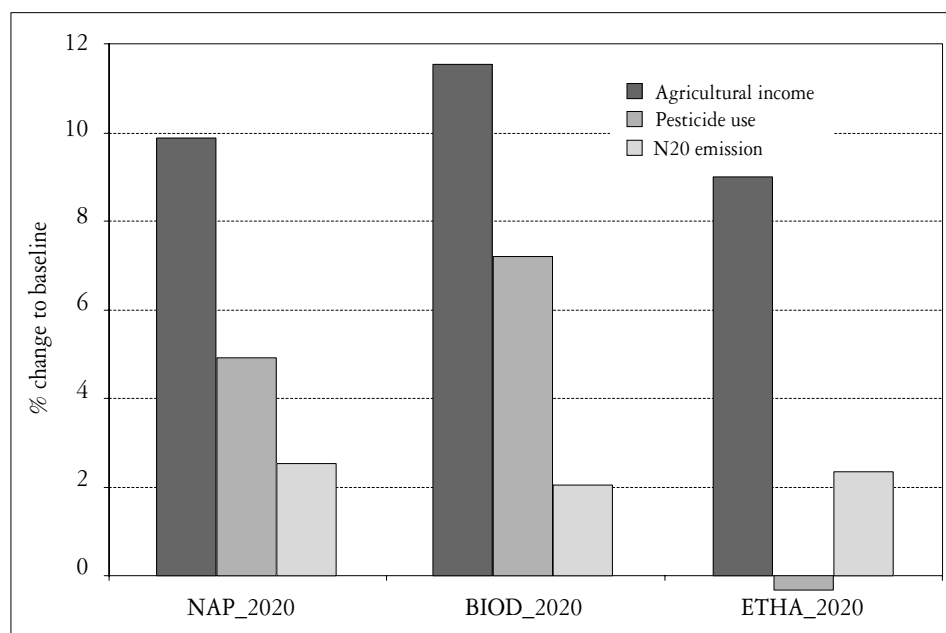
As expected, the EU biofuel policies would boost income in the arable sector and make farmers feel more secure. As shown in figure 4, the agricultural income (operating surplus) would increase in the three policy scenarii (NAP, BIOD and ETHA) by around 10%, 12% and 9%, respectively. This is mainly due to a rise in income from oilseed in the first two scenarii and from sugar beet, corn and wheat, in the last one. The main increase would be in the case of the pure biodiesel “BIOD” scenario, because of the almost doubling of oilseed production and price. The significant positive impact of the ETHA scenario on agricultural income is explained by the higher share of ethanol feedstock crops in the total acreage in France. In fact, a modest increase in their prices and production would be enough to generate a better income.

However, this positive economic impact would be followed by an increase in pesticide use as well as in N₂O emissions. As expected, the greater increase in pesticide use would occur in scenarii with a higher biodiesel share and, particularly in the pure

⁹ The self-selection condition was adopted to estimate the rapeseed implicit costs in these farms.

biodiesel scenario (about 5% in the NAP scenario and 7% in the BIOD scenario). This is owing to the expansion in the area dedicated to rapeseed, a crop which requires a large amount of pesticide per hectare. This increase could be more significant if intensification is taken into account or if we assume that the pesticide requirement per hectare can increase with specialization (i.e., farmers tend to use more pesticides per hectare when the share of rapeseed in total acreage increases) as argued by Bayramoglu and Chakir, 2010. However, under the pure ethanol ETHA scenario, the use of pesticide will slightly decrease due to the reduction of oilseed areas in this scenario, in comparison to the reference run (table 6). These results seriously question the sustainability of the current EU biofuel policy and emphasize the even more dramatic effect of a biodiesel-orientated EU biofuel program (i.e., BIOD scenario), found to use 5% more pesticide than an EU ethanol-orientated program.

Figure 4. Economic and environmental impacts of simulated policy scenarii in the French arable sector

