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Farm Accountancy Cost Estimation and Policy Analysis of European Agriculture

The effects of the single farm payment on cost function and production function

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Executive Summary

The objective of this deliverable is twofold; the first is to develop a quantitative model, based on positive mathematical programming (PMP) that can evaluate the possibility, for a specific crop, to introduce and change technologies in the observed production plan adopted by a group of farms belonging to a given region. The other is to estimate the impact of policy scenarios including CAP reform and increasing market prices on land allocation.

The model is based on the research previously developed and presented in D6.1 on production cost estimation using FADN information. Its main feature is to consider production cost as the dual of the production function and to admit that each farmer can choose his optimal production function (which has a related production cost) according to his experience, skills and constraints. The model provides two different outputs: i) to recuperate the specific variable costs, and the related production function, connected to each observed activity included in the FADN archives. These costs are known by the farmer but are hidden from the researcher who knows only the total production cost; ii) to estimate farmers' behaviour under different policy scenarios including the possibility of introducing new technologies in the production plan. In this case it is possible to differentiate between crops that are already grown on the farm, and to introduce new crops. These latter scenarios are of great interest because they provide more opportunity for farmers to change their production strategy but are also greatly limited, in the implementation through mathematical models, because the researchers must know the production function and the production cost.

As described in D6.1, the starting point of the model considers that FADN archives do not provide information related to the variable costs linked to each farm activity, but only the total variable costs at farm level. This latter information is used as "information guide" in a PMP model in order to provide a reliable estimation of the production function for each activity on each observed farm considered in the FADN sample. Because the model considers all the farms included in the FADN sample, for a given crop, is possible to estimate all the production functions used by each farmer. For simplicity, for each crop, only one production function (the average technology) is usually considered in the model and only one related variable cost is estimated. Each farmer is represented by the adoption of that production function plus or minus a delta represented by their effective position in respect to the "average technology".

Using the above approach, it is possible to consider, for a given crop, more than one production function and to estimate more than one specific variable cost according to a set of variables -the related variable cost, the market price, the set of policy constraints and the "power of the solver" used in the estimation of the related coefficient-, leaving each farmer the possibility to choose the more profitable technologies.

In PMP techniques, all the "average" technologies – and their related variable cost – exploited by the model are considered for the same crop. This information provides the possibility for farmers to adopt new technology when some modification of the status quo is introduced. We can consider the information related to production function, and associated variable cost, as "latent information". This information is estimated by the PMP model and is used only when economic conditions become favourable for the activation of the new production function.

The use of latent information can be useful in two different conditions: i) when the information is related to the production technology for a given crop already grown on other farms but not on the given farm. In this case we consider "*latent technology*"; ii) when the information is related to a given crop that is not grown on any of the farms belonging to the FADN sample. In this case we refer to a "*latent activity*".

In other words, the presence of different production functions is assumed. The PMP model can estimate the variable cost associated to each production function and predict farmer behaviour, represented by a new production plan, according to the new policy scenario.

The analysis presented in the deliverable has been conducted on the Veneto FADN data set and all the farms belonging to FT 1 "arable crops" are considered.

The policy scenario considered in this deliverable aims to use latent technologies and latent crops information after having introduced the latest condition imposed by the Health Check reform and having created a new baseline concerning the market price in 2009. Three policy scenarios are considered:

- Introduction of latent technology related to the production of soft wheat with three different yield levels
- Introduction of latent technology related to the production of maize with three different yield levels
- Introduction of a latent crop as a "new crop" represented by sorghum for energy production.

For assessing the adoption of new technologies, the scenarios consider a progressive increase in price from 0.1 euros/ton to 10 euros/ton with a step-by-step increase of 0.1 euros/ton. This means that 100 cycles of simulation have been carried out for each crop in order to obtain a sensitivity response for the production plan and, in particular, for the technology substitution at individual level. One cycle of 100 simulations on price has been developed for soft wheat split in the three different technologies and one cycle of 100 simulations on price for maize divided in the three technologies. The aim of this simulation is to observe the dynamics of the three technologies progressively modifying the related price and, thus, capturing the process of substitution within the three technologies and between the three technologies and the rest of the production plan. As regards the new crop simulation, the objective is to evaluate under which economic conditions the new crop can be inserted into the production plan of the farms in Veneto.

The results show that the PMP model developed in the framework of the FACEPA project is able to estimate the accounting variable cost for all the activities observed in the FADN database and can also predict the impact of market price or CAP measure on existing crops for which a different technological level is adopted or on new crops that are introduced in a given territory.

The results show that the impact of price variation is sensitive to the farm size and to the level of specialization of the producers. In particular, increasing price for soft wheat and maize will increase the use of the most intensive technology for the two crops and for the three farm types. This strategy will reduce the presence of soft wheat and maize with low yield and increase the technology with higher yield. Of course this strategy will benefit farm income that will increase but will have a negative impact on the environment because it will increase the presence of more intensive crops in Veneto region.

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Abbreviations and Acronyms

CAP	Common Agricultural Policy
FADN	Farm Accountancy Data Network
FAPRI	Food and Agricultural Policy Research Institute
FT	Farm Type
FT1	Arable Crops Farm Type
GAMS	General Algebraic Modelling System
GM	Gross Margin
G-PMP-CE	General PMP Cost Estimator
GSP	Gross Saleable Production
HC	Health Check reform
INEA	National Institute of Agricultural Economics
Maize A	Maize produced with technology A (≤ 6 tons/ha)
Maize B	Maize produced with technology B (> 6 tons/ha ≤ tons/ha)
Maize C	Maize produced with the technology C (≥ tons/ha)
MRS	Marginal Rate of Substitution
PMP	Positive Mathematical Programming
Soft wheat A	Soft wheat produced with technology A (≤ 6 tons/ha)
Soft wheat B	Soft wheat produced with technology B (> 6 tons/ha ≤ tons/ha)
Soft wheat C	Soft wheat produced with technology C (≥ tons/ha)
SWHA	Soft wheat with technology A
SWHB	Soft wheat with technology B
SWHC	Soft wheat with technology C
TVC	Total Variable Cost
UAA	Utilized Agricultural Area

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1 The latent activities in PMP

1.1 Latent technologies and latent activities

The hypothesis supporting the idea that latent information exists related to latent technologies and latent activities arises from the assumption that farmers consider all the available information in the definition of their production plan. Some comes from their past experience and some from the experience of their neighbours or from advice given by experts (agronomists) who suggest introducing new crops.

Neighbouring farms can play the role, for instance, of benchmark or leader in a certain production technology or in a certain production organization. In this sense, a given farmer can use the other's experience as a reference, or indicator, for measuring its efficiency and identifying a path of development of its activity. In this process, farmers are guided by their specific attitude to change the status quo of their farms approaching a dynamic context.

The specific attitude is, in general, relayed on different variables, like risk aversion, level of technical knowledge, availability of capital, family structure, age of the farmer, the presence of support agencies in the territory, etc. All these variables affect the farmer's decision process driving him to select a certain combination of crops to produce in a given year. The result of this decision leads to identifying the rational use of the available inputs taking into account all the production possibilities including the potential production not activated in the past. Why does a given farmer produce soft wheat and alfalfa and not, for instance, tomato and sugar beet, which are produced on other farms in the area? And, are tomato and sugar beet considered in the decision process as potential crops to introduce into the production plan?

The result of this process is that a given farmer could potentially insert them in his production plan, but in reality he will use them only when the economic scenario makes those technologies or those crops profitable. Until then the information is "latent" in the sense that it is known by the farmers but not used.

According to this statement, economic information related to farm crops already exists in the FADN dataset or can easily be introduced, we can call it "latent information". More precisely we can differentiate between i) "latent technology" when the information is related to the production technology for a given crop already existing in the farm production plans of other farms and not on the given farm, and ii) "latent crop" when the information is related to a given crop that does not exist in the farm production plan for any farms belonging to the FADN sample.

A deeper discussion about the components of the decision process allows the different combination of activities to be decided. The farmer is not alone, he is in an environment characterized by several different production decisions that indicate the different production possibilities he could adopt. Among all these possibilities he selects only one combination that he assumes to be the best solution. The driving force that leads farmers to select a certain production plan and not others is the cost function associated to each activity. The total cost function is the economic translation of the available technology and all the other factors leading to the decision. The total cost includes all the variable costs considered, more or less explicitly, within the production plan decision process. The meaning of this total cost function is the total economic cost that considers both the accountancy costs and the implicit costs of the decision. This latter is the part of the cost not revealed by the accountancy books but considered by the farmer in the decision process. There are two types of these costs:

- the hidden costs associated to the selected activity: these indicate the relationships between the activities and relevance of each product within the production plan.
- the costs associated to the activities that could be chosen by the farmers but that were not adopted: these are opportunity costs, i.e. the sacrifice made by the farmer for having preferred to allocate his resources to other activities.

These latter costs allow it to be stated that farmers make decisions taking into account not just the activities that are observed in the production plan, but also all those activities present in the territory where they produce. The activities that are not present in the production plan but present in the decision process can be defined as latent activities. In other words, the latent information is related to activities (technologies or crops) that a given farmer preferred to not adopt since their associated cost was too high with respect to the other processes inserted in the production plan. Indeed, the farmer could introduce new crops into the production plan or change the technology associated to a specific process but he preferred other solutions considered more profitable. This is the concept of latent activities that could potentially be adopted if the environmental conditions change. The latent technology is a different way to produce the crops existing in the production plan. The farmer knows that for producing a given crop he could use a different combination of inputs in order to obtain a different yield performance. If, for example, the farmer produces maize with a certain technology, defined by his own knowledge, own machinery, etc., he knows that he could use another technology to obtain a different level of output or the same level of output with a different level of cost. Using all this information about the different technologies that he could adopt, the farmer decides to adopt only one.

The latent crop is related to information about a new crop that does not exist in the sample at the time of the observation but which is artificially introduced in the farm dataset. Thus it could be implemented when market conditions make this crop profitable.

For both decisions, crops and technologies, farmers are aware of the costs that each choice can entail. In order to identify the economic behaviour of the farmers, the information about the latent information should be considered with the observed activities in the evaluation process. This allows it to be verified under which conditions farmers keep the same activities and in which other conditions they move to other activities. Within this perspective, the farmer's behaviour is analyzed with respect to a production plan where the observed activities are accompanied by latent technologies and latent crops.

1.2 PMP model with latent information

The literature relating to the development of "standard" PMP models describes three stages, each of which is distinguished by a specific objective: i) the determination of the dual values associated with the calibration constraints of the primary problem of linear programming; ii) the estimate of a variable cost function that incorporates all those costs, over and above the accounting costs, considered by the farmer in the definition of the land allocation; iii) the formulation of a non-linear programming problem able to reproduce the initial allocation, but without using the calibration constraints.

