Farm-level economic impacts of EU-CAP greening measures

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Abstract

This paper presents the first EU-wide individual farm-level model (IFM-CAP) intending to assess the impacts of CAP towards 2020 on farm economic and environmental performances across Europe. IFM-CAP is a static positive programming model applied to each EU-FADN individual farm -around 60500 farms- to guarantee the highest representativeness of the EU agricultural sector and to capture the full heterogeneity across EU farms in terms of policy representation and impacts. The model is used to assess the effects of the crop diversification measure, given that it is one of the most challenging aspects of the EU greening policy in terms of modelling and because of the farm-specificity of its implementation and impact. Results show that most non-compliant farms (80 %) chose to reduce their level of non-compliance following the introduction of the diversification measure owing to the sizable subsidy reduction imposed in case of non-compliance. However, the overall impact on farm income is rather limited: farm income decreases by less than 1 % at EU level, and only 5 % of the farm population will be negatively affected. Nevertheless, for a small number of farms, the income effect could be more substantial (more than –10 %).

Keywords: Common Agricultural Policy, Greening, Crop Diversification, Farm-level Model, Positive Programming Model, EU

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[1] The authors are solely responsible for the content of the paper. The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

1. Introduction

Over the last two decades, the Common Agricultural Policy (CAP) has undergone a gradual change from market intervention instruments (e.g. price support) to less distortive farm specific measures attempting to enhance the environmental performance of the EU agricultural sector. This became evident with the introduction of farm specific payments within the Single Payment Scheme (SPS) in 2005 and the 'greening' measures in the 2013 CAP reform. The CAP greening includes three measures that are obligatory for farmers who wish to receive the full direct payment: crop diversification, the maintenance of permanent pasture, and the respect of ecological focus areas (European Parliament and Council, 2013).

The greening measures target land allocation at farm level with the aim to support agricultural practices beneficial to the climate and the environment. The eligibility and uptake of these measures largely depend on farm-specific characteristics (size, cropping pattern, location etc.), posing challenges for policy evaluation and raising the need for new modelling tools. In fact, most of the currently applied models at EU-wide scale are aggregate models (regions, countries, groups of countries) and are not fully able to model policies targeted at farm level without imposing strong behavioral assumptions (Lansink and Peerlings, 1996; Gocht and Britz, 2011; Cantelaube et al., 2012). Farm-specific policies can only be handled by models that are operating at the level of individual farms and that are able to account for farm heterogeneity in terms of policy representation and impacts. The more local and farm-specific the interventions are, the more the modelling at the individual farm-level becomes important (Buysse *et al*., 2007).

There are a growing number of studies attempting to develop farm-level models for policy impact analysis. This growing interest can be attributed to the increasing demand for tools for micro-level policy analysis, in addition to the better understanding of farm-level decision making. The emphasis in farm-level modelling has generally been focused on improving the modelling of farm behavior and the implementation of agricultural support programs (Weersink et al., 2002; Louhichi et al., 2013). Although several modelling approaches have been used[2], mathematical programming is the most frequently used method

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[2] Five categories of models are often used in empirical applications: accounting (Swinton and Lowenberg-DeBoer, 1998; Godwin et al., 2003; Vorotnikova et al., 2014), simulation (Richardson and Nixon, 1986; Lehmann and Finger, 2014; Nendel et al., 2014), agent-based (Happe, 2004; Kellermann et al., 2008; Schouten et al., 2013; Mouysset, 2014), econometric (Boots et al. 1997; Ball et al., 1997; Sckokai and Moro, 2006; Petrick and Zier 2012; Bartolini and Viaggi, 2013; Yang et al., 2014) and mathematical programming (Hazell and Norton, 1986; Buysse et al., 2007; Janssen and Van Ittersum, 2007; Hanley et al. 2012; Manos et al., 2013) models. For a review of farm-level modelling approaches see Weersink et al., (2002), Janssen and Van Ittersum (2007) and Louhichi et al. (2013).

for modelling policies at the farm level. Most of these farm-level models are based either on individual (real) farms (e.g. Buysse et al., 2007) or on representative (average) farms (e.g. Gocht and Britz, 2011; Louhichi et al., 2010). Although representative farm models can assess to some extent the farm-specific policies (such as CAP greening), they are subject to some limitations. They cannot model policies for which eligibility depends on individual farm characteristics and location, and they are subject to aggregation bias. For example, in the case of the crop diversification measure, certain farms have to produce a minimum of two crops, with the main crop representing maximum 75% of arable area. By construction the cropping pattern is much more diversified for a representative farm than it is for the actual individual farms on the basis of which the representative farm was created. As a result, the crop diversification requirement will usually be respected (not binding) at the level of the representative farm, although in reality the restriction is binding at the level of individual farms.

Another drawback of existing farm models is that most of them are developed for a specific purpose and/or location and, consequently, are not easily adapted and reused for other applications and contexts (Louhichi et al., 2010). Out of a large number of EU based representative farm models, only two have full EU coverage: CAPRI-FT (Gocht and Britz, 2011) and AROPAj (De Cara and Jayet, 2011). The other models cover either a specific MS (FAMOS (Schmid, 2004)) or a selected set of MSs/regions (FARMIS (Offermann et al., 2005), FSSIM (Louhichi et al., 2010), AGRIPOLIS (Kellermann et al., 2008) and SAPIM (OECD, 2010)).

With respect to modelling the impact of CAP greening measures, empirical evidence of their environmental and socio-economic impacts are very limited, especially at EU level. While a number of studies have opened the debate on the effectiveness of greening measures (Matthews, 2012; Singh et al., 2014; Westhoek et al., 2013), the few available farm-level models contribute only partially to the ongoing debate because they are applied only to selected MSs/regions and/or for specific agricultural sectors. For example, Solazzo et al. (2014) evaluate the effect of greening on Italian farms in the tomato sector. Mahy et al. (2014), Heinrich (2012), Czekaj et al. (2013) and Brown and Jones (2013) provide case-studies on the impact of the crop diversification measure for respectively Flanders, Germany, Poland and the United Kingdom, respectively. Other papers deal with measures such as decoupled payments (Fragoso et al., 2011; Moro and Sckokai, 2013), the young farmers scheme (Bournaris et al., 2014) or the impact of CAP on natural resource management

(Gibbons et al., 2005; Cortignani and Severini, 2009). None of these models allows for a comprehensive EU-wide analysis of CAP greening measures at farm level.

This paper attempts to contribute to the literature by extending the current modelling approaches in several respects. We develop an EU-wide individual farm-level model, IFM-CAP (Individual Farm Model for Common Agricultural Policy Analysis), which (i) allow a more flexible assessment of a wide range of farm-specific policies; (ii) be applied on a EU-wide scale; (iii) reflect the full heterogeneity[3] of EU farms in terms of policy representation and impacts; (iv) cover all main agricultural production activities in the EU; (v) permit a detailed analysis of different farming systems; and (vi) estimate the distributional impacts of policies across the farm population. The model is developed based on the FADN (Farm Accountancy Data Network) micro data. Model capability is illustrated in this paper with an analysis of the impacts of the crop diversification measure for the EU-27. The paper is structured as follows: Section 2 describes the IFM-CAP model in more detail. Section 3 presents the baseline and the crop diversification scenarios simulated with IFM-CAP. In section 4, the results of the model application are presented. Finally, Section 5 draws the main conclusions and policy implications.

2. IFM-CAP model

2.1. Main specification and mathematical structure

The IFM-CAP model[4] is a static positive mathematical programming model, which builds on the EU-FADN (Farm Accountancy Data Network) data, and is complemented by other relevant EU-wide data sources such as EUROSTAT, FSS, CAPRI database, etc. In order to reach the best representativeness and to capture the full heterogeneity of the EU farm population, the whole FADN farm constant sample between 2007 and 2009 (around 60,500 farms) is individually modelled.

IFM-CAP relies on profit[5] maximizing behavior and attempts to find the optimal land allocation among production activities, taking into account resource (arable and grass land

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[3] The Farm Accountancy Data Network (FADN) survey (therefore the IFM-CAP model) does not cover all the agricultural holdings in the EU but only those that, because of their size, could be considered commercial (the specific threshold varies by each MS).