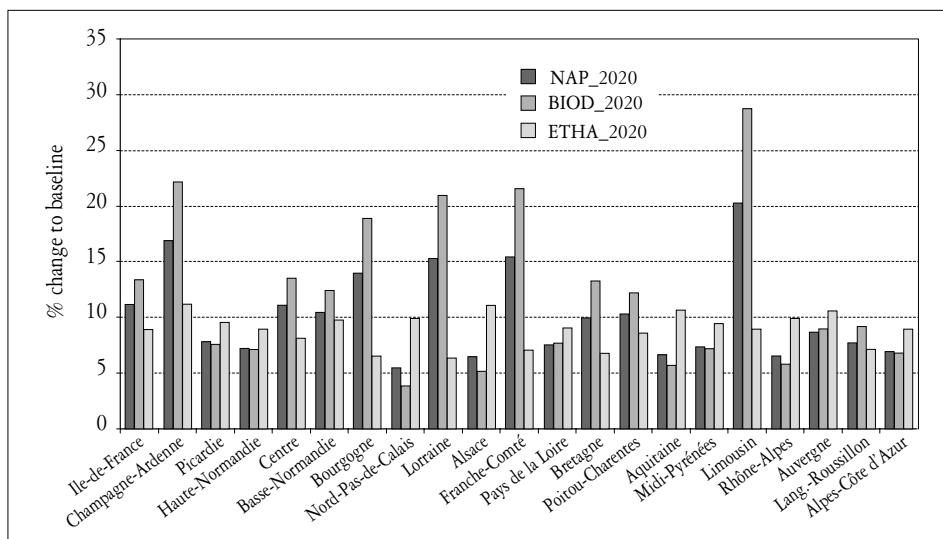


Regarding the effects on N₂O emissions, the three scenarii would provoke a similar relative increase in the nitrous oxide quantity emitted in the atmosphere, around 2%. This is due to the fact that mineral fertiliser applied in the three scenarii, which is the main source of emissions in our case, would be quite linear with the produced quantity for the different crops.

The regional effects on agricultural income follow from price and quantity impacts on the output side. The bottom line in terms of agricultural income is crucially determined by the impacts on revenues from rapeseed in the NAP and BIOD scenarii and from sugar beet, corn and wheat in the ETHA scenario. In general, most of the simulated arable farms would be positively affected by EU biofuel policies and

their agricultural income would increase, in different degrees, according to agro-climate, resource endowment and socio-economic conditions. The highest percentage increases would appear under the central and the pure biodiesel scenarii and are projected for regions with a big initial share of rapeseed share such as in Champagne-Ardenne (17%; 22%), Lorraine (15%; 20%), and Bourgogne (14%; 19%), following the rise in both oilseed price and production (figure 5). The Limousin region would record a significant increase as well, nearly 20% in the NAP scenario and 29% in the BIOD scenario; however, in absolute terms, this rise is of minor importance.

Figure 5. Agricultural income change under simulated policy scenarii per region

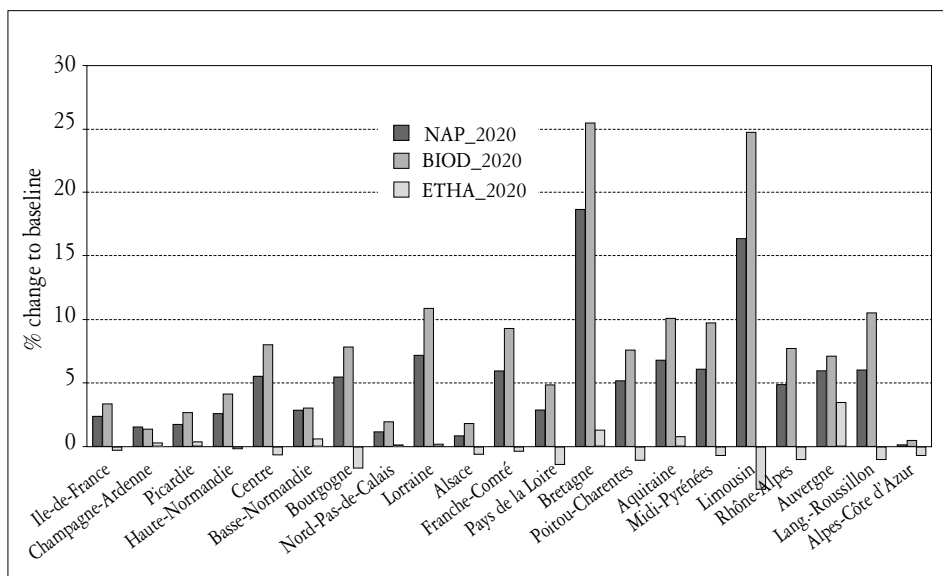


Within the context of the pure ethanol scenario, the percentage increase in income would be quite similar across regions. It would range from 6 to 11%, attributed to both price and production increases of sugar beet, corn and wheat products. The largest rises are predicted in regions specialised in cereal products such as Champagne-Ardenne (11%), Ile de France (9%) and Normandie (10%), or those specialised in sugar beet, namely Picardie (10%) and Nord-Pas-de-Calais (10%).