The PMP model designed to consider the impact of policies on non-observed activities, in this case, (ideally) considers a farm with only two existing products ($x_r, x_l; k = 2$), where x_r represents the quantities of the observed product (*r*), while x_l represents the quantities of the latent product (*l*); the quantitative levels of the two processes are known ($\bar{x}_{r,}\bar{x}_l$). The activity is subject to limiting factors (b); while the matrix of the technique $A_{m\times k}$ is obtained from the ratio between the value of the factor dedicated to each activity and the corresponding quantity produced. The primary problem of the PMP is the following (1):

$$\begin{aligned} \max_x \quad & TR = p'x \\ & \textit{Soggetto}\ \text{a} \\ & Ax \le b \\ & x \le \bar{x} + \varepsilon \\ & x \ge 0 \end{aligned} \qquad (1)$$

Breaking down the variables of the problem (1), between observed and latent products, the problem can be formulated as follows:

$$\max TP = \sum_{r=1}^{R} \pi_r x_r + \sum_{l=1}^{L} \pi_l x_l$$

$$S.t.$$

$$\begin{array}{lclcll} \sum_{r=1}^{R} a_{ri} x_r & + & \sum_{l=1}^{L} a_{li} x_l & \leq & b_i & \forall i \\ x_r & & & \leq & \bar{x}_r + \varepsilon & \forall r \\ & & x_l & \leq & \bar{x}_l + \varepsilon & \forall l \\ x_r, x_l \geq 0 & & & & & \forall r \forall l \end{array}$$

In matrix form:

$$\max TP = \boldsymbol{\pi}'_r \mathbf{x}_r + \boldsymbol{\pi}'_l \mathbf{x}_l$$

$$S.t.$$

$$\begin{array}{ll} \mathbf{B}\mathbf{x}_r + \mathbf{M}\mathbf{x}_l \leq \mathbf{b} & (\mathbf{y}) \\ \mathbf{x}_r \leq \mathbf{x}_r + \varepsilon & (\;_r) \\ \mathbf{x}_l \leq \mathbf{x}_l + \varepsilon & (\;_l) \\ \mathbf{x}_r, \mathbf{x}_l \geq 0 & \end{array}$$

where π_r and π_l are the marginal profit of the observed and latent activities respectively. $\mathbf{y}$ is the vector of the shadow prices of the binding resources, while λ_r and λ_l are the dual values associated to the calibrating constraints. Using the information on the implicit costs in the decision process, the problem described calibrates, or reproduces, the observed allocation choices of the farm under consideration.

In the definition of the problem, the latent crop is added from the first phase, assigning it a production level x_l of epsilon, that is a level very little close to zero, while the data relative to the prices are assumed by the market and must guarantee a condition of positive marginal profit. The data relative to the production and technology (yield), are assumed by experts or by other similar crops. The formulation of the linear programming problem (2) redefined through the *Lagrange* function assumes a new auxiliary function:

$$L = \boldsymbol{\pi}'_r \mathbf{x}_r + \boldsymbol{\pi}'_l \mathbf{x}_l + \mathbf{y}'\left(\mathbf{b} - \mathbf{B}\mathbf{x}_r - \mathbf{M}\mathbf{x}_l\right) + \boldsymbol{\lambda}'_r\left(\bar{\mathbf{x}}_r + \varepsilon - \mathbf{x}_r\right) + \boldsymbol{\lambda}'_l\left(\bar{\mathbf{x}}_l + \varepsilon - \mathbf{x}_l\right) \quad (3)$$

Let us assume the positivity of the $\mathbf{x}$ vector and considering that the primary and dual problems are equivalent, problem (2) can be written according to the following form:

$$\max L \quad (4)$$

submitted to the following first order conditions:

$$\frac{\partial L}{\partial x_r} = \pi_r - \sum_{i=1}^{I} a_{ri} y_i - \lambda_r \le 0 \qquad \text{and} \qquad \frac{\partial L}{\partial x_r} x_r = 0 \qquad \text{for} \qquad x_r \ge 0 \tag{5}$$

$$\frac{\partial L}{\partial x_l} = \pi_l - \sum_{i=1}^{I} a_{li} y_i - \lambda_l \le 0 \qquad \text{and} \qquad \frac{\partial L}{\partial x_l} x_l = 0 \qquad \text{for} \qquad x_l \ge 0 \tag{6}$$

$$\frac{\partial L}{\partial y_i} = b_i - \sum_{r=1}^{R} a_{ri} x_r - \sum_{l=1}^{L} a_{li} x_l \le 0 \qquad \text{and} \qquad \frac{\partial L}{\partial y_i} y_i = 0 \qquad \text{for} \qquad y_i \ge 0 \tag{7}$$

$$\frac{\partial L}{\partial \lambda_r} = \overline{x}_r + \varepsilon - x_r \le 0 \qquad \text{and} \qquad \frac{\partial L}{\partial \lambda_r} \lambda_r = 0 \qquad \text{for} \qquad \lambda_r \ge 0 \tag{8}$$

$$\frac{\partial L}{\partial \lambda_l} = \overline{x}_l + \varepsilon - x_l \le 0 \qquad \text{and} \qquad \frac{\partial L}{\partial \lambda_l} \lambda_l = 0 \qquad \text{for} \qquad \lambda_l \ge 0 \tag{9}$$

At the optimum, the equation (7) becomes $\mathbf{B}\mathbf{x}_r^* + \mathbf{M}\mathbf{x}_l^* = \mathbf{b}$, and shows the full saturation of factor $\mathbf{b}$. From this relationship we obtain the rate of substitution between the two activities (latent and realized). Taking the derivative of equation (7) and by substitution of x_r with x_l, we obtain:

$$MRS_{\mathbf{x}_l,\mathbf{x}_r} = M^{-1}B \tag{10}$$

The marginal rate of substitution (MRS) of (10) shows the “cost” in terms of x_r due to the decision to produce one additional unit of x_l. We can consider it as a measure of technical efficiency between the two activities. Economic efficiency can be defined as

$$\mathbf{c} = \left(\mathbf{M}^{-1}\mathbf{B}\pi\right)_l - {}_r \tag{11}$$

Opportunity cost of x_l provides the exact measure of the cost effectiveness of substituting activity x_r with activity x_l. A negative opportunity cost reveals the advantage of introducing the new activity x_l that is more profitable than activity x_r. In a traditional LP problem, this condition implies an over specialization of the activity x_l, while the same problem specified with the PMP principles, the specialization of the most profitable activity is bound by the constraint $\overline{x}_l + \varepsilon$. Furthermore, the hypothesis according to which x_l represents the process that provides the higher profit admits as a consequence the full saturation of the calibration constraint associated with the same. In other words, the endogenous variable x_l is hypothesized to have a level equal to $\overline{x}_l + \varepsilon$, to be considered as the optimum level of the variable. As regards the determination of the optimum level of the variable x_r, the first-order condition of the *Lagrange* function (7) provides the tool for resolving the linear problem of the first PMP stage.

We know that the vector of structural constraints $\mathbf{b}$ is given by $\mathbf{b} = \mathbf{B}\overline{\mathbf{x}}_r + \mathbf{M}\overline{\mathbf{x}}_l$, and $\mathbf{x}_l^* = \overline{\mathbf{x}}_l + \varepsilon$. As a consequence equation (7) can be written as:

$$\mathbf{M}(\overline{\mathbf{x}}_l + \varepsilon) + \mathbf{B}\mathbf{x}_r = \mathbf{M}\overline{\mathbf{x}}_l + \mathbf{B}\overline{\mathbf{x}}_r \tag{12}$$

$$\mathbf{x}_r^* = \overline{\mathbf{x}}_r - (\mathbf{mrs})\varepsilon \tag{13}$$

In this respect, the last equivalence provides the exact measure of the reduction of $\overline{\mathbf{x}}_r$ as a consequence of the increasing of $\overline{\mathbf{x}}_l$ equal to ε. In conclusion, the activity vector that maximizes the objective function is the following:

$$\mathbf{x}^* = \begin{bmatrix} \mathbf{x}_r^* = \overline{\mathbf{x}}_r - (\mathbf{mrs})\varepsilon \\ \mathbf{x}_l^* = \overline{\mathbf{x}}_l + \varepsilon \end{bmatrix}.$$

The solution of the above problem shows that $\mathbf{x}_r < \overline{\mathbf{x}}_l + \varepsilon$, considering the non-degeneration of problem (2), the dual value of the positive constraint linked to the activity x_r, has a null value. Moreover, the shadow value of the production factor represents the cost of each unit factor used in the production activity. This price is the cost considered in the definition of the optimal production plan and is determined by the solution of equations (5) and (6). Given that in equation (9) the *Lagrange* multiplier linked to the calibration constraint $\mathbf{x}_r$ has a null value, the $\mathbf{y}$ vector has the following form

$$\mathbf{y}^* = \mathbf{M}\mathbf{p}_r \quad \rightarrow \quad dual \;\; value \;\; of \; input \;\; \mathbf{b} \tag{14}$$

Equation (14) shows that the dual value of the fixed factor is given by marginal production of the sole activity $\mathbf{x}_r$. We have to remember that the cost for increasing the production factor by one unit is equal to the cost of technical coefficient of one additional unit of the production $\mathbf{x}_l$. Moreover, the increasing of fixed production factors has as a consequence the activation of the process $\mathbf{x}_r$, whose constraint is not yet saturated.

The most profitable activity $\mathbf{x}_l$ completes the associated constraint and its marginal value is positive. If equation (5) is solved by $\boldsymbol{\lambda}_l$, we obtain.

$$\boldsymbol{\lambda}_l^* = \mathbf{p}_l - (\mathbf{mrs})\mathbf{p}_r \quad \rightarrow \quad marginal \ \ variable \ \ cost \ \ of \ \ x_l \qquad (15)$$

The solutions of the *Lagrange* functions, both of the primary problem and of the equivalent dual problem, demonstrate the existence of the internal solution to the model with the determination of the substitution relationship of the two activities (realized and latent) and of the respective shadow prices linked to the existing activities subject to constraint.

The dual variable λ_l^* implies a number of considerations regarding its economic significance, as it represents the difference between the selling price of a unit of x_l and the cost of production, evaluated at the price of the marginal activity x_r. This difference can be interpreted as the profit for the producer obtained from an additional unit of x_l. Moreover, the price of the latent activity supplies the measurement of the opportunity cost for the production of one additional unit of x_l.

The value of λ_l^* represents the cost sustained for having removed from the production the units of x_r needed to produce one unit of x_l. The cost of this substitution is negative, or x_l is more interesting, in economic terms, than x_r. This substitution justifies the use of the portion of inputs for obtaining x_r for producing the latent activity x_l. The marginal cost of the realized activity x_r is zero, because there are no other less efficient activities to substitute.

1.3 The Q matrix estimation and the self-selection problem

The possibility of being able to determine the opportunity cost for all the activities considered in the production plan (observed and latent activities), enables the PMP procedure to calculate a matrix of variable cost in respect to all the production activities considered by the farmer and thus develop a strategic plan for his farm. In order to reach this result, the cost matrix (commonly referred to as the Q matrix) – that represents the second stage of the PMP methodology - is calculated using the dual information obtained in the previous stage for all the farms included in the sample and for all the considered activities.