[4] The IFM-CAP model starts with a simplified prototype, to which improvements will be added in different steps. After refinement of this prototype, farm and market interactions will be added; improvements will be made regarding the modelling of farm behavior (e.g. modelling of risk and of labor and capital allocations). Finally, additional issues such as the modelling of environmental issues and second pillar policies will be considered. This paper only presents the methodology and results of the IFM-CAP prototype.

[5] An improved model version including risk and uncertainty is under development.

and feed requirements) and policy constraints such as sales, quotas and set-aside obligations. Land constraints are used to match the available land that can be used in a production operation and the possible use by the different agricultural activities. Constraints relating feed availability and feed requirements of animal activities are used to ensure that the total energy, protein and fiber requirements are met by farm-grown or/and purchased feed.

Farm profit is defined as the sum of gross margins minus a non-linear (quadratic) activity-specific function. The gross margin is the total revenue including sales from agricultural products and compensation payments (coupled and decoupled[6] payments) minus the accounting variable costs of production activities. The accounting costs include costs of seeds, fertilizers, crop protection, feeding and other specific costs. The quadratic activity-specific function is a behavioral function introduced to calibrate the farm model to an observed base year situation,[7] as is usually done in positive programming models. This function intends to capture the effects of factors that are not explicitly included in the model such as price expectation, risk aversion, labor requirement and capital constraints (Heckelei, 2002).

The FADN database provides only total accounting costs per variable input category (e.g. seeds, fertiliser, pesticide, feed, etc.), without indicating the unit input costs of each (crop and animal) output that is needed to capture policy impacts and to represent technologies in an explicit way. To overcome this lack of information, we opt for a Bayesian econometric estimation of unit input costs based on the farm-level input costs per category reported in FADN, assuming a Leontief production function (i.e. input use increases linearly with production activity levels).

The removal of the accounting variable costs from the quadratic behavioral function by introducing a Leontief production function for variable input costs, was motivated by the fact that the primal technology representation through the Leontief production function (i) provides an explicit link between production activities and the total physical input use, (ii) eases the linkage to environmental indicator calculation, and (iii) allows the simulation of policy measures linked to specific farm management. According to Heckelei and Wolff (2003), the main disadvantage of this approach is the lack of rationalization, as intermediate input uses are assumed to be independent of the unknown marginal costs captured by the quadratic behavioral function.

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[6] All farm area is assumed to be eligible.

[7] In principle, any non-linear convex function with the required properties can reproduce the base year solution. For simplicity, and in the absence of any strong arguments for other types of functions, a quadratic function is usually employed.

A single model template was applied for all modelled FADN farms in order to ensure a uniform handling of all the individual farm models and their results. That is to say, all the individual farm models have an identical structure (i.e. they have the same equations and variables but the model parameters are farm specific), and no cross-farm constraints or relationships are assumed in the current version of the model, except in the calibration phase, in which all individual farms in each region are pooled together to estimate the behavioral function parameters. To render equations easily understandable, vectors are designated by bold lowercase letters, typeset matrices by uppercase letters and scalars by italic letters. For simplicity, indices for farms are omitted.

The general mathematical formulation for IFM-CAP is as follows:

$$\underset{x \geq 0}{\mathrm{Max}}\ \boldsymbol{\pi} = \mathbf{p}'(\mathbf{y} \circ \mathbf{x}) + \mathbf{s}'\mathrm{x} - \mathbf{C}\mathrm{x} - \mathbf{d}'\mathrm{x} - 0.5\mathrm{x}'\mathbf{Q}\mathrm{x} \qquad (1)^{8}$$

S.t.

$$\mathbf{A}\mathrm{x} \leq \mathbf{b} \quad [\boldsymbol{\rho}] \qquad (2)$$

where $\boldsymbol{\pi}$ is the objective function value, **x** is the (N×1) vector of non-negative activity levels (i.e. hectares) for each agricultural activity *i*, **p** is the (N×1) vector of product prices (including feed and young animal prices), **y** is the (N×1) vector of yields, **s** is the (N×1) vector of production subsidies (coupled and decoupled payments), **C** is the (N×K) matrix of accounting variable cost for K input categories (seed, fertilizer, plant protection, other specific costs and feeding costs), **d** is the (N×1) vector of the linear part of the behavioral activity function and **Q** is the (N×N) symmetric, positive (semi-) definite matrix of the quadratic part of the behavioral activity function. **A** is the (N×M) matrix of coefficients for M resource and policy constraints (land, obligation set-aside, quotas and animal feeding), **b** is the (M×1) vector of available resources (arable and grassland) and upper bounds to the policy constraints, and **ρ** is the vector of their corresponding shadow prices. Product prices, yields, subsidies, set-aside rate, quotas (sugar beet and milk) and land availability are given (i.e. derived from FADN or estimated in the data preparation step) and are assumed to be known with certainty. The parameters **C**, **d** and **Q** are estimated using Highest Posterior Density estimation (Heckelei et al., 2008).[9]

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[8] The symbol $\circ$ indicates the Hadamard product.

[9] A detailed mathematical description of the first version of IFM-CAP can be found in Louhichi et al. (2015).

2.2. Model calibration

Over the last decade, several PMP approaches have been developed to derive the parameters of the behavioral functions (**d** and **Q**) and to accurately calibrate programming models[10]. However, as the number of observations is usually not sufficient 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. In order to reduce the arbitrary parameter specifications and estimate more reliable behavioral functions covering all the parameters, the more recent applied programming models have either (i) used exogenous information on supply elasticities (Britz and Witzke, 2012; Mérel and Bucaram, 2010) and/or on shadow prices of resources (Henry de Frahan et al., 2007) or (ii) estimated programming model parameters in an econometric sense using either cross-sectional data (Heckelei and Wolff, 2003; Buysse et al., 2007; Arfini et al., 2008) or time series data (Jansson and Heckelei, 2011).

In this paper, we use both multiple observations (cross-sectional data) and prior information on supply elasticities ($\bar{\boldsymbol{\varepsilon}}$) and on dual values of constraints ($\bar{\boldsymbol{\rho}}$) to calibrate the model. Supply elasticities are taken from available econometric studies at NUTS 2 level (Jansson and Heckelei 2011). Prior information on dual values is derived from FADN.

We calibrate the model for the base year 2007-2009. Thus, the calibration problem in this case consists of selecting the set of parameters (**d**, **Q**, ρ) so that the optimization model (1) and (2) replicates exactly the observed farm production structure ($\mathbf{x^0}$) in the base-year and reproduces, as closely as possible, the given farm shadow values ($\bar{\boldsymbol{\rho}}$) and the aggregated supply responses at the NUTS2 level ($\bar{\boldsymbol{\varepsilon}}$).

To perform the estimation we derive the first-order conditions (FOCs) of the optimization model (1) and (2), which is assumed to approximate farmer behavior (Heckelei, 2002) and, then, we apply the Highest Posterior Density (HPD) method to estimate the unknown parameters (**d, Q,** ρ).

The use of the HPD approach for parameter estimation is carried out under the following assumptions:

- The HPD model minimizes, in each NUTS 2 region, the weighted sum of normalized squared deviations of estimated regional own-price (diagonal) supply elasticities and of farm dual values of constraints from the prior subject to a set of data consistency

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[10] For a review on PMP models see Henry de Frahan et al. (2007), Mérel and Bucaram (2010), Paris (2011), Mérel et al. (2011) and .Heckelei et al. (2012).

(FOC) constraints. The normalized squared deviations of farm dual values are weighted with the proportion of the farm in the NUTS 2 region to obtain a weighted average normalized squared deviation at the NUTS 2 level. The normalized squared deviations of regional supply elasticities are normalized and weighted with the proportion of observed activity level in total regional land to allow activities with a high proportion of the area to dominate.