The regional environmental effects in terms of pesticide use are quite different across regions and scenarii and are driven mainly by the change in rapeseed area. The largest percentage increases are revealed under both central and pure biodiesel scenarii and would occur in regions with low initial rapeseed shares which respond strongly to price change such as Bretagne, Limousin, Languedoc-Roussillon. However, because of their small total arable land as well as their low per hectare pesticide use, in comparison to other regions, these increases would be slight in absolute terms.

Under the pure ethanol scenario, the percentage change of pesticide use compared to baseline would be insignificant in most of the regions (less than 0.05%), except in Limousin where a slight decrease (around -3%) would be recorded explained by the reduction of oilseed areas in favour of cereals and sugar beet which require a small amount of pesticide per hectare (figure 6).

Figure 6. Pesticide use change under simulated policy scenarii per region



6. Sensitivity of ASMMA results to yield growth under current biofuel policies

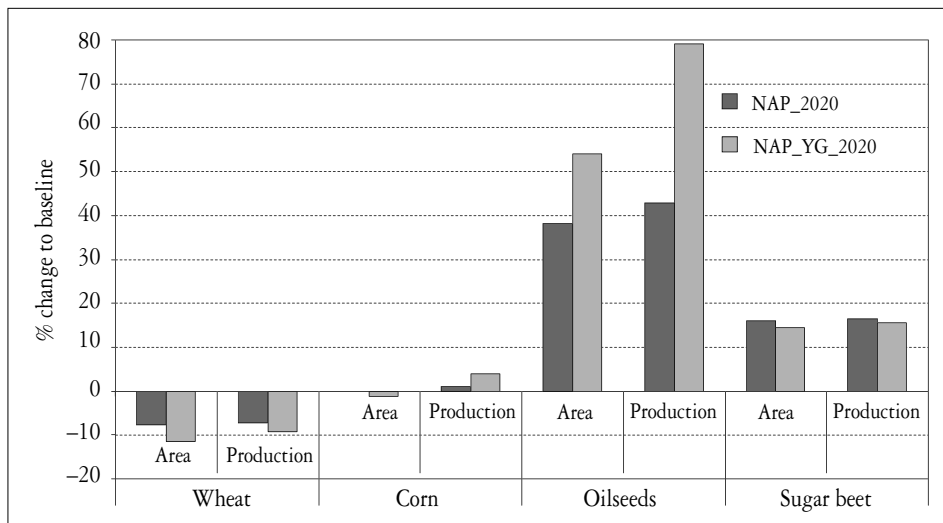
The following analysis was performed in order to assess the sensitivity of ASMMA results to a potential yield growth under the current biofuel policies (NAP scenario). In fact, the supply model ASMMA is unable to simulate the switching between production intensities and, thus, to capture endogenously the potential growth of yield under the simulated biofuel policies. In this sensitivity analysis, we assume that the yield growth determined endogenously with the MIRAGE-BioF model at EU level remains valid for France. This corresponds to an increase in wheat, corn, rape, sunflower, and sugar beet yields by around 2%, 3.5%, 13%, 5% and 0.5%, respectively.

Figure 7 shows the impacts of current biofuel policies with (NAP_YG) and without (NAP) yield-growth assumption on land use and production. From this figure, it appears, clearly, that the expected high yield growth for oilseeds would boost their areas in detriment of cereals, notably wheat and barley. The 2% increase in wheat yield seems not enough to improve its competitiveness against oilseed products and maintain its area as under the NAP scenario. The areas of corn and sugar beet would decrease slightly in comparison to their observed levels under NAP scenario.

Regarding production, this figure shows that the increase in oilseed production would be more pronounced when yield growth is taken into account. Its percentage increase would expand from 43% under the NAP scenario up to 79% under the NAP_YG scenario. It shows as well that the yield growth of the other feedstock crops would compensate the decrease of their areas (corn and sugar beet) or at least reduce (wheat) its impact on production. This means that if EU biofuel policies would induce yield growth for the major feedstock crops, then the pressure on land could be reduced

or even reversed. However, this finding has to be considered with some caution since the development is achieved using constant prices of NAP scenario. In fact, the high increase of oilseed production would certainly be accompanied by falling prices, which may reduce the rate of the yield increase by acting to slow down yield-enhancing technological investment.

Figure 7. Effect of current biofuel policies with (NAP_YG) and without (NAP) yield-growth assumption



7. Conclusion

This paper assesses the micro-economic impacts of current EU biofuel policies on the French arable sector by linking micro (ASMMA) and macro (MIRAGE-BioF) models. The application of the macro model reveals that current biofuel policies would significantly affect the EU agricultural market and lead to a high percentage increase in oilseed prices as well as to a slight rise in the prices of cereal products, as the competition for land leads to an overall decrease in cereal production. It also shows that ethanol (ETHA scenario) and biodiesel (NAP and BIOD scenario) demands have quite different effects in terms of land use change and CO₂ emissions, confirming therefore previous results (Al-Riffai *et al.*, 2010; Britz and Hertel, 2011).