Many references are available on the calculation of the cost matrix (Howitt, 1995; Paris and Howitt, 1998; Arfini and Paris, 2000) indicating that there are three basic stages: i) the specification of the functional form of the total variable cost obtained through integration of the known levels of the production activities; ii) the choice of method for estimating the parameters of the cost function; iii) the estimation of the parameters of the function using the selected method.

As regards the type of non-linear function, there are a wide range of possibilities in the literature, including: the quadratic form, the weighted entropy form (Paris and Howitt, 1998) and Leontief's generalized function (Howitt, 1995). In our case, we will use the quadratic form with respect to the quantities, C(x) = x'Qx /2, where the Q matrix is symmetric, positive and semi-defined. As regards the estimation method, the maximum entropy method is used applied starting from the Q matrix decomposed according to Cholesky's factorization, as suggested by Paris and Howitt (1998).

When a sample with n farms is available it is necessary to consider those farms not as an "average" farm, but instead as individual farms. Each farm has its own cost function that will differ from others by a deviation from an "average cost function" for the entire sample. According to this hypothesis all the information related to each activity considered for all the sample will be considered and will be made available to all the farmers, even to those that at the initial level have not activated a given crop.

In order to enable all the farmers included in the sample to use the information relative to all the realized and latent processes, and not to limit production possibilities to the processes effectively practised on their own farms, the cost function, represented as $\mathbf{mc}(\mathbf{x}) \equiv \overline{\boldsymbol{\lambda}}_{\mathbf{LP}} + \overline{\mathbf{c}} = \mathbf{Q}\overline{\mathbf{x}}_{\mathbf{R}}$, is considered as a frontier function for the entire sample of farms (Arfini and Paris, 2000). While the cost functions of each individual farm are expressed as a non-negative deviation from the frontier function. So, the marginal cost function of the *nth* farm is represented as $\mathbf{mc}(\mathbf{x_n}) \equiv \boldsymbol{\lambda}_{\mathbf{LPn}} + \mathbf{c_n} = \mathbf{Q}\mathbf{x}_{\mathbf{Rn}} + \mathbf{u_n}$, where the non-negative vector $\mathbf{u_n}$ corresponds to the deviations of the *nth* farm (Arfini and Paris, 2000).

This formulation assumes a special significance as it enables all the activities present in the territory to be considered in the production plan of a farmer even if not effectively practised on the farm in question at the time of accounting. In order to allow for this behaviour on the part of the farmers, the marginal costs of each business are further specified, distinguishing the existing activities from those which have not been implemented. This objective is achieved by formulating two sets of constraints for the *nth* farm. The first is connected with the existing crops, which will have a marginal cost given by the **Q** matrix specified for the frontier cost multiplied by the observed productions and by a (positive) deviation component with respect to the frontier itself. In this case, the relationship between the two marginal costs can be described in the following equation:

cm$_{nk}|$ $\mathbf{x_{Rk}} > 0$: $\boldsymbol{\lambda}_{\mathbf{nk}} + \mathbf{c_{nk}} = \mathbf{Q_k x_{Rn}} + \mathbf{u_{nk}}$, if the **k** activity - is produced, $\mathbf{k} = 1,\ldots,\mathbf{J_n}$. (16)

The second set of constraints concerns the activities not implemented by the *nth* farm. In this case the marginal cost of the non-implemented process (the latent process) could be less than or equal to that specified for the frontier. In the second case, the relationship between the marginal costs can be represented as a weak inequality compared to the marginal cost level of that activity in the context of the sample:

cm$_{nk}|$ $x_{Rk} = 0$: $\bar{\lambda}_k + \bar{c}_k \leq Q_k \boldsymbol{x}_{Rn} + u_{nk}$, if the *k* activity is not produced, $\mathbf{k} = 1,\ldots,\mathbf{J} - \mathbf{J_n}$.(17)

Returning to the farm with the two types of activities, one of which is latent, the Q matrix estimated for this farm with two processes for each type of activity is as follows:

$$\hat{Q} = \begin{bmatrix} q_{r1,r1} & q_{r1,r2} & q_{r1,l1} & q_{r1,l2} \\ q_{r2,r1} & q_{r2,r2} & q_{r2,l1} & q_{r2,l2} \\ q_{l1,r1} & q_{l1,r2} & q_{l1,l1} & q_{l1,l2} \\ q_{l2,r1} & q_{l2,r2} & q_{l2,l1} & q_{l2,l2} \end{bmatrix} \tag{18}$$

The Q matrix maintains all the information on substitution and complementarity relationships between activated and latent production processes even if latent production is not yet present in the farm plan. As a consequence, during the simulation phase, the initial production organization can be modified by including also those new processes, which exist in latent form, if their economic return is greater than the existing one.

1.4 The simulation model

The estimation of the cost function according to the approach described above, guarantees the reproduction of the existing land allocation without further need of the calibration constraints present during the first stage. This latter model uses the information related to cost of production estimated in the second phase. The model, which this time is non-linear, appears as follows:

$$\begin{aligned} \max_{\mathbf{x}} \quad & \boldsymbol{\pi}_r^{'}\mathbf{x}_r + \boldsymbol{\pi}_l^{'}\mathbf{x}_l - \frac{1}{2}\begin{bmatrix}\mathbf{x}_r & \mathbf{x}_l\end{bmatrix}\mathbf{Q}\begin{bmatrix}\mathbf{x}_r \\ \mathbf{x}_l\end{bmatrix} \\ & \mathbf{B}\mathbf{x}_r \quad + \quad \mathbf{M}\mathbf{x}_l \quad \leq \quad \mathbf{b} \\ & \mathbf{x}_r \qquad\qquad\qquad \geq \quad 0 \\ & \qquad\qquad\quad \mathbf{x}_l \quad \geq \quad 0 \end{aligned} \tag{19}$$

The cost function takes the place of the calibration constraints of the problem (2), applying an economic threshold to the choice of allocation of the production activities. Moreover, the cost function $\frac{1}{2}\mathbf{x'Qx}$ can be interpreted as the economic profit of the producer (Paris, 1997) i.e. a piece of information that is not usually transmitted by the traditional models of mathematical programming. In this context, the identity between the objective function of the primary problem and that of the dual problem at optimum demonstrates that:

$$\underbrace{\boldsymbol{\pi}_r^{'}\mathbf{x}_r + \boldsymbol{\pi}_l^{'}\mathbf{x}_l - \frac{1}{2}\begin{bmatrix}\mathbf{x}_r & \mathbf{x}_l\end{bmatrix}\mathbf{Q}\begin{bmatrix}\mathbf{x}_r \\ \mathbf{x}_l\end{bmatrix} - \mathbf{b'y}^*}_{revenue-total\ \cos ts} = \underbrace{\frac{1}{2}\begin{bmatrix}\mathbf{x}_r & \mathbf{x}_l\end{bmatrix}\mathbf{Q}\begin{bmatrix}\mathbf{x}_r \\ \mathbf{x}_l\end{bmatrix}}_{profit}. \tag{20}$$

The PMP model constructed in this stage enables an analysis to be conducted of the effects produced by changes in market and policy variables, making full use of the cost information that guided the farmer in the choice of the production system observed, taking into account the latent information about latent activities.

1.5 The PMP model extension to databases without specific costs

The PMP model that describes the possibility of also considering the “latent information” is improved with the use of the PMP FACEPA approach, according to which the model also estimates the variable accounting costs associated to each crop. Since the FADN database doesn’t transmit the information about the specific cost of production, the farm evaluation models risk not being able to analyze the impact of a change in market or policy conditions on the farmer’s behaviour and the related production plan. This is why a specific PMP model has been developed to take into consideration this missing information in the FADN database (see Deliverables 6.1 and 6.2). According to this new approach, the PMP model is split into two phases: a) the aim of the first is to estimate specific accounting variable costs by activity through the reconstruction of a non-linear function of the total variable cost that considers the exogenous observed information on the total variable costs for the individual farm; b) the aim of the second is the calibration of the observed production situation through the resolving of a farm gross margin maximization problem, in the objective function of which the cost function estimated in the previous phase is included.

The first phase is defined by an estimation model of a quadratic cost function in which the squares of errors are minimized:

$$\min_{u} LS = \frac{1}{2}\mathbf{u}'\mathbf{u} \tag{21}$$

subject to

$$\mathbf{c}+\boldsymbol{\lambda} = \mathbf{R}'\mathbf{R}\overline{\mathbf{x}} + \mathbf{u} \qquad \text{se } \overline{x} > 0 \tag{22}$$

$$\mathbf{c}+\boldsymbol{\lambda} \geq \mathbf{R}'\mathbf{R}\overline{\mathbf{x}} + \mathbf{u} \qquad \text{se } \overline{x} = 0 \tag{23}$$

$$\mathbf{c}'\overline{\mathbf{x}} \leq TC \tag{24}$$

$$\mathbf{u}'\overline{\mathbf{x}} + \frac{1}{2}\overline{\mathbf{x}}'\left(\mathbf{R}'\mathbf{R}\right)\overline{\mathbf{x}} \geq TC \tag{25}$$

$$\mathbf{c}+\boldsymbol{\lambda}+\mathbf{A}'\mathbf{y} \geq \mathbf{p}+\mathbf{A}'\mathbf{s} \tag{26}$$

$$\mathbf{b}'\mathbf{y}+\boldsymbol{\lambda}'\overline{\mathbf{x}} = \mathbf{p}'\overline{\mathbf{x}}+\mathbf{s}'\mathbf{h}-\overline{\mathbf{c}}\overline{\mathbf{x}} \tag{27}$$

$$\mathbf{R} = \mathbf{L}\mathbf{D}^{1/2} \tag{28}$$

$$\sum_{n=1}^{N} u_{n,j} = 0 \tag{29}$$

By means of the model (21)-(29) a non-linear cost function can be estimated using the explicit information on the total farm variable costs (*TVC*) available in the FADN database. The restrictions (22) and (23) define the relationship between marginal costs derived from a linear function and marginal costs derived from a quadratic cost function. $\mathbf{c}+\boldsymbol{\lambda}$ defines the sum of the explicit process costs and the differential marginal costs, i.e. the costs that are implicit in the decision-making process of the farmer and not accounted for in the farm bookkeeping. Both components are variables that are endogenous to the minimization problem. **R** is the Cholesky matrix component to guarantee that the cost matrix be symmetric positive semidefinite; while **u** is the vector of deviation from the frontier function. To guarantee consistency between the estimate of the total specific costs and those effectively recorded by the accounting system, the restriction (24) imposes that the total estimated explicit cost should not be more than the total variable cost observed in the

FADN database. Restriction (25) defines a further restriction on the costs estimated by the model, where the non-linear cost function must at least equal the value of the total variable cost (*TVC*) measured. In order to guarantee consistency between the estimation process and the optimal conditions, restriction (26) introduces the traditional condition of economic equilibrium, where total marginal costs must be greater or equal to marginal revenues; the marginal revenue is defined by the price, p, and the possible coupled payments, $\mathbf{A}'\mathbf{s}$.