- Prior information on dual values of land (arable and grassland) are set to land rental prices, those of sugar beet quota restriction are set to the gross margin differential between sugar beet and the next best alternative crop, and those of set-aside obligations are set to arable land rental prices (i.e. knowing that the only constraints in the base year for crops are land, sugar beet quota and obligatory set-aside). Large standard deviations for prior information are used to allow the data to dominate.
- The calibration to the exogenous supply elasticities is performed in a non-myopic way, i.e. we take into account the effects of changing dual values on the simulation response (Heckelei, 2002; Mérel and Bucaram, 2010).
- The estimation procedure is applied only to arable crops, keeping livestock and permanent grassland fixed during this step. Moreover, to simplify the already complex estimation problem, the inequality on set-aside and quota restrictions is replaced with equality (i.e. both restrictions are assumed to be binding).
- The estimated B matrix related to the Q matrix (see further) is common across farms belonging to the same region and the same farm type (grouped based on production specialization). However, the Q matrix is crop and farm specific owing to the farm-specific scaling factors, as suggested in Heckelei and Britz (2000), i.e. we exploit information contained in the cross-sectional sample to specify (farm-specific) quadratic activity functions with cross-effects for crop activities.
- B matrix estimation relies only on observed activities on each farm, meaning that the well-known self-selection problem is not explicitly handled in this estimation. To cope with this problem, we adopted the following ad hoc modelling decisions in the simulation phase: in each NUTS 2 region, the gross margin of the non-observed activities is equal to the farm-type average gross margin, the activity's quadratic function parameter is equal to the activity's average quadratic function parameter within the farm type, and the linear term's quadratic function is derived from the difference between the gross margin and the dual values of constraints.

- The exchange of production factors and production rights between farms is not allowed (i.e. there are no land or quota markets).

The general formulation of the corresponding HPD problem is now straightforward[11]:

$$\mathbf{Min}\left[\boldsymbol{\psi}_{\mathbf{f}}\,'\frac{(\boldsymbol{\rho}_{\mathbf{f}}-\overline{\boldsymbol{\rho}}_{\mathbf{r}})^2}{(\boldsymbol{\sigma}_{\mathbf{r}}^{\boldsymbol{\rho}})^2}+\widehat{\mathbf{x}}_{\mathbf{r}}\,'\frac{(\boldsymbol{\varepsilon}_{\mathbf{r}}-\overline{\boldsymbol{\varepsilon}}_{\mathbf{r}})^2}{(\boldsymbol{\sigma}_{\mathbf{r}}^{\boldsymbol{\varepsilon}})^2}\right] \tag{3}$$

$$\mathbf{y'_f\,p_f + s_f - C_f - d_f - Q_f x_f^0 - A_f \boldsymbol{\rho}_f = 0} \tag{4}$$

$$\mathbf{b_f - A_f}\,\mathrm{x}_{\mathbf{f}}^{\mathbf{0}} = 0 \tag{5}$$

$$\boldsymbol{\varepsilon}_{\mathbf{f}} = \left[\mathbf{Q_f^{-1} - Q_f^{-1}A_f(A_f'Q_f^{-1}A_f)^{-1}A_f'Q_f^{-1}}\right]\frac{\mathbf{gm_f}}{\mathbf{x_f^0}} \tag{6}$$

$$\boldsymbol{\varepsilon}_{\mathbf{r}} = \frac{\sum_{\mathbf{f}}\boldsymbol{\varepsilon}_{\mathbf{f}}\mathbf{x_f^0 w_f}}{\sum_{\mathbf{f}}\mathbf{x_f^0 w_f}} \tag{7}$$

$$\mathbf{Q_f} = \boldsymbol{\delta}_{\mathbf{f}}\mathbf{B}\boldsymbol{\delta}'_{\mathbf{f}} \tag{8}$$

$$\mathbf{B = L'L} \tag{9}$$

where **f** indexes farm, **r** indexes NUTS2 region, **ψ** is the (F×1) vector of farm weight within the NUTS2 region ($\Psi_f = w_f \big/ \sum_f w_f$), **w**$\mathbf{w_f}$ is the (F×1) vector of farm weighting factor, $\mathbf{x^0}$ is the (N×1) vector of non-negative observed activity level (i.e. hectares) for each of **N** agricultural activities, $\hat{\mathbf{x}}_{\mathbf{r}}$ is the (N×1) vector of the *normalized* weight of observed activity level for each activity *i* in the NUTS2 region ($\hat{x}_{r,i} = N_r x_{r,i}^0 \big/ \sum_{i=1}^{N} x_{r,i}^0$), **p** is the (N×1) vector of product prices, **y** is the (N×1) vector of yields, **s** is the (N×1) vector of production subsidies (coupled and decoupled payments), **C** is the (N×K) matrix of unit input cost for **K** input categories estimated separately using the HPD approach, **d** is the (N×1) vector of the linear part of the behavioral activity function, **Q** is the (N×N) symmetric, positive (semi-)definite matrix of the quadratic part of the behavioral activity function, **A** is the (N×M) matrix of coefficients for M resource and policy constraints, **b** is the (M×1) vector of available resources and upper bounds to the policy constraints, and **ρ** is the vector of their corresponding shadow prices, $\bar{\boldsymbol{\varepsilon}}$ is the (N×N) matrix of exogenous supply elasticities at NUTS2 level (Jansson and Heckelei, 2011) and represents the center of the elasticity prior, **ε** is the (N×N) matrix of estimated

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[11] Indices *f* and *r* are introduced here to distinguish between variables defined at farm level and those at regional (NUTS2) level.

supply elasticities at farm and NUTS2 levels, **δ** is a scaling factor ($\delta_{f,i} = \sqrt{1 / x^0_{f,i}}$), **B** is a (N×N) parameter matrix related to the **Q** matrix (**B** is common across farms belonging to the same farm type (grouped based on production specialization)), $\frac{\mathbf{gm}}{\mathbf{x^0}}$ is the gross margin $(gm = py + s - C)$ divided by the observed activity level (x^0).

Prior information on dual values of constraints is assumed to be normally distributed with the means $(\bar{\boldsymbol{\rho}})$ and standard deviations $(\boldsymbol{\sigma}^{\boldsymbol{\rho}}_{\mathbf{r}})$ calculated at NUTS2 level using the farm weights. The standard deviation of NUTS2 elasticities $(\boldsymbol{\sigma}^{\boldsymbol{\varepsilon}}_{\mathbf{r}})$ is assumed to be 50% of the mean.

The constraints (4) and (5) represent the FOCs of the optimization model, (1) and (2), with equality constraints (i.e. data consistency constraints). Equations (6) and(7) compute supply elasticities at farm and NUTS2 levels. Equation (8) calculates the farm-specific Q matrix. Equation (9) is the Cholesky decomposition which ensures that the quadratic part of the activities' behavioral function is a symmetric, positive (semi-)definite matrix.

The estimated parameters (**d, Q, ρ**) in equations (4)-(9) guarantee the reproduction of the observed production structure when the model (1) and (2) is run for the base year.

2.3. Data requirements

As mentioned above, IFM-CAP is parameterized using FADN data for the three-year average around 2008 (2007, 2008 and 2009). The FADN data is supplemented by other datasets such as the CAPRI databank and Eurostat. Before being used, the FADN data are screened and adjusted to the IFM-CAP modelling framework. This includes the identification and correction of out-of-range values for key variables, handling missing values and addressing the issue of variables that are not available in FADN. Three types of data are required for running IFM-CAP: farm resource data, input-output data for production activities and calibration data.

(i) Farm resource data involve available farmland (i.e. total Utilized Agricultural Area, arable land and grassland), sugar beet quota rights and the minimum set-aside rate. These data are used for setting lower/upper bounds for resource and policy constraints in the model. Farmland is directly available in FADN. Sugar beet quotas are estimated using the national share of quota because for most of the Member States these data are not reported in the FADN database. The set-aside rate is set to the observed rate (i.e. the proportion of set-aside in the total area).[12] Data on labor and capital resources are not included, as they are not explicitly modelled but captured by the quadratic terms (i.e. PMP terms).