The application of the micro model shows that current EU policies (i.e., current targets) would strongly impact land use and production of first-generation feedstock crops in France. The highest percentage increase would be in rapeseed area, following the rise in biodiesel demand and projected to occur in regions with a low initial rapeseed land share. This increase would boost agricultural income of all arable farms, in various degrees, according to agro-climate, resource endowment, and socio-economic conditions; but it would lead as well to significant environmental consequences in terms of pesticide use and N₂O emissions. All these economic and environmental

trends would be more pronounced under the biodiesel-orientated EU biofuel program (BIOD scenario) which predicts a bigger increase in rapeseed production as well as in agricultural income than current policies, but engenders more pesticide use. The regional differences fade away under the biodiesel scenario, and rapeseed would occupy more than a quarter of total area in almost half of the regions, which would be unsuitable from both agronomic and environmental point of views. Within a ethanol-orientated EU biofuel program (ETHA scenario), the rise in land use for feedstock crops (wheat, sugar beet and corn) would be relatively small; however, measured in absolute terms, it would be important due to their large initial shares in the total area. This would lead to an increase in agricultural income, mainly in regions specialised in cereal products such as Champagne-Ardenne, Picardie and Ile de France, or those specialised in sugar beet, namely Nord-Pas-de-Calais. The environmental impact of this scenario in terms of pesticide use is very low compared to the other ones but overall crop prices increase is more pronounced because of the impact on cereals.

These findings have to be considered, however, with some caution due to model assumptions and limitations. On the macro level, the impact on prices that we find is driven by iso-elastic supply function. Although this assumption is in line with usual practices in the literature, non-linear patterns in the price response could also be envisaged and limit price expansion. Additionally, at the micro level, this supply model has three major limitations: the first one is its incapability to simulate endogenously the switching between different production intensities required to capture farm management adjustment to policy and price changes. The second limitation is the non-consideration of farm structural change and a last one is the non-representation of other agricultural sub-sectors (e.g. a detailed representation of the livestock sector would definitely improve the assessment of land competition) and other biofuel feedstock crops (i.e. second-generation biofuel crops). A better understanding of yield responses to prices in the French and EU context, as well as a potential of expansion of rapeseed would certainly be helpful to refine in the future the estimate for such large shocks on the agricultural system.

Overall, our linkage approach confirms the negative impacts of biofuel policies in terms of environmental effect and economic impact for the consumer. Biodiesel-orientated policy would have the strongest impact on revenue for farmers but also would significantly raise oilseed prices for the world consumers as well as increase negative environmental externalities through pesticide use. On the other side, ethanol-orientated policy would have less impressive price effect on single crops but would impact even more food consumption. The environmental impact would however be lower. These different effects tend to strengthen the view already developed by the mitigation literature that a social- and environmentally desirable biofuel policy cannot be achieved through EU grown first generation feedstocks.

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APPENDIX A: ASMMA Calibration Procedure

As explained in the text, we follow Heckelei and Britz (2000) formalism for ASMMA calibration as it allows for the easy and flexible use of prior information such as price elasticities. According to this formalism, the cost function is defined at the farm level and the marginal cost of the f -th farm can be represented as follows:

$$MC_f = d_f + Q_f x_f^0 = \lambda_f + c_f \quad \forall x_f^0 > 0$$

where MC_f is the vector of marginal costs in farm f , c_f is the vector of observed variable costs per unit of activity, λ_f are the dual variables associated with the calibration constraints, x_f^0 is the vector of observed activity levels, d_f is the vector of the linear part of the activities' implicit cost function and Q_f is the matrix of the quadratic part of the activities' implicit cost function. It is given by:

$$Q_f = S_f B S_f'$$

$$S_{fii} = \sqrt{\frac{1}{x_{fi}^0}}$$

where S_f constitutes the $(n \times n)$ diagonal scaling matrices for each farm f , and B is a $(n \times n)$ parameter matrix related to Q_f . The B matrix – common across farms inside the same region – is estimated using exogenous regional supply elasticities (Jansson and Heckelei, 2011) as a prior in order to avoid a kind of arbitrary setting of parameters.