The total marginal costs also consider the use cost of the production factors defined by the product of the technical coefficients matrix A' and the shadow price of the restricting factors y; while the marginal revenues are defined by the sum of the products' selling prices, p, and any existing public subsidies. The additional restriction (27) defines the optimal condition, where the value of the primary function must correspond exactly to the value of the objective function of the dual problem. In order to ensure that the matrix of the quadratic cost function is symmetrical, positive and semi-defined, the model adopts Cholesky's decomposition method, according to which a matrix that respects the conditions stated is the result of the product of a triangular matrix, **L**, a diagonal matrix, **D**, and the transpose of the first triangular matrix (28). Last but not least, restriction (29) establishes that the sum of the deviations, $u_{n,j}$, must be equivalent to zero.

The cost function estimated with the model (21)-(29) may be used in a model of maximization of the farm gross margin, ignoring the calibration restrictions imposed during the first phase of the classical PMP approach. In this case, the dual relations entered in the preceding cost estimation model guarantee the reproduction of the situation observed. The model, therefore, appears as follows:

$$\max_{x\geq 0} ML = \mathbf{p}'\mathbf{x} + \mathbf{s}'\mathbf{h} - \left\{ \frac{1}{2}\mathbf{x}'\hat{\mathbf{Q}}\mathbf{x} + \hat{\mathbf{u}}'\mathbf{x} \right\} \tag{30}$$

subject to

$$\mathbf{Ax} \leq \mathbf{b} \tag{31}$$

$$A_j x_j - h_j = 0 \qquad \forall j = 1,\ldots,J \tag{32}$$

The model (30)-(32) precisely calibrates the farming system observed, thanks to the function of non-linear cost entered in the objective function which preserves the (economic) information on the levels of production effectively attained. Restriction (31) represents the restriction on the structural capacity of the farm, while the relation (32) enables us to obtain information on the hectares of land (or number of animals) associated with each process j. Once the initial situation has been calibrated through the maximization of the gross margin, it is possible to introduce variations in the public subsidy mechanisms and/or in the market price levels in order to evaluate the reaction of the farmer to the changed environmental conditions. The reaction of the farmer will take into account the information used during the estimation phase of the cost function, in which it is possible to identify a real, true matrix of the farm choices, i.e. Q. In this framework, the PMP methodology described in this section will be implemented for recovering the specific production costs related to the process whose data are collected by the FADN.

2 The application of the PMP model with latent information to the case of Veneto region

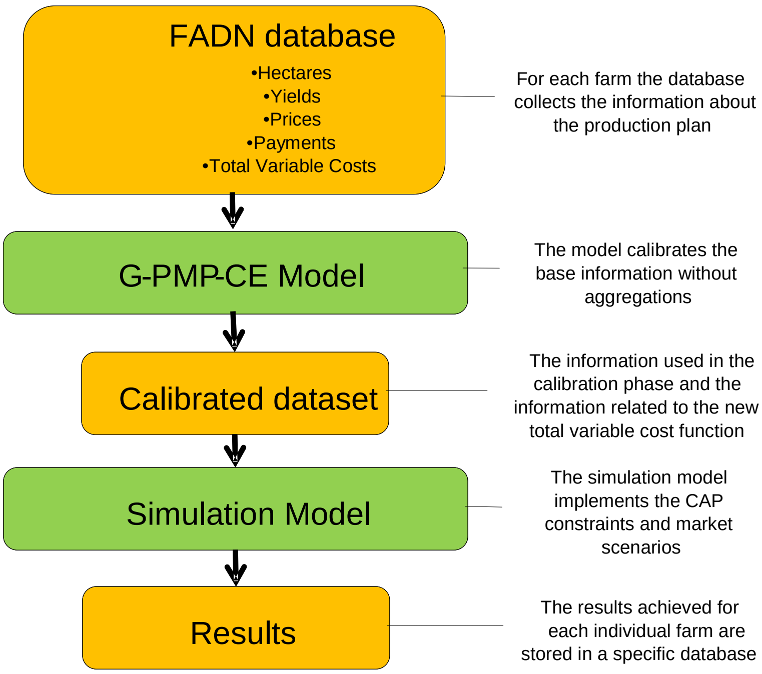
2.1 Hypothesis adopted and assumptions

The objective of this deliverable is to test the PMP model with latent information within a framework where some variables, like market prices and agricultural policy might change. In particular, the evaluation process with the PMP model would indicate the farm strategy with respect to the choice of latent information considering an evolution in some environmental variables, like market prices and CAP mechanisms. The model presented in the previous chapter is a PMP based model that implements the latent information approach with the estimation of the specific costs missing from the FADN database. The model tries to estimate the specific costs for the observed and realized activities and for latent technology and latent crops; latent information is used in the simulation phase of the PMP procedure in order to capture the farmer's behaviour with respect to the possibility of changing the technology or changing the set of products observed in the basic year.

The information used is exclusively originated from the FADN database and focuses on the case study of Veneto region in Italy. In order to work with information as homogenous as possible, as indicated also in Deliverable 6.2, the sample of farms belonging to the Veneto region is restricted to the subset of farms specialized in arable crops, i.e. farm type 1 (FT1). The only activities considered are annual crops, since livestock production requires information that is difficult to model and often missing from the FADN database (e.g. meat yield, prices); also permanent crops, like fruits, are not considered in the model, since for this type of process the model should be formulated to consider the long-term evolution of these activities and the long-term competition with annual crops. In order to avoid livestock production information perturbations in the estimation process and competition with annual and permanent crops, only annual crops have been kept in the database, considering that the influence of the other activities inside arable crops specialized farms is not relevant.

The data is used in the model at individual level, so that each farmer is subjected to behaviour estimation and simulation. Each farm is firstly depicted in the observed situation with its production plan and the potential latent activity that each farmer could consider in the production plan. For each activity, realized and latent, the information collected is related to the hectares cultivated (for the latent crops, the hectares assumed are a very small portion of the cultivated land), the yield, the market prices and every specific public subsidy. In order to estimate the specific cost of production of each crop, the only information considered in the analysis and obtained from the FADN archive is the total variable costs at farm level. The total variable cost is important in order to drive the model as well as possible to recover the most realistic specific cost per crop. Furthermore, the information about the single farm payments, amount and number of rights, is collected from the European database and used at farm level. The figure below shows the structure of the model and relevant information needed and produced in each phase,

Figure 1: Structure of the PMP model



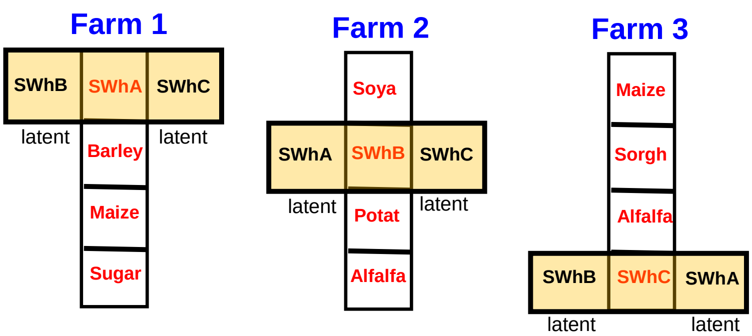
Summarizing the layout of the model structure, one can say that the first phase is dedicated to the identification of the relevant information to use in the model. This part of the data processing defines filters in order to use the information useful for the PMP evaluation and organizes the data in order to be used with GAMS, the algebraic package adopted for building the model. The model calibration, by means of the General PMP Cost Estimator (G-PMP-CE) model, provides important information about the specific costs of realized and latent productions. These costs are used in order to calibrate the model and to simulate farmer behaviour with respect to modification in CAP and market scenarios. The simulation model uses the calibrated dataset (all the information coming from the calibration procedure at farm level) in order to assess how farmers react to new scenarios taking into account the CAP constraints. The results obtained with the simulation model are stored in a specific database in order to organize the analysis.

2.2 Latent information in the simulation phase

The evaluation purpose is twofold: on the one hand, we want to estimate the impact of policy and market scenarios on the possibility of adopting a new production technology in the production plan; on the other hand, the objective is to assess the role of CAP and the market in introducing a new crop to the the production plan.

Graph 1 presents the scheme of a scenario where the objective is to evaluate the capacity of one technology not considered in the basic production plan to substitute another technology already adopted on the farm. For example, we can suppose that for soft wheat a set of three different production technologies exists, characterized by different yields, costs and prices, and suppose that the sample is composed of three farms, each one adopting a different technology for soft wheat.

Graph 1: Decision scheme for latent technology scenarios



This type of simulation phase aims to evaluate when and in what way the technologies not adopted by the farmer enter the production plan. The two technologies that are not chosen by the farmer should be considered, in this context, as latent technologies, i.e. technologies present in the sector, considered by the farmer in his decision process but not adopted.

In this analysis, **two crops** grown in the basic year have been submitted to the latent technology evaluation. More specifically, **soft wheat** and **maize** have been divided into three different technologies according to the yields: in order to take into account the different technologies adopted by the farmer in producing crops, we consider the yield level as the parameter for identifying the farm technology. **Soft wheat** was investigated in order to identify three yield classes that can reveal three different technologies present within the Veneto sample:

a) ≤ 5 tons/ha

b) > 5 tons/ha and ≤ 7 tons/ha

c) > 7 tons/ha

Each of these three technologies for producing soft wheat are characterized by different pricesm according to FADN information and different costs, according to size, territorial location, farm structure, managerial variables, etc. The latter are estimated using the previously explained PMP approach, in order to highlight the implicit costs for these different technologies. In the simulation phase, all the information concerning the three technologies is used in order to evaluate if the farmers with a given type of technology in the basic situation, in a new environmental framework, are available to substitute it with a new technology present in the sample (because adopted on a given number of sample farms).

The same procedure is developed for **maize** production, for which we have identified three yield classes, i.e. three production technologies:

a) ≤ 10 tons/ha

b) > 10 tons/ha and ≤ 12 tons/ha

c) > 12 tons/ha

Also in this case, the simulation tries to evaluate in which conditions of agricultural policy and market prices farmers with a given basic technology for maize can substitute that technology with a different one among those identified in the sample.

According to the other simulation scheme, another set of scenarios concerns the possibility of introducing a new crop not present in the production plan but, again, considered within the framework of the decision process. In this case, it would appear useful to investigate if the CAP policy can play a role in influencing the profitability of the new crop in place of the basic crops.