(ii) Input and output data for production activities consist of yields, product prices, production subsidies and accounting variable costs for all crop and animal activities on each farm. The data are used for the calculation of the gross margin per hectare or per head of each production activity to be embedded in the model objective function as well as for the definition of input coefficients for resource and policy constraints. The data on yields, prices and subsidies are derived from FADN. Data on accounting unit costs for crops (i.e. specific costs related to seeds, fertilizers, crop protection and other crop-specific costs) are estimated using a Bayesian approach with prior information on input-output coefficients from the DG-AGRI input allocation module. The feeding costs are also estimated using a Bayesian approach with prior information on animal feed requirements from CAPRI and data on farm-level feed costs, feed prices, feed nutrient contents and fodder yields from FADN, CAPRI and Eurostat, respectively.

(iii) Calibration data consist of activity levels (i.e. hectares or heads), rental prices, the gross margin differential between sugar beet and the next best alternative crop and supply elasticities at NUTS2 level. The observed activity level (x^0) is used to calibrate the model, assuming it is the optimal crop allocation in the base year. The land rental prices, the supply elasticities and the gross margin differential between sugar beet and the next best alternative crop are used as prior information in calibration.

The left-hand side of Figure 1 summarizes the data needs of IFM-CAP and their sources. As shown in this figure, some data are not used directly in the optimization process but only as prior to estimate certain input coefficients.

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[12] Note that the set-aside rate is not set to the policy rate because for some farms the observed rate is found to be lower than the policy rate, which can inhibit model calibration.

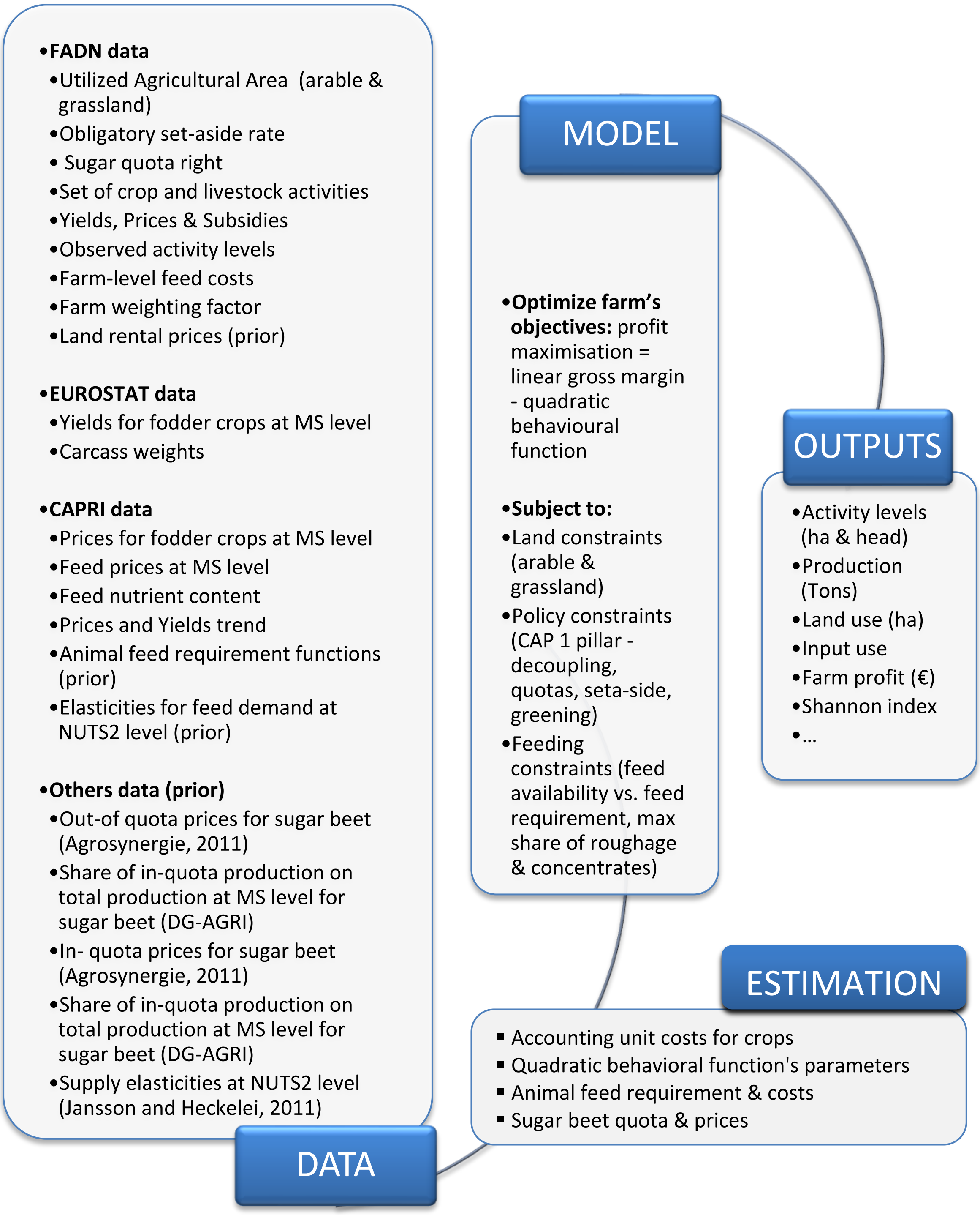

Figure 1. IFM-CAP model description

3. Baseline and the crop diversification scenario

3.1. Baseline

As IFM-CAP is a comparative static supply model that does not take into account the dynamics of market developments and market inter-linkages (price feedbacks), the baseline construction relies on an external baseline. More precisely, we use CAPRI projections[13] to construct the IFM-CAP baseline for the year 2020, taken as the time horizon for running simulations. One important feature of the CAPRI baseline is that it is developed in conjunction with the European Commission (EC) baseline. The EC constructs medium-term projections for the agricultural commodity markets on an annual basis. The projections present a consistent set of market and sectoral income prospects elaborated on the basis of specific policy and macroeconomic assumptions (Nii-Naate, 2011; Himics, et al., 2013).

To construct the IFM-CAP baseline, three assumptions are adopted: (i) a continuation of the CAP Health Check up to 2020; (ii) an assumed inflation rate of 1.9 % per year; and (iii) an adjustment of baseline prices and yields using growth rates from the CAPRI baseline. As the CAPRI growth rates of yields and prices are defined at NUTS2 level, we impose the same growth rate on all farms belonging to the same NUTS2 region. All the other parameters (e.g. farm resource endowments and farm weighting factors) are assumed to remain unchanged up to 2020.

The generated baseline scenario is used as a reference point for the comparison of the effects of the crop diversification scenario.

3.2. Crop diversification scenario

The 2013 CAP reform introduces explicit measures to remunerate the provision of public goods by farmers, the so called "greening payment" (European Parliament and Council, 2013). Under the CAP greening measures, 30% of direct payments is conditional on complying with three mandatory requirements: (i) crop diversification for arable crops; (ii) maintenance of permanent grassland; and (iii) allocation of 5% of land to “Ecological Focus Areas” (EFAs).

In this paper we focus on modelling the crop diversification measure, given that it is the most challenging aspect of the greening policy in terms of modelling and because its implementation and impact are farm specific. The implementation of the scenario in the model closely follows the adopted EU regulations (i.e. regulation No 1307/2013 and delegated regulation No 640/2014). The crop diversification requirement applies only to farms with an arable area greater than 10 hectares. Farms with more than 75 % of their total eligible land covered by grassland and farms with 75% of their arable area cultivated with

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[13] For more information, refer to Blanco-Fonseca (2010), Britz and Witzke (2012) and Himics et al. (2013) and (2014).

forage are not subject to the crop diversification measure[14]. Furthermore, there are stricter requirements for farms having more than 30 hectares of arable land (group 2) compared with farms with arable land between 10 and 30 hectares (group 1). The latter farms need to have at least two different crops and the main crop should not exceed 75 % of the arable land. The former farms are required to have at least three crops and the main crop should not cover more than 75 % of the arable land and the two main crops together should not cover more than 95 % of the arable land (Table 1).