The scaling matrix S improves the responses of the model to the changes in the acreage of any crop. To stress the effect of the scaling mechanism, Heckelei and Britz (2000) give an example for two farms with identical total area but different shares of crop land. According to the example, it is assumed that there is a 10 ha increase in the acreage of a crop. If the total acreage of this crop in farm one is 1 ha and 100 hectares in farm two prior to the change of the acreage, then 10 hectare increase in the acreage of this crop would imply a 1,000 percent relative increase for the first farm but only a 10 percent increase for the second farm. Hence, the scaling of the B matrix ensures the same marginal cost increases in both farms for the same percentage increase in crop acreage. Using this scaling mechanism makes it possible to take into account this difference in the calculation of marginal costs depending on the differences in crop acreage for different farms.

The general formulation of the corresponding ME problem is as follows:

$$\max H(pd, pb) = - \sum_f \sum_k \sum_i pd_{fki} \ln pd_{fki} - \sum_k \sum_i \sum_j pb_{kij} \ln pb_{kij}$$

Subject to:

Data-consistency constraints

$$\lambda_{fi} + c_{fi} = d_{fi} + \sum_j s_{fii} s_{fij} b_{ij} x_i^0 \quad \forall f, i, j, x^0 > 0$$

$$d_{fi} = \sum_k pd_{fki} z_{fki} \quad \forall f, i$$

$$b_{ij} = \sum_k pb_{kij} z_{kij} \quad \forall i, j$$

Adding-up or normalization constraints

$$\sum_k pb_{kij} = 1 \quad \forall i, j$$

$$\sum_k pd_{fki} = 1 \quad \forall f, i$$

Curvature restrictions

$$b_{ij} = b_{ji} \quad \forall i, j$$

$$l_{ii} = \sqrt{b_{ii} - \sum_b l_{ib}^2} \quad \forall i$$

$$l_{ij} = \frac{b_{ij} - \sum_b l_{ib}l_{jb}}{l_{ii}} \quad \forall i, j$$

Non-negativity conditions

$$l_{ii} \geq 0; \quad pb_{kij} \geq 0; \quad pd_{fki} \geq 0$$

where i and j are index crop activities, d_f is a $(n \times 1)$ vector of the linear part of the activities' implicit cost function in farm f , Q_f represents a $(n \times n)$ matrix of the quadratic part of the activities' implicit cost function in farm f , S_f constitutes the $(n \times n)$ diagonal scaling matrices for each farm f , and finally B is a $(n \times n)$ parameter matrix related to Q_f . zd and zb are the support points for vector d and the matrix B , respectively. To define the number of support points, their bounds and their spacing, we have adopted the following assumptions:

For the B matrix, 5 support points (i.e., $K = 5$) are chosen and their values are suggested to be defined as follows:

$$zb_{ij} = zbs_{ij} \frac{arev_{ij}}{\epsilon_{ij}}$$

Where

$$zbs_{ij} = \begin{cases} [0.01, 0.3, 0.9, 1.25, 1.5] & \forall i = j \\ [-2, -0.66, 0, +0.66, +2] & \forall i \neq j \end{cases}$$

$$arev_{ij} = \frac{1}{2} (\overline{REV}_i + \overline{REV}_j)$$

$$\overline{REV}_i = \overline{p_i y_i}$$

where ϵ is the regional supply elasticity estimated by Jansson and Heckelei (2011), $arev$ is the regional average gross revenue of crop i and j , \overline{p} , \overline{y} and \overline{REV} are the land weighted average of price, yield and gross revenue for crop i across farms within each region.

For the linear terms d , 5 support points are also chosen, centered around the observed costs and ranged between ± 15 times the dual value plus the slope term:

$$zd_{fi} = c_{fi} + \{-15, -7.5, 0, +7.5, +15\} (\lambda_{fi} + rev_i / \epsilon_{ii})$$

The last three equations are known as curvature restrictions and they result from a classic Cholesky decomposition of the form $B = L.L'$. They are included in order to guarantee that a positive (semi) definite matrix B , and consequently positive (semi) definite matrices Q , will be recovered. A violated curvature property might result in a specification of the objective function that does not calibrate to the base year, since in this case only first order but not second order conditions for a maximum are satisfied at the observed activity levels (Heckeley and Britz, 2000).