The new crop considered in the analysis is sorghum for energy production. We have assumed that this crop is not present in the basic production set at regional level. The crop enters the regional production plan as a new production possibility with the related technological and economic information. In this sense, we want to test a hypothetical development of a biomass chain based on sorghum production estimating the price starting at which this new type of activity can be inserted among the other basic information. The results that will be obtained are interesting in order to define a threshold price for sorghum and to evaluate the relationships with the other crops.

2.3 Policy and market scenarios

The simulation model was developed in order to consider the effective situation in terms of policy and market in 2009. To do that, the model implements the CAP mechanisms in place in 2009 and the market prices of the same year. Starting from 2007, the year of data collection, the simulation for 2009 has updated the information on prices and CAP support, providing a new production plan at individual and regional level. This represents the reference scenario in our analysis, i.e. the scenario used for comparing the results obtained implementing the other simulations.

In terms of policy scenario, the model tries to reproduce the Health Check Reform (HC). On the basis of the HC document, the scenarios developed consider the actual situation in terms of aid provided for fruit and vegetables and the reform that will affect those products starting in 2011. As the data adopted for this study refers to 2007, the model foresees a specific scenario that reproduces the transition period currently characterizing the fruit and vegetable sector. Then, in compliance with the decision of the Italian Minister, a scenario was evaluated in which all the subsidies, fruit and vegetables included, are decoupled according to the historical approach. The first scenario is the reference (base) scenario, while the second one is the situation forecast for 2011 onwards. It is important to mention that the decoupling developed in the model for fruit and vegetables only concerns annual fruits and vegetables (mainly tomatoes) and not permanent crops, like peaches, plums, etc.

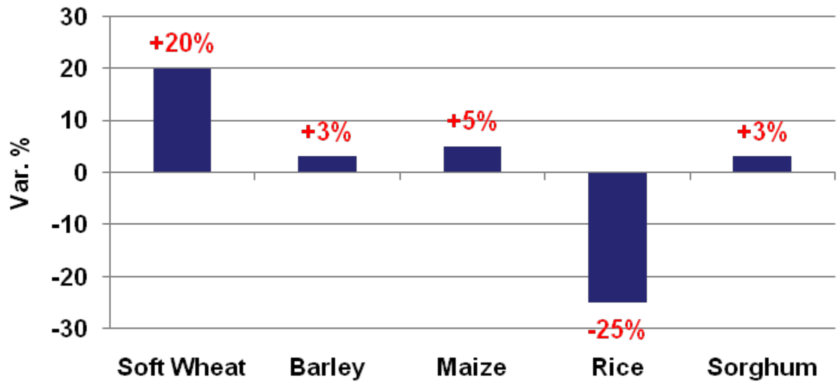
The modulation is also considered in the model. In the HC, modulation is the principal instrument addressing the financial strengthening of the second pillar, draining resources from the first pillar. In consideration of the new issues identified in the HC document as the new challenges to be tackled within rural development (climate change, renewable energies, water management and biodiversity protection), the Commission introduced a reinforcement of the compulsory modulation. The HC introduced a new mechanism based on a progressive increase of the modulation rate from 5% to 10% for the payments between 5,000 euros and 300,000 euros and 14% for part of the payments exceeding 300,000 euros.

In summary, we can first identify three scenarios:

1. Basic situation (2007): the scenario concerns the calibrated data, i.e. the production situation provided by the sample;

2. Transitional fruit and vegetable reform period (reference scenario): the scenario reproduces, in terms of agricultural policy and market conditions, the situation existing in 2009 and is used as reference scenario for the simulation purposes;
3. Total decoupling scenario: all the payments are decoupled according to the HC reform and new modulation rates are introduced. The market conditions are those projected for 2013 (the last year of HC validity) by FAPRI for some relevant crops (Graph 2).

Graph 2: Variation of market prices for some relevant crops (2013/2009)



The model does not consider animal production, so the milk quota modifications are not taken into account.

Starting from these scenarios, the farm behavioural reaction towards the new activities is analyzed. The scenarios developed for responding to this issue should be divided in two groups: the first one related to the technology change and the second to the new crop introduction.

For assessing the adoption of new technologies, the scenarios consider a progressive increase in the price from 0.1 euros/ton to 10 euros/ton with a step-by-step increase of 0.1 euros/ton. This means that for each product 100 cycles of simulation have been carried out in order to get a sensitivity response for the production plan and, in particular, for the technology substitution at individual level. One cycle of 100 simulations on price has been developed for soft wheat split in the three different technologies and one cycle of 100 simulations on price for maize divided in the three different technologies. The aim of this simulation is to observe the dynamics of the three technologies progressively modifying the related price and, thus, capture the process of substitution within the three technologies and between the three technologies and the rest of the production plan.

As regards the new crop simulation, the objective is to evaluate under which economic conditions the new crop can be inserted in the production plan of the farms in Veneto. The new crop, represented by sorghum for biomass production, is submitted to a cycle of simulation that foresees the progressive increase in its price, starting from zero and reaching 150 euros/ton. Also in this case, the simulations can be considered as a sensitivity analysis of sorghum with respect to the price evolution, but with further information to explore. Indeed, this approach applied to the potential new crop can provide useful information about the threshold at which the crop becomes profitable for the farm. If the objective is to assess if it is possible to develop a new food chain using a product that traditionally doesn't exist in a given territory, the simulation model developed in this framework can be useful in order to indicate the price level needed in order to obtain a production response in line with the food chain objective. For example, in the case of sorghum for biomass, it is important to know the price that can allow a sufficient raw material supply to be created for the processing industry. This kind of simulation can also provide information about the change of the main economic variables and the production plan composition in relation to the price modification.

2.4 Data entry description

This section describes the sample of farms used in the analysis for estimating the effects of the single farm payment on cost function and production function. The analysis was developed with respect to the farms belonging to farm type 1 "arable crops" in the Veneto Region (Italy). The data were collected from the national FADN archive for the year 2007. For each farm the database collects the information about the production plan; therefore, the variables considered in the model were: area (in terms of hectares), production (in terms of tons), and prices (euros/ton).

The sample considered in the analysis was composed of 413 farms. In order to give a statistical description of the Veneto sample, four classes of farm size (in terms of hectares) were identified with the relative numbers.

≤ 20 hectares	=>	218 farms
> 20 and ≤ 50 hectares	=>	122 farms
> 50 and ≤ 100 hectares	=>	40 farms
> 100 hectares	=>	33 farms

Table 1: Statistical description of Veneto FADN sample – Farm type 1

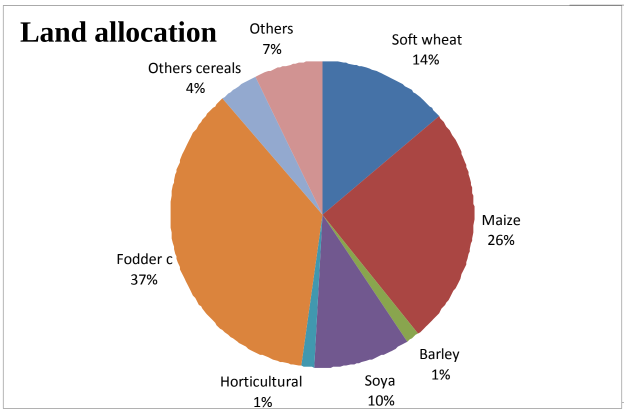
Class of UAA	N. of Farms	AV. UAA (ha)	Cereals / tot (%)	GSP/ha (€)	Total Variable Costs / ha (€)
≤ 20 hectares	218	9,00	46	1200	534
> 20 and ≤ 50 hectares	122	31,72	49	1098	487
> 50 and ≤ 100 hectares	40	70,11	44	1196	521
> 100 hectares	33	231,87	42	1197	489
Total	413	39,44	45	1177	500

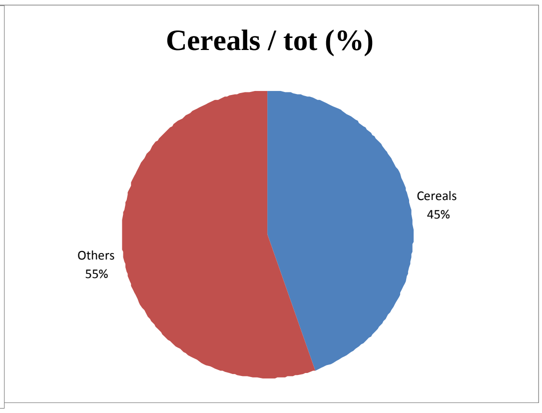
The average size of each farm in the sample is 39.44 ha, although it ranges from an average size of 9 ha, for the small farms, to an average size of 231 ha, for the big ones. On average, the incidence of cereals on the total UAA is 45%.

The average gross saleable production (GSP) per hectare is 1.2 euros for farms belonging to the first size class; 1.0 euro for farms belonging to the second class, and 1.1 euros for farms belonging to the third and fourth class. The total variable cost per hectare is 500 euros. The data analysis shows that for the small farms, the highest level of land productivity measured by GSP/ha is also accompanied by higher total variable costs (Table 1).

Considering the entire sample of 413 farms, in Veneto fodder crops are the main crop type, covering 36% of the total area. Other important crops are maize that represents 25% of the entire acreage, soft wheat, with 14% and soya, with 11% (Figure 2). Overall, the incidence of cereals on the total area is 45%, as illustrated by Figure 3.

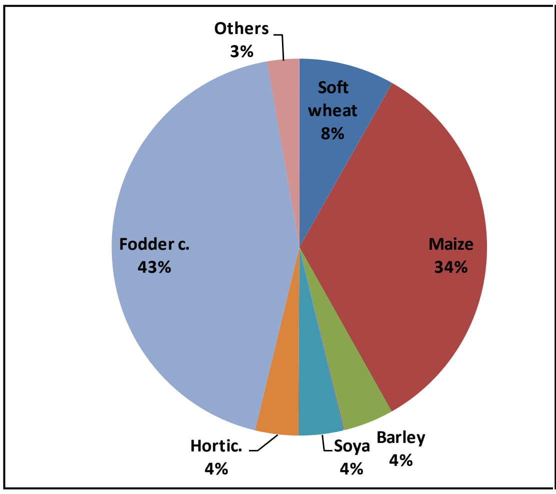
Figure 2: Land allocation **Figure 3: Incidence of cereal on total area (in %)**





Analysing the crop distribution within the four classes of UAA, it emerges that on small farms there is a strong production specialization, while the production becomes more diversified on big farms. On the farms with an area of less than 20 ha, fodder crops and maize are the most important crops, involving 43% and 34% of the total area respectively. On the other farms fodder crops and maize are again the most important crops in terms of area, but their incidence on the total area decreases, leaving more space for other crops (Figure 4).