Farms not complying with these requirements are subject to a reduction in direct payment (i.e. the greening payment) corresponding to the non-compliant area plus a penalty. The penalty depends on the proportion of non-compliant area but is applied at an increasing rate. For example, if the proportion of non-compliant area is lower than 3% of the total eligible area, then the penalty is zero. However, if this proportion is more than 50%, then the penalty corresponds to a reduction in the greening payment of one quarter. Hence the total eligible area minus the non-compliant area and minus the penalty represents the total area that can benefit from the greening payment (see Table 1).

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[14] Organic producers, and farmers in the "small farmers scheme" are exempted from the greening obligations. Also, MS can opt to define practices (certification or specific agri-environmental schemes) that yield a level of benefit for the climate and the environment that is equivalent to or higher than the three greening obligations. These exemptions are not implemented in the model.

Table 1: **Crop diversification measure as implemented in IFM-CAP**

	Exempt farms	**Farms group 1**	**Farms group 2**
Arable land (*AL*)	< 10 ha*	10 ha - 30 ha	≥ 30 ha
Min. number of cultivated crops	-	2	3
Max. proportion of main crop in *AL* (%)	-	75%	
Max. proportion of two main crops in *AL* (%)	-	-	95%
Non-compliant area (*W*)		$W = min(1,(X75/25\ \% + X95/5\ \%))*AL*0.50$	
Proportion of non-compliant area (sh)		$sh = W/(EL-W)$	
Penalty (*P*)	-	$sh \leq 3\% \Rightarrow P = 0$ $3\% < sh \leq 20\% \Rightarrow P = (2*W)/4$ $20\% > sh < 50\% \Rightarrow P = (EL-W)/4$ $sh > 50\% \Rightarrow P = EL/4$	
Area eligible for receiving the greening payment (*GP*)	-	$GP = EL - W - P$	

Notes: *X75*: percentage area of main crop going beyond the 75 % threshold; *X95*: percentage area of two main crops going beyond the 95 % threshold; *EL*: Eligible Land (Basic Payment Scheme/Single Area Payment Scheme).

*Excluded are also those farms where (i) fodder area + fallow area ≥ 75 % of *AL*, (ii) *AL* – (fodder + fallow) < 30 ha, (iii) grassland + other herbaceous fodder crops > 75 % UAA, or (iv) *AL* – other herbaceous crops < 30 ha.

In the event that the farmer is not-compliant for three years the calculation of the penalty (*P*) and non-compliant area (*W*) differs. However as IFM-CAP is not a dynamic model, this issue cannot be considered and thus the simulations may underestimate the penalties.

Source: Compiled based on the Regulation No 1307/2013 (EU, 2013) and the Delegated Regulations No 639/2014 and No 640/2014 (EU, 2014).

4. Results

In this section we report the simulation results for the crop diversification scenario for the EU-27. We focus the analysis on the income and land use effects of the crop diversification measure and provide results at MS and EU aggregate level, by farm specialization and farm size and for the full distribution of individual farms.

Out of the five million commercial farms represented in IFM-CAP for the EU-27[15], only 31 % are subject to the crop diversification measure (i.e. concerned farms); the remainders (69 %) are exempted from the measure. The latter include non-arable farms, farms with a small arable area (less than 10 ha) or farms with a large proportion of land planted with fodder crops. The MSs with the largest proportion of concerned farms include Denmark (90 %), Slovakia (88 %), Germany (73 %), Sweden (72 %), Finland (70 %), the Czech Republic (67 %), Belgium-Luxembourg (64 %) and France (60 %). These MSs have a farm structure dominated by large farms and/or by specialized farms and/or have a large arable sector. On

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[15] Note that we assume no structural change in the model, therefore the number of farms is fixed in the base year, the baseline and the diversification scenario.

the other hand, the smallest proportion of concerned farms is found in Malta (1 %), Ireland (7 %), Slovenia (10 %), Romania (12 %), Bulgaria (13 %), Cyprus (13 %), Portugal (13 %) and Greece (14 %). Many of these MSs have a high proportion of small commercial farms in the total commercial farm population, which are exempted from the diversification measure. The remaining MSs have a proportion of concerned farms between 20 % and 60 % (Table 2).

In the baseline scenario, the proportion of farms not complying with the diversification measure represents around 15 % of concerned farms in the EU-27. This proportion varies between 0 % in Malta and 51 % in Cyprus. The non-compliant farms in the baseline scenario represent a hypothetical situation in breach of the diversification requirement before the implementation of the measure. It corresponds to the minimum proportion of farms that would need to adjust their land allocation in order to comply with the diversification measure. Otherwise, these non-compliant farms would face a reduction in subsidy (i.e. lower greening payments) (Table 2).

Under the diversification scenario, the proportion of non-compliant farms in the EU-27 is around 10 %. In most MSs the proportion of non-compliant farms is lower (except for Slovakia, where it remains unchanged) than in the baseline (Table 2). Note that this proportion represents farms that do not fully comply with the diversification measure. This means that they may have partially adjusted the area to the requirements, but still a proportion of their area is non-compliant[16]. According to the results reported in Table 2, most of the non-compliant farms increased their compliance level in the diversification scenario relative to the baseline. Out of 10 % of non-compliant farms in the EU-27 in the diversification scenario, 8 % are more compliant than in the baseline. The rest (2 % of concerned farms) have the same non-compliance level in both scenarios. This implies that approximately 80 % of non-compliant farms reduce their non-compliance level in response to the introduction of diversification measures relative to the baseline, whereas 20 % do not change their non-compliance level at all.

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[16] For example, if the non-compliant area is less than 3 %, the administrative penalty (*P*) is not imposed, implying that some farms may choose this level of non-compliance**.**

Table 2. Farms affected by the crop diversification measure (% of farms)

MS	Exempt farms (% of total farms)	Concerned farms (% of total farms)	Baseline		Diversification		
			Compliant (% of concerned)	Non-compliant (% of concerned)	Compliant (% of concerned)	Non-compliant (% of concerned)	
						All	Farms that increased compliance level relative to baseline
BL	35.6	64.4	88.6	11.4	91.1	8.9	7.9
DK	9.8	90.1	85.6	14.4	90.2	9.8	8.2
DE	26.1	73.4	92.7	7.3	97.2	2.8	2.4
EL	86.2	13.8	74.7	25.3	79.9	20.1	13.5
ES	71.8	28.2	63.8	36.2	75.2	24.8	16.2
FR	39.8	60.2	93.1	6.9	96.3	3.7	3.5
IR	93.2	6.8	54.0	46.0	72.6	27.4	24.9
IT	79.4	20.6	79.5	20.5	88.0	12.0	9.4
NL	70.8	29.2	64.5	35.5	72.2	27.8	20.2
AT	51.1	48.9	95.3	4.7	98.2	1.8	1.8
PT	87.5	12.5	74.4	25.6	82.9	17.1	14.2
SE	27.8	72.2	90.7	9.3	95.9	4.1	3.5
FI	23.3	69.7	80.4	19.6	92.5	7.5	7.1
UK	55.8	44.1	84.7	15.3	92.2	7.8	6.2
CY	86.7	13.3	48.8	51.2	70.2	29.8	16.6
CZ	32.7	67.2	95.7	4.3	96.9	3.1	2.5
EE	46.7	53.3	92.9	7.1	96.9	3.1	3.1
HU	50.1	49.8	90.0	10.0	92.0	8.0	7.4
LT	38.9	61.1	96.5	3.5	98.6	1.4	1.2
LV	61.0	38.8	93.4	6.6	94.7	5.3	4.3
MT	99.0	1.0	100.0	0.0	100.0	0.0	0.0
PL	59.9	40.1	86.7	13.3	90.1	9.9	8.6
SI	90.3	9.7	96.0	4.0	98.2	1.8	1.8
SK	9.8	88.4	94.9	5.1	94.9	5.1	1.9
BG	87.4	12.6	75.1	24.9	82.6	17.4	4.6
RO	87.6	12.4	97.6	2.4	97.8	2.2	1.9
EU-27	**68.9**	**31.0**	**84.7**	**15.3**	**90.1**	**9.9**	**7.6**

Source: model results

Table 3 reports the income effects of the crop diversification scenario at MS level. The results show that the potential decrease in income caused by the implementation of the crop diversification measure is small. The overall income loss represents less than 1 % compared with the baseline. The largest decrease in income is observed in Finland, but its magnitude is still small (about 0.2 %). The results by farm production specialization and farm size aggregated over all MSs reveal more sizable income effects for certain farm specializations, but they are still below 1 % (Table 4, Table 5). However, at MS level the income change decreases up to 6.5 % for certain farm specializations and up to around 1.5 % for certain farm sizes (Table 4, Table 5).