Table A1. Price and yield changes between base year (2006) and baseline (2020)

| | Price change *(%) | Average national yield change **(%) |
|---------------|-------------------|-------------------------------------|
| Soft wheat | 17.41 | 11.50 |
| Durum wheat | 36.25 | 9.34 |
| Triticale | 24.53 | 9.36 |
| Barley | 16.79 | 8.57 |
| Oats | 16.09 | 10.46 |
| Corn | 4.04 | 7.23 |
| Other cereals | 14.58 | 11.98 |
| Rapeseed | 22.73 | 26.22 |
| Sunflower | 31.08 | 13.64 |
| Soya | 39.04 | 4.81 |
| Pulses | 24.02 | 17.27 |
| Potatoes | -19.92 | 16.13 |
| Sugar Beet | -3.70 | 7.92 |
| Flax and hemp | -9.01 | 11.56 |
| Corn fodder | 6.63 | 11.95 |

Source: * EUROSTAT 2006-2009 average; ** CAPRI trend module

Additional references

Jansson T., Heckeley T. (2011) Estimating a primal model of regional crop supply in the European Union, *Journal of Agricultural Economics* 62(1), 137-152.

APPENDIX B:

Supplementary Information on MIRAGE-BioF Simulations

The standard MIRAGE model is fully documented in Decreux and Valin (2007). All the specification changes and modular development of the MIRAGE-BioF version are documented in Bouët *et al.* (2010) and Laborde and Valin (2012). We provide here a quick overview of MIRAGE main features based on these works. For more details the reader is invited to consult the original documents.

General features

The core structure of the MIRAGE model follows that of standard multi-country, multi-sector CGEs. Each country produces a certain quantity of goods through a nested production functions system where intermediate inputs and value added are aggregated through Leontieff technology, each of them being a Constant Elasticity of Substitution composite of different aggregates of inputs and factors, respectively. Goods are consumed by final consumers (public and private agent) and firms or are exported to foreign markets. The final consumption is represented through a Linear Expenditure System-Constant Elasticity of Substitution functional form. Imported goods are differentiated from domestic goods following the Armington assumption, which allows us to distinguish different levels of market integration. Real exchange rates between regions are endogenously adjusted to maintain current account as a share of the world gross domestic product. The model can be run in a static or a recursively dynamic setting, depending on the scope of the study.

Specificities of MIRAGE-BioF version

In order to properly address biofuel policy challenges, special attention has been paid in the BioF version to the representation of agricultural supply function and land substitution and expansion. We implemented a more precise disaggregation of factors, isolating a bundle of land and chemical fertiliser in the tree structures of factors to better control for yield response to shock in fertiliser prices and to increase in demand. This allows for precise tracking of the effect of fertiliser input, other factor inputs, and land expansion. We also used a nested Constant Elasticity of Transformation (CET) design to replicate substitution between cereals and oilseeds, as well as (to a lesser extent) other agricultural use.

Beside these innovations, the model includes a detailed description of the insertion of biofuel in the consumption chain, a modelling of binding incorporation mandates, and a representation of co-products production. Multi-level CES nesting structures for input, specific to many sectors, were used to represent various degrees of substitution across intermediates. More information on this parameterization can be found in Bouët *et al.* (2010), or obtained from the authors on request.

Our initial source of data has been the latest available Global Trade Analysis Project (GTAP) database, version 7, which describes global economic activity for the 2004 reference year in an aggregation of 113 regions and 57 sectors (Narayanan and Walmsley 2008). Several GTAP sectors were disaggregated, starting with the oilseed production and processing sectors. Twenty-three new sectors in total were carved out of the GTAP sector aggregates: the liquid biofuels sectors (an ethanol sector with four feedstock specific sectors and a biodiesel sector), major feedstock sectors (maize, rapeseed, soybeans, sunflower, palm fruit, and the related oils), co- and by-products of distilling and crushing activities, the fertiliser sector and the transport fuel sector (see table B.1 and table B.2 for sectoral and regional aggregation in the model). Armington elasticities were adapted for the new sector created (see table B.3).

Modification provided for the present article

The version used for the present assessment is based on the same model as in Laborde and Valin (2012). In order to better harmonize the behaviour of MIRAGE to ASMMA supply response, the model was recalibrated for this article in order to take advantage of ASMMA farm level information. This was done in two steps, first, we decided to add an additional level in the nesting to increase substitution between rapeseed, sunflower and wheat and better represent the flexibility in wheat rotation. Maize and sugar were

maintained at an intermediate level, whereas other crops were kept as less substitutable. The overall consistency of response of the two models could then be cross-checked through the relative change in production associated to the different shocks (see table B.4). The own and cross price elasticity matrix obtained from this calibration is displayed in table B.5.