Figure 4.a: Crop distribution on farms 0-20 ha **Figure 4.b: Crop distribution on farms 20-50 ha**



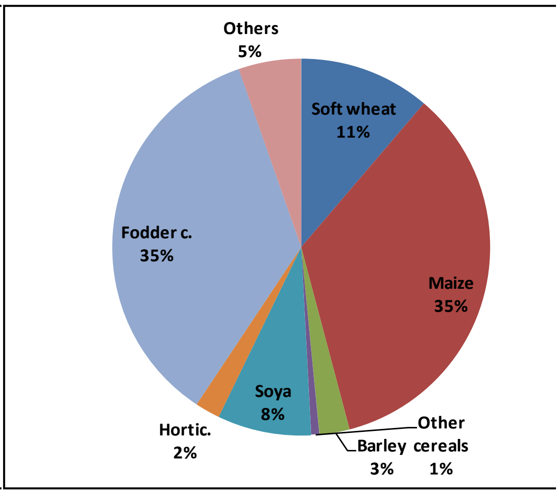


Figure 4.c: Crop distribution on farms 50-100 ha

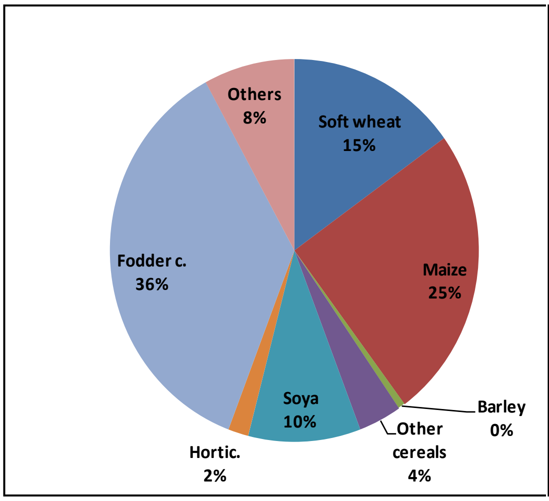
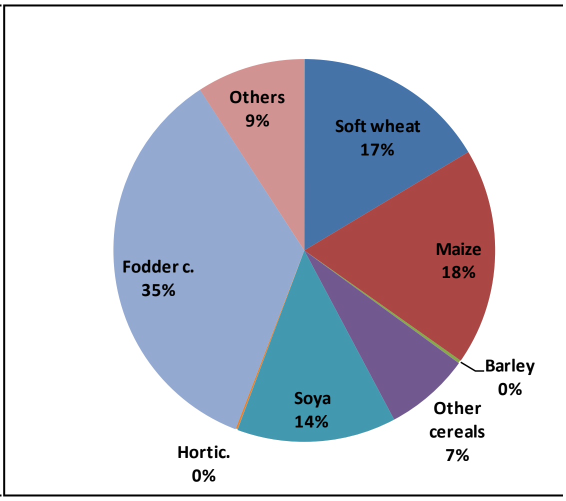


Figure 4.d: Crop distribution on farms > 100 ha



In order to obtain an appropriate level of estimation, the quality of the data was also verified in terms of degree of homogeneity and presence of outliers. The sample analysis highlighted the degree of dispersion of observations for soft wheat and maize with respect to prices and yields. For maize there is a good level of homogeneity, with few cases of farms that deviate from the cluster of observations. Also for soft wheat the dispersion is low, although there are some observations out of the range (Figures 5 and 6).

Price and yield distribution in FT1 sample for Veneto case study

Figure 5: Soft Wheat

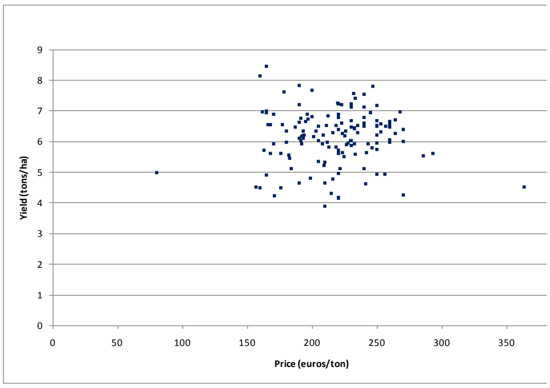
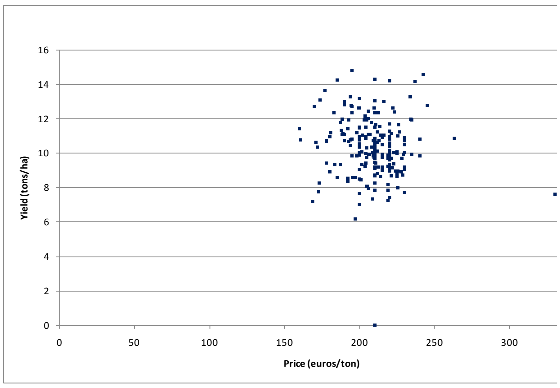


Figure 6: Maize



3 PMP model implementation with latent activities

3.1 Results obtained for the latent technologies

Results show how the PMP FACEPA is able to estimate the accounting variable cost for all the activities observed in the FADN database and is also able to predict the impact of market price or CAP measure on existing crops that adopt a different technological level or on new crops that are introduced in a given territory.

Results show how the impact of price variation is sensitive to the farm size and level of specialization of the producers. In particular, increasing price for soft wheat and maize will increase the use of the most intensive technology for the two considered crops and for the three farm types. This strategy will reduce the presence of soft wheat and maize with low yield and increase the technology with higher yield. Of course this strategy will benefit farm income that will increase, but will have a negative impact on the environment because it will increase the acreage of more intensive crops in Veneto region.

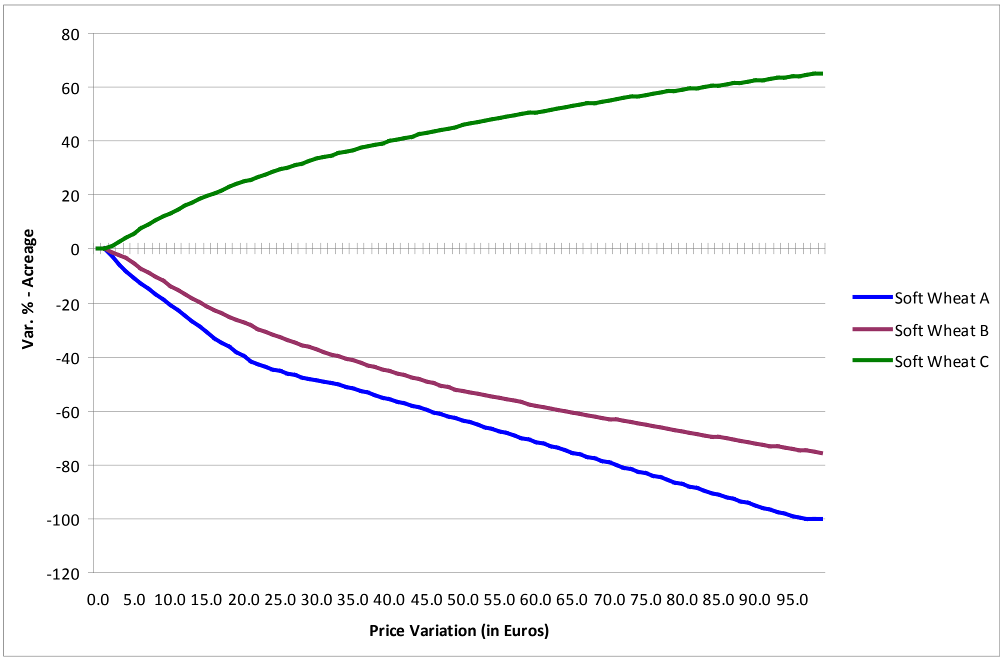
In the next section the graph is presented relative to the main impact on the land use of farms aggregated by their level of production intensity. For better understanding the model results, it is important to remark that the option to activate one of the technology not present in the basic scenario is available at farm level when Health Check CAP modifications are introduced. For this reason all the three technologies might be present in the first sensitive price scenario that follows the Health Check scenario.

3.2 Soft wheat

3.2.1 Entire sample

Figure 7 shows how new market conditions for soft wheat can affect farmers' decisions to adopt other types of technologies to produce the same crop. The price increase indicates the prevalent technology very clearly: soft wheat technology C is the dominant one, i.e. the technology with the highest productivity associated with the highest marginal profit. The green curve identifies a progressive increasing in the incidence of the soft wheat C with the increase of the related market price; this positive response to the market prices corresponds to an important decrease for the soft wheat technologies A and B. Technology A, even under a relevant rise in its market prices suffers the competition with the other two technologies, in particular with technology C. This latter substitutes the acreage of technology A, that appears to be the marginal and least competitive technology in the sample. Technology B is, on the contrary, much more resistant to the competition with the soft wheat C than technology A. Indeed, even if higher relative profitability of C largely benefits from the price increase, technology B maintains more than the 20% of the acreage with a price increase of 100 euros/ton.

Figure 7: Three technologies of soft wheat evolution changing the prices (all farms)



The positive variation of the soft wheat C indicates, as mentioned above, a process of substitution of the less intensive and profitable technologies in favour of the more intensive and profitable one; but, the process of substitution doesn't just involve the three technologies of soft wheat but also the other crops, because the simulation approach considers the adaptation of the entire farm production plan considering all the crops grown on the farm. For this reason, a rise in the relative profitability of one crop, induced by a market price increase, can affect all the crops with a lower relative profitability. In figure 8, the variations of the incidence of the three soft wheat technologies are compared with two important regional crops, maize and soya. The surface area of soft wheat C increases using the acreage of the other two technologies, but also the acreage of maize and soya that in the market scenarios reduce by up to 35% and 25% respectively. In terms of percentage incidence (figure 9), maize is the crop most affected that from an incidence of 35% on the total area moves to 20%.