The most affected are farms specializing in cereals, oilseeds and protein crops and in general field cropping. The decrease in income of these farm types varies across the MSs, but it reaches up to 6.5 % compared with baseline for certain MSs (Table 4). This is in line with expectations, given that the crop diversification measure targets arable farming. These farm types are followed by farms specialized in cattle rearing and fattening and sheep and goats. These farm types tend to have a less diversified production structure on their arable land, given that their main activity is not necessarily linked to arable cropping. They are more likely to breach the crop diversification requirement. For the remaining farm specializations the maximum decrease in income across the MSs is very small: less than –0.5 % compared with the baseline (Table 4).

By farm size, the most affected are farms in the middle class (between 8 and 16 European size units (ESUs)) followed by large ones. Small farms are marginally affected by the crop diversification measure (Table 5). This is in line with expectations, given that small farms (i.e. those with less than 10 ha of arable land) are exempted from the crop diversification measure and/or are subject to less strict diversification requirements (i.e. farms with arable land between 10 and 30 ha).

Table 3. Income effect of the crop diversification measure by MS (% change relative to baseline)

MS	Change relative to baseline (%)
BL	–0.001
DK	–0.001
DE	–0.002
EL	–0.007
ES	–0.006
FR	–0.001
IR	–0.013
IT	–0.004
NL	–0.002
AT	–0.002
PT	–0.005
SE	–0.004
FI	–0.216
UK	–0.003
CY	–0.012
CZ	0.000
EE	–0.003
HU	–0.002
LT	0.000
LV	–0.015
MT	0.000
PL	–0.002
SI	–0.002
SK	0.000
BG	–0.001
RO	–0.008
EU-27	**–0.003**

Source: model results

Table 4. Income effect of the crop diversification measure by farm specialization in the EU-27 (% change relative to baseline)

Farm specialization	Average	Min.	Max.
Cereals, oilseeds and protein crops	–0.016	–6.58	0.00
General field cropping	–0.003	–1.69	0.00
Horticulture	–0.004	–0.07	0.00
Vineyards	0.000	0.00	0.00
Fruit	0.000	–0.01	0.00
Olives	–0.005	–0.01	0.00
Permanent crops	–0.001	–0.05	0.00
Dairy farms	–0.005	–0.03	0.00
Sheep and goats	–0.023	–0.86	0.00
Cattle rearing and fattening	–0.001	–2.15	0.00
Pigs and poultry	0.000	0.00	0.00
Mixed crops	–0.005	–0.12	0.00
Mixed livestock	–0.002	–0.18	0.00
Mixed crops and livestock	–0.002	–0.12	0.00

Source: model results

Table 5. Income effect of the crop diversification measure by farm size in the EU-27 (% change relative to baseline)

Farm size	Average	Min.	Max.
< 2 ESU	0.000	0.00	0.00
2 to < 4 ESU	0.000	0.00	0.00
4 to < 6 ESU	–0.001	–0.02	0.00
6 to < 8 ESU	–0.004	–0.02	0.00
8 to < 12 ESU	–0.004	–1.41	0.00
12 to < 16 ESU	–0.005	–0.92	0.00
16 to < 40 ESU	–0.005	–0.15	0.00
40 to < 100 ESU	–0.004	–0.12	0.00
100 to < 250 ESU	–0.003	–0.58	0.00
≥ 250 ESU	–0.001	–0.01	0.00

Source: model results

The aggregate impacts reported in Table 3, Table 4 and Table 5 may hide sizeable effects for individual farms. To gain further insight, Figure 2 shows the distribution of the percentage change in farm income relative to the baseline for all EU-27 MSs (i.e. the total number of farms in the EU-27 is equal to 100). This figure is constructed by sorting, in ascending order, all of the farms according to the size of the income change until all farms (100 %) are reported. As shown in this figure, only a small proportion of farms is affected by the diversification measure. Although the income change of some farms is substantial (more than a 10 % decline), the total proportion of farms affected by the measure represents only around 5 % of the total farm population in the EU-27. Thus, about 95 % of the farm population is not affected at all, either because they are already complying in the baseline or because they are not concerned by the crop diversification measure (i.e. they are exempt farms).

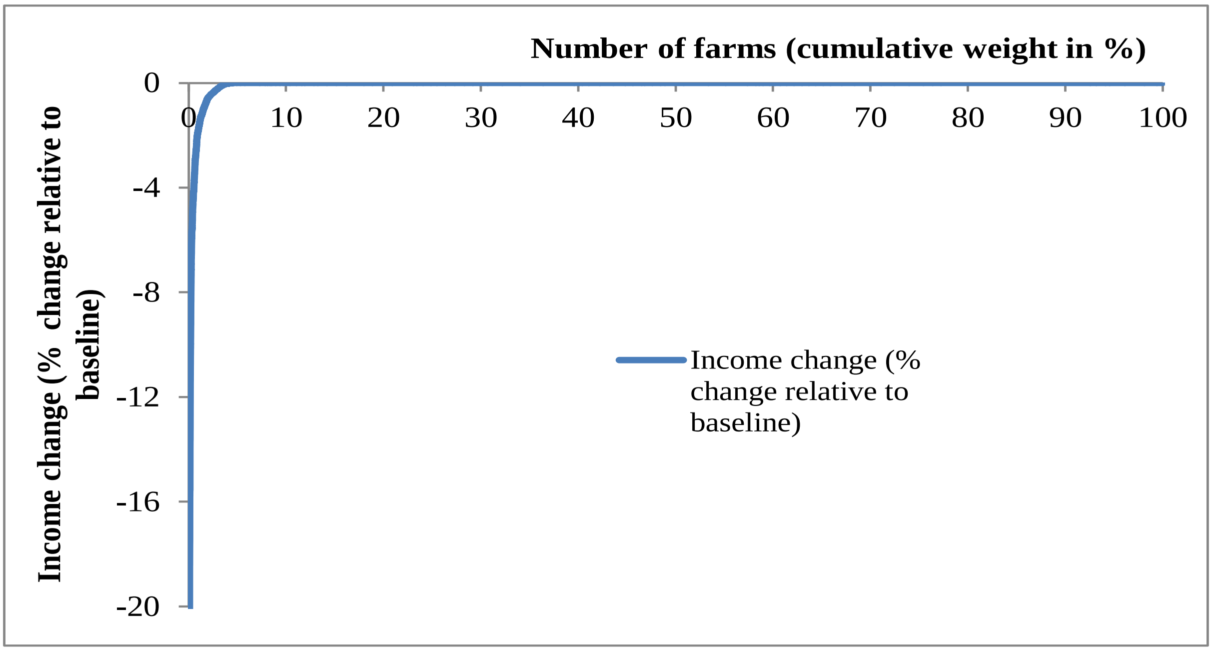

Figure 2. The distribution of the income change for the crop diversification scenario by individual farm (all farms, % change relative to baseline)

The low income effect reported above is largely explained by the limited impact of the crop diversification measure on land allocation. Table 6 illustrates the degree of non-compliance of land allocation in the baseline and crop diversification scenario. Similar to above, the non-compliant area in the baseline scenario represents a hypothetical area in breach of the diversification requirement before the implementation of the measure. It corresponds to the minimum area that farms would need to adjust in order to comply fully with the diversification measure and to avoid a reduction in their greening payments. As reported in Table 6, the arable area not complying with the diversification measure in the baseline is 0.6 % of the utilized agricultural area (UAA) in the EU-27. It ranges from 0 % to 5.4 % of UAA across different MSs (Table 6, panel a). Note that the degree of non-compliance can be slightly higher if calculated per concerned arable area. The concerned arable area is equal to the total arable area at MS level minus the arable area of farms exempted from the diversification measures. As reported in Table 6, panel b, the proportion of non-compliant area in the total concerned arable area is 1 % in the baseline in the EU-27 and it varies between 0 % and 6.5 % at MS level. Non-compliance is mostly related to the 75 % threshold imposed for the main crop cultivated on the farm. The area that does not comply with the 95 % threshold is significantly less important, representing less than 0.14 % of UAA and 0.21 % in the concerned arable area (Table 6, panels a and b). This result could also partly be explained by the fact that the 75 % threshold applies to all farms with an arable area greater than 10 hectares, whereas the 95 % threshold applies only to farms with an arable area greater than 30 hectares.