Although the scenarii modelled are the same, the results we provide here are different from the one produced in Laborde and Valin (2012). This is mainly the effect of the recalibration, which leads to different allocations across feedstock shares within ethanol and biodiesel targets in the model. Additionally, the baselines used in the two papers are different. EU initial incorporation level is different because the base year for the present paper is 2006, which means the shock is 35% larger. Biofuel targets in other countries are only considered for the US and Brazil in the present setting, to better reproduce elasticities in the static design. This therefore impacts accordingly production in each of the feedstock sectors for the EU. The overall impact however remains the same, as it can be seen through variation in world price levels.

Additional references

- Decreux Y. & Valin H. (2007) MIRAGE, *Updated version of the model for trade policy analysis focus on agriculture and dynamics* (Working Papers 2007-15). CEPII research center. <http://www.cepii.fr/anglaisgraph/workpap/summaries/2007/wp07-15.htm>.
- Hertel T., Hummels D., Ivanic M., Keeney R. (2007) How confident can we be of CGE-based assessments of free trade agreements? *Economic Modelling* 24(4), 611-635.
- Narayanan B.G. & Walmsley T.L. (2008) Global Trade, Assistance, and Production: The GTAP 7 Data Base. Center for Global Trade Analysis, Purdue University.

Table B1. List of the 55 sectors in the MIRAGE-BioF model

| # | Sector | Description | # | Sector | Description |
|----|-----------|---------------------|----|--------------|-------------------------|
| 1 | Rice | Rice | 29 | Forestry | Forestry |
| 2 | Wheat | Wheat | 30 | Fishing | Fishing |
| 3 | Maize | Maize | 31 | Coal | Coal |
| 4 | PalmFruit | Palm Fruit | 32 | Oil | Oil |
| 5 | Rapeseed | Rapeseed | 33 | Gas | Gas |
| 6 | Soybeans | Soybeans | 34 | OthMin | Other minerals |
| 7 | Sunflower | Sunflower | 35 | Ethanol | Ethanol - Main sector |
| 8 | OthOilSds | Other oilseeds | 36 | EthanolCane | Sugar Cane Fermentation |
| 9 | VegFruits | Vegetable & Fruits | 37 | EthanolBeet | Sugar Beet Fermentation |
| 10 | OthCrop | Other crops | 38 | EthanolMaize | Maize Fermentation |
| 11 | Sugar_cb | Sugar beet and cane | 39 | EthanolWheat | Wheat Fermentation |
| 12 | Cattle | Cattle | 40 | DDGSCane | Sugar Cane Bagasse |

Table B1. List of the 55 sectors in the MIRAGE-BioF model (*continued*)

| # | Sector | Description | # | Sector | Description |
|----|-----------|---------------------------------------|----|--------------|---------------------------------|
| 13 | OthAnim | Other animals (inc. hogs and poultry) | 41 | DDGSBeet | Sugar Beet Pulp |
| 14 | CrushPalm | Palm Fruit processing | 42 | DDGSMaize | Maize DDGS |
| 15 | CrushRape | Rapeseed crushing | 43 | DDGSWheat | Wheat DDGS |
| 16 | CrushSoyb | Soybean crushing | 44 | Biodiesel | Biodiesel transformation |
| 17 | CrushSunf | Sunflower crushing | 45 | Manuf | Other Manufacturing activities |
| 18 | OilPalm | Palm Oil | 46 | WoodPaper | Wood and Paper |
| 19 | OilRape | Rapeseed Oil | 47 | Fuel | Fuel |
| 20 | OilSoyb | Soy Oil | 48 | PetrNoFuel | Petroleum products, except fuel |
| 21 | OilSunf | Sunflower Oil | 49 | Fertiliz | Fertilisers |
| 22 | MealPalm | Palm Fruit Fiber | 50 | ElecGas | Electricity and Gas |
| 23 | MealRape | Rape Meal | 51 | Construction | Construction |
| 24 | MealSoyb | Soybean Meal | 52 | PrivServ | Private services |
| 25 | MealSunf | Sunflower Meal | 53 | RoadTrans | Road Transportation |
| 26 | OthFood | Other Food sectors | 54 | AirSeaTran | Air & Sea transportation |
| 27 | MeatDairy | Meat and Dairy products | 55 | PubServ | Public services |
| 28 | Sugar | Sugar | | | |

Table B2. List of the 14 regions represented in the MIRAGE-BioF model

| # | Region | Description | # | Region | Description |
|---|-----------|-----------------------------------|----|-----------|--|
| 1 | Argentina | Argentina | 8 | EU27 | European Union (27 members) |
| 2 | Asia | Rest of South and South-East Asia | 9 | IndoMalay | Indonesia and Malaysia |
| 3 | Brazil | Brazil | 10 | JPNKOR | Japan and Republic of Korea |
| 4 | CAMCarib | Central America and Caribbean | 11 | LAC | Other Latin America countries |
| 5 | Canada | Canada | 12 | Oceania | Australia, New-Zealand and Pacific Islands |
| 6 | China | China | 13 | SSA | Sub Saharan Africa |
| 7 | CISRoEur | CIS countries and Rest of Europe | 14 | USA | United States of America |