Figure 8: Three technologies of soft wheat evolution changing the prices wrt maize and soya (all farms)

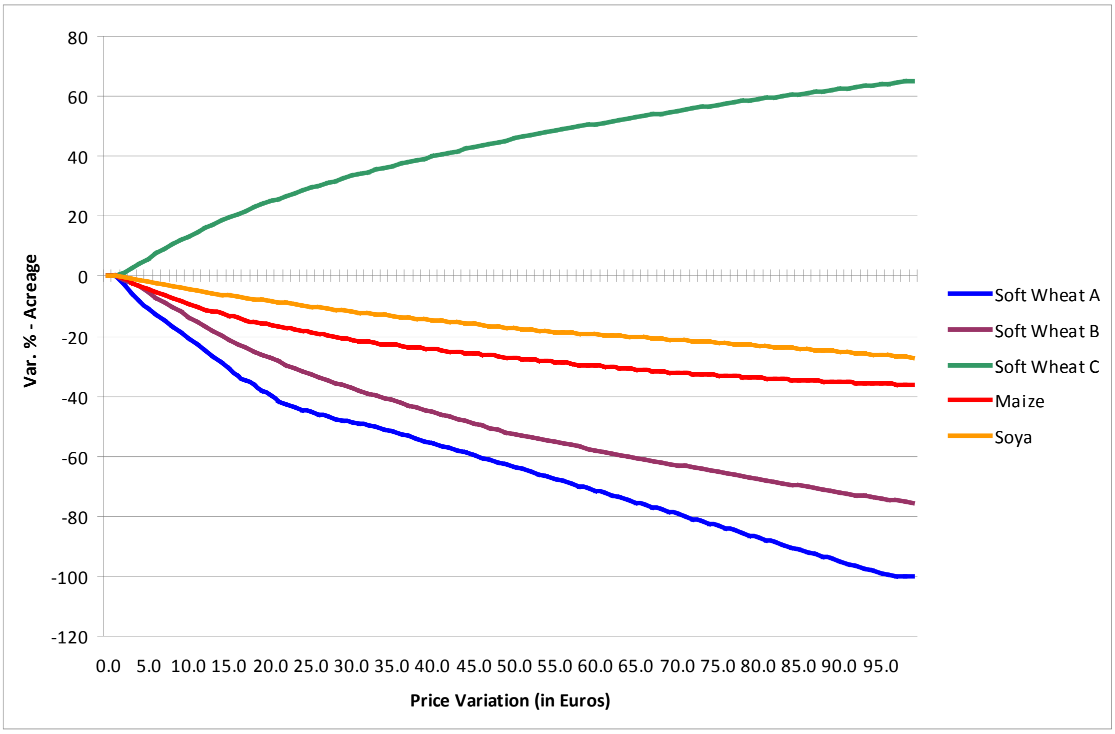
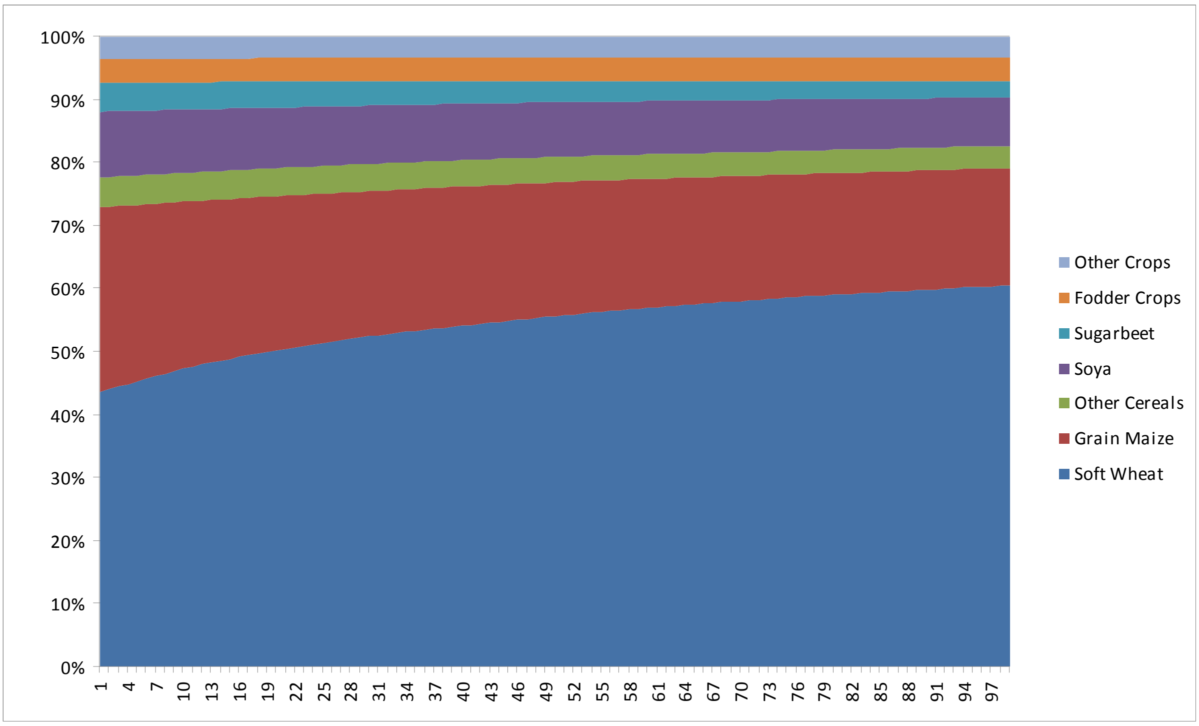
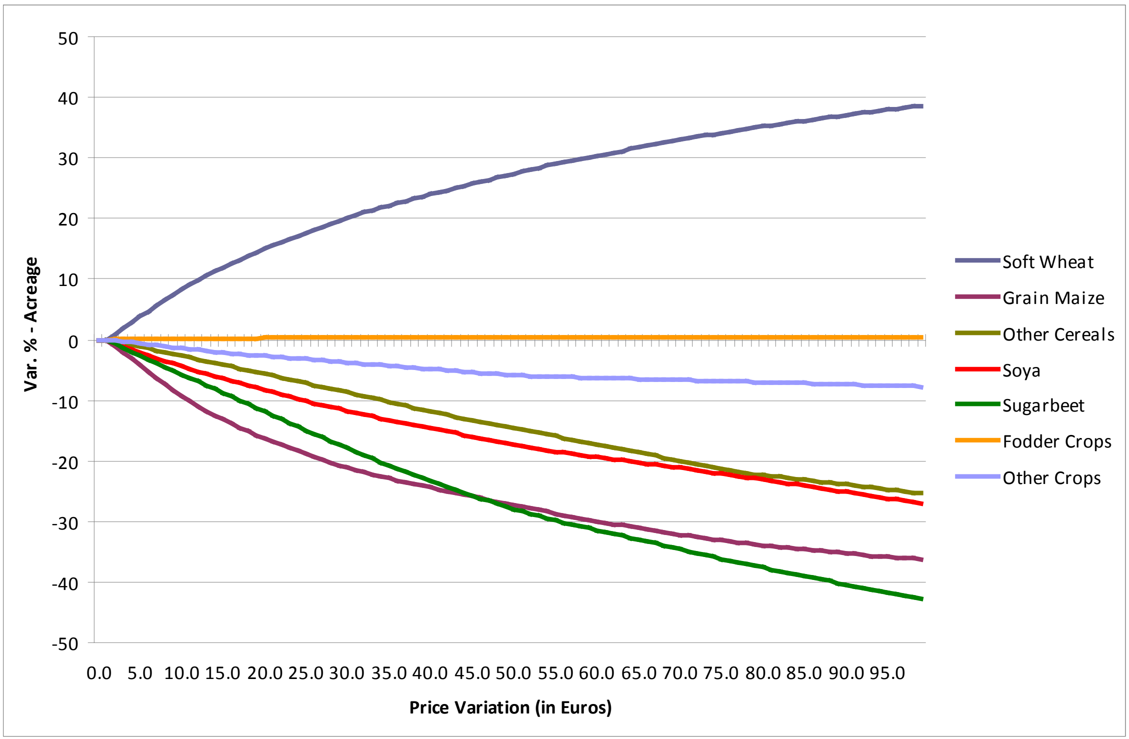


Figure 9: Production plan dynamics according to soft wheat price variation (all farms)



It is interesting to observe how each crop reacts to the soft wheat price increase. As we have highlighted previously, the increase in soft wheat produced a reduction in soya and maize. In this, we considered the dynamics of soft wheat technologies with respect to two important crops in the regional production set. The results obtained by the PMP model provide information for the entire production plan, so that it is possible to analyze the behaviour of each crop with respect to soft wheat. Figure 10 shows the percentage variation of the acreage assigned to the main group of crops that are present in the sample. As the figure shows, the curves that incorporate the sensitivity of the group of crops to the variation of soft wheat prices indicate the relevance and the dominance of soft wheat with respect to each other crop. The crops less competitive towards the soft wheat price increase are maize and sugar beet, which show the largest decrease in percentage terms. On the contrary, the fodder crops don't seem to be influenced by the market price modification, remaining stable at the basic situation. After a certain point, fodder crops show a very small trend towards increasing in response to the big expansion of soft wheat and the rotation criteria that the model requires. Indeed, the PMP model traces a relationship between the cereal crop and fodder crops in order to identify a sort of rotation criterion that must be considered and to provide a more realistic framework during the simulation phase. In other words, the model states that the relationship between the two groups of crops calculated as the ratio between the two total acreages observed in the basic year, less a little tolerance, must remain the same.

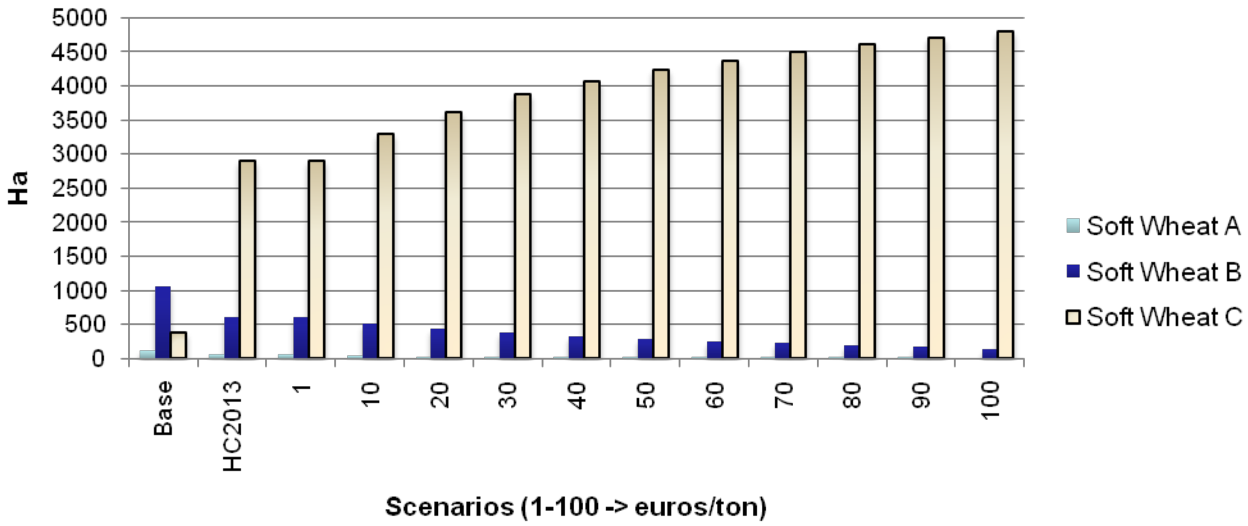
Figure 10: Percentage variation of the groups of crops changing the prices wrt the reference scenario (all farms)



The figures above highlighted the evolution of the crop acreage, in particular soft wheat, with respect to a variation in market prices. The discussion was addressed to this dynamics without considering the role of the CAP policy in defining this kind of behaviour. In the previous trends the price variations are overlapped with the agricultural policy mechanisms and for this reason the policy component becomes a neutral element in the analysis. The CAP policy reform (the Health Check) is integrated from the first price scenario. In order to indicate the role of the CAP policy in the farmer behaviour and, in particular, in the decision among the different available technologies to adopt, we propose the graph below (Figure 11) where the first three scenarios identify the change in agricultural policy. More specifically, the first scenario (Base) that identifies the basic scenario, or the reference scenario, the scenario concerning the 2009 situation (in policy and market terms), can be compared with the second scenario (HC2013) where all the Health Check mechanisms come completely into force and complete the process of transition to the total decoupling and plain modulation (the two main CAP elements considered in our analysis).