In the crop diversification scenario, the non-compliant area is reduced significantly compared with the baseline (Table 6, panels a and b). The proportion of non-compliant area in both UAA and concerned arable area is reduced by more than 50 % under the diversification scenario in the EU-27. This is explained by the relatively high subsidy reduction that would be imposed on farms if they did not comply. The (hypothetical) average subsidy reduction per hectare of non-compliant area is EUR 451 in the baseline in the EU-27 and varies between EUR 127 in Poland and EUR 758 in the Netherlands in the baseline (Table 7)[17]. As penalties are expressed as a proportion of the direct payments, their value depends strongly on the value of direct payments per hectare, which varies across the MSs. MSs with a lower level of direct payments (e.g. BG, PL, SK, RO) also have smaller greening payments (and also a potential reduction in subsidy) than MSs with higher direct payments (e.g. DK, FR, NL). Note that although the non-compliant area is significantly reduced, the total affected area is small (less than 0.5 % of UAA).

Farms types with the greatest non-compliant area in the concerned area in the diversification scenario are specialized in permanent crops, horticulture, pigs and poultry and mixed crops (Table 8, panel a). For farm size, the most affected are middle-sized farms between 6 and 16 ESU followed by large farms (Table 8, panel b).

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[17] In Malta the subsidy reduction is zero because all farms comply with the diversification measure.

Table 6. Total area not complying with the diversification measure by MS

a) Proportion in UAA (%)

MS	Baseline			Diversification		
	Total	**75% threshold**	**95% threshold**	**Total**	**75% threshold**	**95% threshold**
BL	0.50	0.44	0.06	0.28	0.27	0.01
DK	0.58	0.47	0.11	0.28	0.28	0.00
DE	0.68	0.56	0.12	0.32	0.28	0.03
EL	1.62	1.44	0.17	1.13	1.07	0.06
ES	1.66	1.22	0.44	0.81	0.71	0.10
FR	0.21	0.17	0.05	0.06	0.06	0.00
IR	0.27	0.23	0.04	0.10	0.09	0.01
IT	0.96	0.74	0.22	0.49	0.45	0.05
NL	1.56	1.41	0.14	0.98	0.92	0.06
AT	0.28	0.26	0.02	0.05	0.05	0.00
PT	1.45	1.28	0.17	0.59	0.55	0.04
SE	0.54	0.37	0.17	0.15	0.13	0.02
FI	1.40	1.10	0.30	0.37	0.35	0.02
UK	0.23	0.15	0.08	0.11	0.10	0.01
CY	5.42	4.28	1.14	3.83	3.35	0.49
CZ	0.07	0.05	0.02	0.03	0.02	0.01
EE	0.29	0.23	0.06	0.15	0.15	0.00
HU	0.33	0.25	0.07	0.20	0.18	0.01
LT	0.26	0.19	0.08	0.07	0.07	0.01
LV	0.34	0.25	0.09	0.24	0.19	0.04
MT	0.00	0.00	0.00	0.00	0.00	0.00
PL	0.72	0.65	0.07	0.42	0.40	0.02
SI	0.05	0.04	0.01	0.02	0.02	0.00
SK	0.26	0.21	0.05	0.24	0.21	0.04
BG	0.55	0.43	0.12	0.38	0.34	0.03
RO	0.35	0.25	0.10	0.08	0.07	0.01
EU-27	**0.63**	**0.49**	**0.14**	**0.31**	**0.28**	**0.03**

b) Proportion in the concerned arable area (%)

MS	Baseline			Diversification		
	Total	**75% threshold**	**95% threshold**	**Total**	**75% threshold**	**95% threshold**
BL	0.85	0.75	0.10	0.47	0.45	0.02
DK	0.63	0.51	0.12	0.31	0.30	0.00
DE	0.94	0.77	0.17	0.44	0.39	0.05
EL	2.41	2.15	0.26	1.69	1.60	0.09
ES	2.92	2.15	0.77	1.43	1.25	0.18
FR	0.30	0.23	0.07	0.09	0.09	0.00
IR	2.18	1.83	0.35	0.81	0.75	0.06
IT	1.36	1.04	0.32	0.70	0.63	0.07
NL	3.47	3.15	0.32	2.19	2.05	0.14
AT	0.53	0.49	0.04	0.09	0.09	0.00
PT	2.39	2.10	0.29	0.97	0.90	0.07
SE	0.62	0.42	0.20	0.17	0.15	0.02
FI	1.43	1.13	0.31	0.38	0.36	0.02
UK	0.53	0.35	0.17	0.25	0.23	0.03
CY	6.45	5.10	1.36	4.56	3.98	0.58
CZ	0.10	0.07	0.03	0.04	0.02	0.01
EE	0.38	0.30	0.07	0.20	0.20	0.00
HU	0.40	0.31	0.09	0.24	0.22	0.01
LT	0.31	0.22	0.09	0.09	0.08	0.01
LV	0.47	0.34	0.13	0.33	0.27	0.06
MT	0.00	0.00	0.00	0.00	0.00	0.00
PL	0.89	0.80	0.09	0.52	0.50	0.02
SI	0.15	0.14	0.02	0.06	0.06	0.00
SK	0.37	0.30	0.07	0.35	0.29	0.05
BG	0.64	0.50	0.14	0.43	0.40	0.04
RO	0.41	0.29	0.12	0.10	0.09	0.01
EU-27	**0.98**	**0.76**	**0.21**	**0.47**	**0.43**	**0.04**

Source: model results

Table 7. Subsidy reduction per hectare of non-compliant area (EUR/ha)

MS	Baseline	Diversification
BL	539	298
DK	716	274
DE	523	258
EL	571	392
ES	363	178
FR	615	288
IR	574	372
IT	651	263
NL	758	426
AT	473	226
PT	331	206
SE	478	210
FI	741	322
UK	671	233
CY	331	137
CZ	245	219
EE	125	58
HU	244	123
LT	210	88
LV	181	87
MT	0	0
PL	127	91
SI	461	333
SK	139	80
BG	142	69
RO	187	64
EU-27	**451**	**218**

Source: model results

Table 8. Area not complying with the diversification measure by farm type in EU-27 (% of concerned arable area)

a) By farm specialization

Farm specialization	Baseline			Diversification		
	Average	Min.	Max.	Average	Min.	Max.
Cereals, oilseeds and protein crops	0.99	0.04	16.22	0.54	0.01	12.39
General field cropping	0.75	0.04	4.37	0.40	0.04	2.19
Horticulture	2.88	0.55	16.80	1.94	0.08	15.42
Vineyards	1.49	0.35	7.97	0.94	0.20	6.32
Fruit	1.08	0.34	22.77	0.69	0.04	10.97
Olives	1.51	0.16	2.78	1.17	0.65	2.28
Permanent crops	2.70	0.03	22.50	1.51	0.43	5.79
Dairy farms	0.90	0.04	7.08	0.28	0.00	4.13
Sheep and goats	1.40	0.22	11.80	0.48	0.01	9.45
Cattle rearing and fattening	0.76	0.05	14.62	0.20	0.02	3.41
Pigs and poultry	2.46	0.77	15.10	1.17	0.08	15.10
Mixed crops	1.53	0.03	4.94	0.96	0.00	3.22
Mixed livestock	1.02	0.07	7.54	0.45	0.01	5.45
Mixed crops and livestock	0.62	0.01	10.19	0.23	0.01	6.83

b) By farm size

Farm size	Baseline			Diversification		
	Average	**Min.**	**Max.**	**Average**	**Min.**	**Max.**
< 2 ESU	0.07	1.27	1.27	0.07	1.27	1.27
2 to < 4 ESU	0.32	0.09	3.86	0.25	0.23	3.82
4 to < 6 ESU	0.65	0.03	4.65	0.48	0.00	3.73
6 to < 8 ESU	1.67	0.15	11.52	1.23	0.06	10.66
8 to < 12 ESU	1.44	0.09	3.99	0.85	0.06	3.43
12 to < 16 ESU	1.57	0.00	10.42	0.86	0.02	10.42
16 to < 40 ESU	1.30	0.12	7.51	0.64	0.02	3.63
40 to < 100 ESU	0.91	0.02	4.53	0.38	0.00	2.37
100 to < 250 ESU	0.95	0.14	10.41	0.34	0.05	7.64
≥ 250 ESU	0.67	0.01	3.47	0.40	0.00	2.71