Table B3. Values of Armington domestic-to-import elasticities used in MIRAGE-BioF for bioenergy related sectors

| Sector | Armington Elasticity | Sector | Armington Elasticity |
|---------------------------|----------------------|----------------|----------------------|
| Wheat | 4.5 | Biodiesel | 5.2 |
| Maize | 4.5 | Ethanol | 5.2 |
| Sugar beet/cane | 2.7 | Oil Palm | 6.6 |
| Soybeans | 4.9 | Oil Rapeseed | 6.6 |
| Sunflower | 4.5 | Oil Soybeans | 6.6 |
| Rapeseed | 4.9 | Oil Sunflower | 6.6 |
| Palm Fruit | 4.9 | DDGS Wheat | 10 |
| Rice | 3 | DDGS Maize | 10 |
| Other crops | 2.9 | Pulp Beet | 10 |
| Other oilseeds | 2.5 | Coproduct Cane | 10 |
| Veg fruits | 1.9 | Meal Palm | 10 |
| Cattle raw products | 3 | Meal Rape | 10 |
| Other animal raw products | 1.3 | Meal Soybeans | 10 |
| Meat & Dairy | 4 | Meal Sunflower | 10 |
| Other food | 2 | | |
| Sugar refined | 2.7 | | |

Note: All import elasticities are sourced from the Hertel *et al.* (2007), except for new products, whose elasticities are set two times larger than those of their aggregates to reflect the fact that products are more homogenous. We then follow the practice from this same paper which assumes a factor two between domestic-to-import elasticity and import substitution elasticity. Completely new products such as oilseed cakes and ethanol by products were arbitrarily given a value of 10 to represent their high homogeneity. Taking higher values of Armington elasticities for homogenous products was tested but did not led to significant decrease of EU price response, because world prices were already responsive in the initial scenarii.

Table B4. Increase in production of main commodities in MIRAGE-BioF and ASMMA

| | NAP | | BIOD | | ETHA | |
|------------|--------------|--------|--------------|--------|--------------|--------|
| | MIRAGE ASMMA | | MIRAGE ASMMA | | MIRAGE ASMMA | |
| | EU | France | EU | France | EU | France |
| Wheat | -4% | -7% | -6% | -14% | 4% | 5% |
| Maize | -4% | 1% | -8% | -2% | 2% | 9% |
| Sugar beet | 14% | 16% | -2% | -1% | 27% | 40% |
| Soybeans | -2% | -3% | 1% | 9% | -10% | -15% |
| Sunflower | 20% | 17% | 39% | 37% | -6% | -5% |
| Rapeseed | 67% | 57% | 90% | 87% | -3% | -3% |

Source: MIRAGE-BioF & ASMMA results

Table B5. Matrix of Supply Own and Cross price elasticities in MIRAGE-BioF at calibration in 2006

| | Wheat | Maize | Sugar_cb | Soybeans | Sunflower | Rapeseed | OthCrop | VegFruits |
|-----------|-------|-------|----------|----------|-----------|----------|---------|-----------|
| Wheat | 0.75 | -0.21 | -0.10 | -0.01 | -0.10 | -0.18 | 0.03 | 0.04 |
| Maize | -0.62 | 1.09 | -0.10 | -0.01 | -0.05 | -0.11 | 0.03 | 0.04 |
| Sugar_cb | -0.45 | -0.15 | 2.28 | -0.01 | -0.03 | -0.08 | 0.02 | 0.03 |
| Soybeans | -0.61 | -0.23 | -0.11 | 1.22 | -0.04 | -0.10 | 0.03 | 0.04 |
| Sunflower | -1.00 | -0.20 | -0.09 | -0.01 | 1.75 | -0.15 | 0.03 | 0.03 |
| Rapeseed | -0.81 | -0.16 | -0.08 | -0.01 | -0.07 | 2.16 | 0.02 | 0.03 |
| OthCrop | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.14 | 0.02 |
| VegFruits | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 1.16 |

Note: The calibration of MIRAGE-BioF was adjusted to be as much as possible close to ASMMA elasticities after price and yield adjustments. Therefore, values are slightly shifted from their level in 2006 presented in table 2 of the article.