Source: model results

Figure 3 displays the distribution of non-compliant area across individual farms for the baseline and crop diversification scenarios. The horizontal axis is similar to that in Figure 2, with the exception that we cut the axis at 15 %, in order to better illustrate the changes for the affected farms. The remaining 85 % of farms that are not shown in the figure have no non-compliant area. The figure reveals that only a small proportion of farms (around 4.7 %) have a non-compliant area in the baseline. Under the diversification scenario, the proportion of farms that are not compliant drops to 3 %.

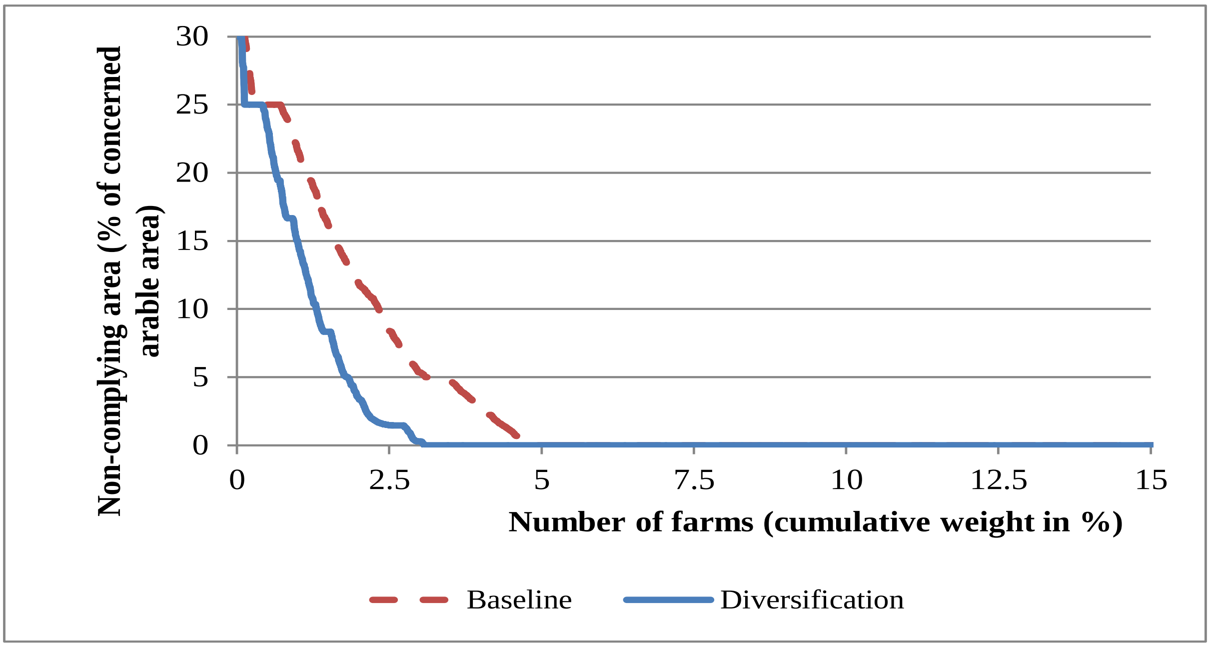

Figure 3. The distribution of non-compliant area by individual farm (% of concerned arable area)

5. Conclusions and discussion

This paper presents the EU-wide individual farm-level model, IFM-CAP. The rationale for development of such a farm-level model is based on the increasing demand for a micro-simulation tool able to model farm-specific policies and to capture farm heterogeneity across the EU in terms of policy representation and impacts. Based on positive mathematical programming, IFM-CAP seeks to improve the quality of policy assessment upon existing aggregate and aggregated farm-group models and to assess distributional effects over the EU farm population. To guarantee the highest representativeness of the EU agricultural sector, the model is applied to every EU-FADN individual farm (around 60 500 farms). In this paper, the IFM-CAP has been applied to simulate the responses of EU farmers to the 2013 CAP reform, more specifically to the crop diversification measure.

From a policy perspective, the main finding of this model application is that the effect of crop diversification on farm income is rather limited at the aggregate level. Agricultural income at MS level decreases by less than 1 %. At the individual farm level the impact could be more pronounced (more than –10 %), although the number of affected farms by the measure remains small (around 5 % of the total farm population). The proportion of reallocated area due to the diversification measure represents less than 0.5 % of the total agricultural area. The most constraining component of the diversification measure appears to be the 75 % threshold imposed for the main cultivated crop for farms with an arable area greater than 10 hectares. Another important outcome of the simulation analysis is that most non-compliant farms (80 %) choose to reduce their non-compliance level with the introduction of the diversification measure owing to the sizable subsidy reduction imposed.

These findings have to be considered, however, with some caution on account of the model's assumptions. First of all, the model is calibrated on the average values over the three years 2007, 2008 and 2009 instead of single year data. As the farm production plan of an average year is less specialized than that of a single year (i.e. the number of crops of an average year will most likely be higher than the number of crops in each single year), this implies that the crop diversification constraint will be less binding in our model than it is in reality. Therefore, our results will probably underestimate the non-compliant area in the baseline scenario and the overall effect of the crop diversification measure. A second potential caveat in our analysis is that we assume a fixed organizational structure, implying that land can be reallocated only within farms in response to the introduction of the crop diversification measure. In reality, farmers may reallocate land between farms or may decide to adjust other elements of farm organization that are not necessarily linked to land allocation. For example, farms may enter into unofficial arrangements with neighboring farms to rearrange claims for the greening payments in order to ensure compliance and, thus, to avoid the decrease in income related to potential land relocation. If this is the case, our results overestimate the overall effects. Third, we do not take market feedbacks (output price changes) into account in the model. The diversification measure will probably increase the overall output price level because of the productivity reduction effect. The price effects may thus offset some of the impacts (e.g. income change) simulated in the paper. Fourth, certain crops are defined in the model as an aggregation of a set of individual crops (e.g. fodder crops), which may also lead to a slight overestimation of the simulated impacts. Furthermore, given that the exact implementation of the 2013 CAP reform was not known at the time of preparation of this paper, direct payments in the baseline are assumed to be at the level reported in FADN in the base year. In addition, not all the specificities regarding the 'greening' implementation are considered in the model. In the scenario analysis in particular, it is not considered either that organic producers and farmers in the 'small farmers' scheme' are exempted from the greening obligations or that MSs can opt to define practices that yield an equivalent or higher beneficial effect for the climate and the environment as the three 'greening' obligations. A careful analysis of each of these limitations to the current model is needed to test the robustness of these results and to provide a complete picture of the EU-wide impact of the crop diversification measure.

From the methodological viewpoint, this paper highlights the relevance of farm-level model for making finer policy analysis at EU-wide scale. To the best of our knowledge, the model presented here is one of the few farm-level models which allows the assessment of farm-specific policies, reflects the full heterogeneity of EU farms, covers all main agricultural production activities in EU, and provides detailed analysis of farming systems at different scales (individual farm, farm-type, NUTS2, MS and EU).

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