In the BASE scenario, it is possible to see the hectares covered by the three types of soft wheat after the simulation with agricultural policy and price at 2009; while in the scenario HC2013, the three soft wheat technologies are simulated taking into account the total decoupling for fruits and vegetables and the reinforced modulation rate. The HC completion seems to influence the cross profitability of the crops so that the soft wheat with the technology more advantageous considerably increases its weight with respect to the other technologies but also with respect to the other crops. The soft wheat C moves from 400 hectares to 2800 hectares, indicating that the change in agricultural policy could influence the modification of the farm technology. The progressive increase in soft wheat price produces the increase in soft wheat C and the reduction of the other two types of crops.

Figure 11: Acreage evolution of the three soft wheat technologies changing the prices (all farms)

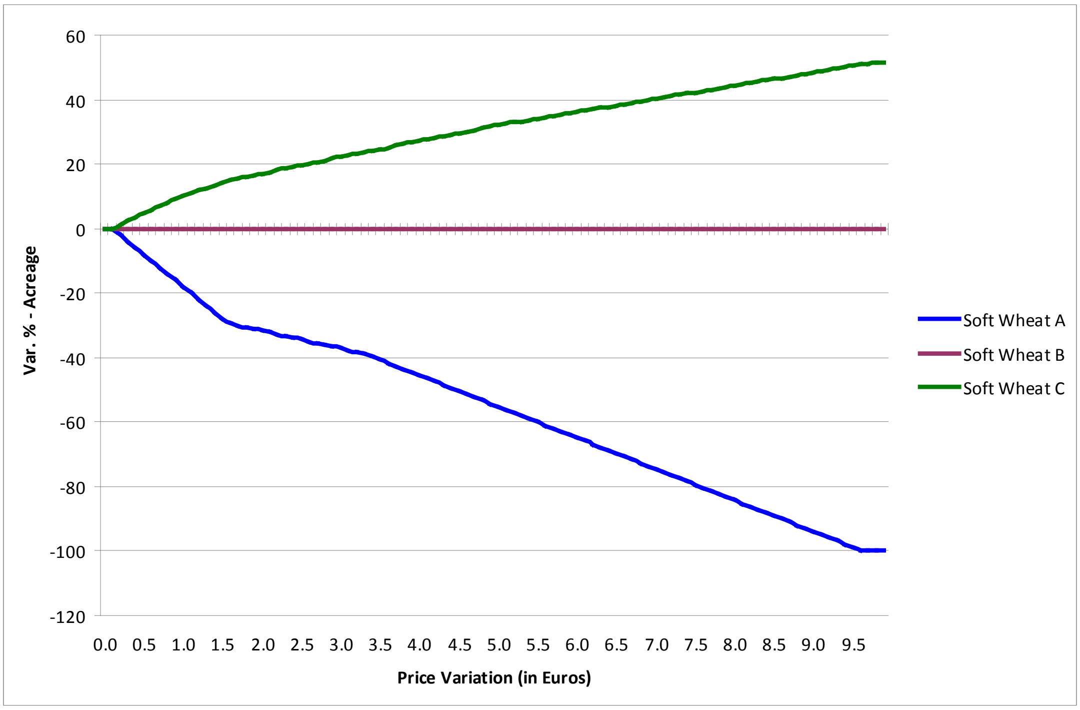


3.2.2 Farms with soft wheat technology A

In the previous section, the main results obtained for the Veneto region have been proposed with the aim of providing some useful references in order to understand the meaning of the simulations carried out within the framework of this project task. In this section, we report the results obtained for the farms adopting one of the three different technologies for producing soft wheat. In this context, the farms using technology A for producing soft wheat are investigated for capturing the behaviour in response to the scenarios foreseen in our analysis.

Figure 12 shows the response of the three technologies of soft wheat on those farms. It is clear that the rise in the soft wheat price produces a decrease of the less profitable technology, in this case technology A, and an increase in the acreage cultivated with soft wheat C, which is evaluated as the most profitable technology. Technology B is not activated, because on average it is less efficient and profitable than technology C. When the price approaches an increase of 100 euros/ton, technology A disappears.

Figure 12: Three technologies of soft wheat evolution changing the prices (soft wheat technology A - farms)



The relationship of soft wheat with the rest of the production plan indicates that the positive variation of the soft wheat price with the introduction of the new technology considerably reduces the profitability of the other crops. In particular, the surface area of maize and soya decrease in favour of soft wheat.

The discussion about the role of the agricultural policy in the change of technology can be introduced considering figure 13, where the reference scenario (BASE) and the situation proposed for 2013 (HC2013) are compared. The adoption of the total decoupling in all agricultural sectors added to a more intensive modulation push the farmer to specialize in the crop where he can benefit better from the cost reduction and higher productivity. The behaviour is very similar to that observed for the sample: a reduction in soft wheat A with a strong increase in soft wheat C that from the scenario HC2013 reinforces its weight in the production plan.

Figure 13: Three technologies of soft wheat evolution changing the prices wrt maize and soya (soft wheat technology A - farms)

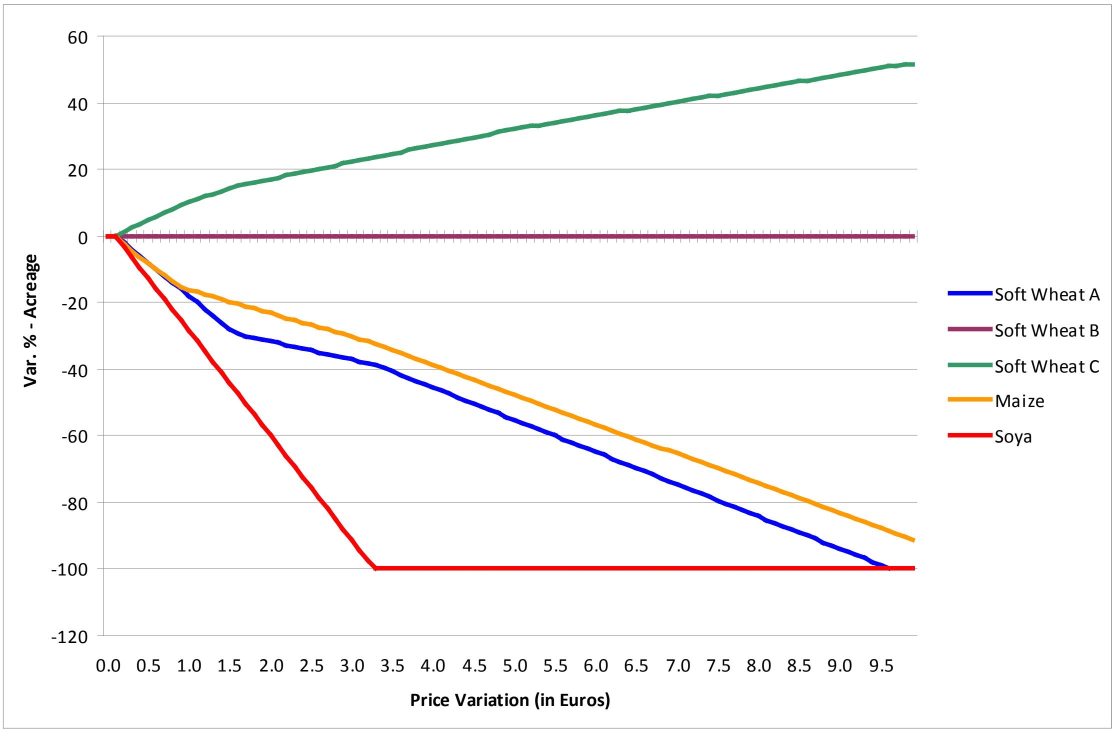


Figure 14: Production plan dynamics according to soft wheat price variation (soft wheat technology A - farms)

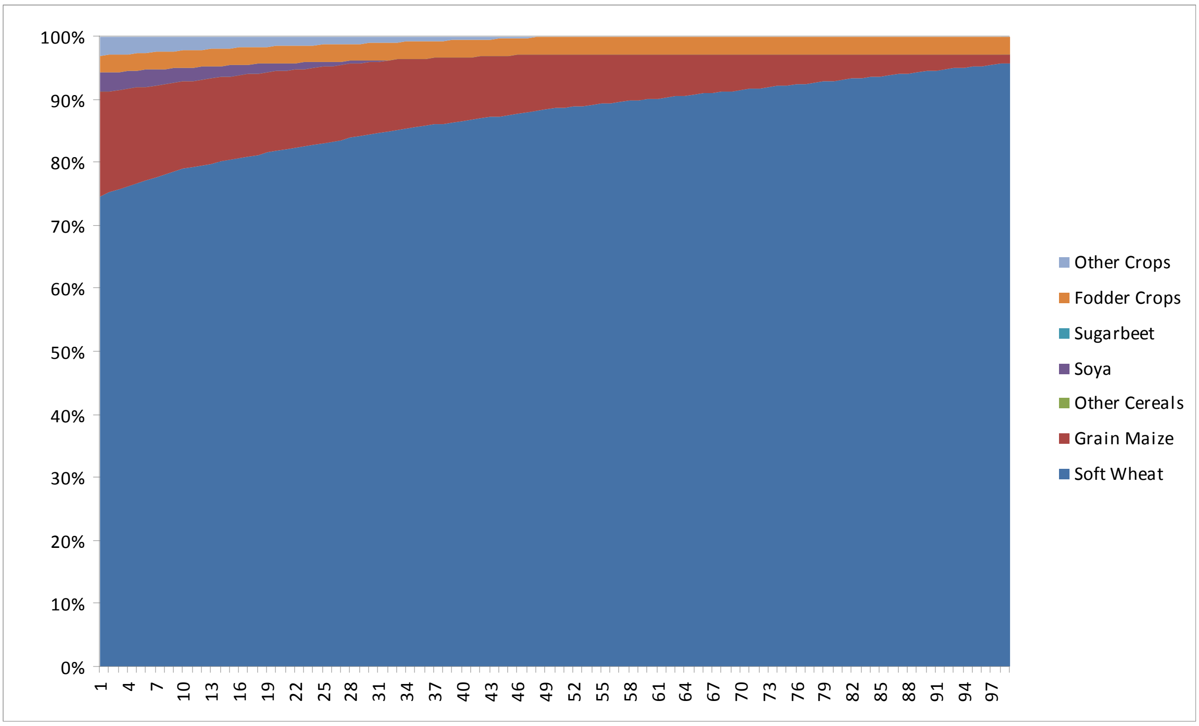


Figure 15: Percentage variation of the groups of crops changing the prices wrt the reference scenario (soft wheat technology A - farms)

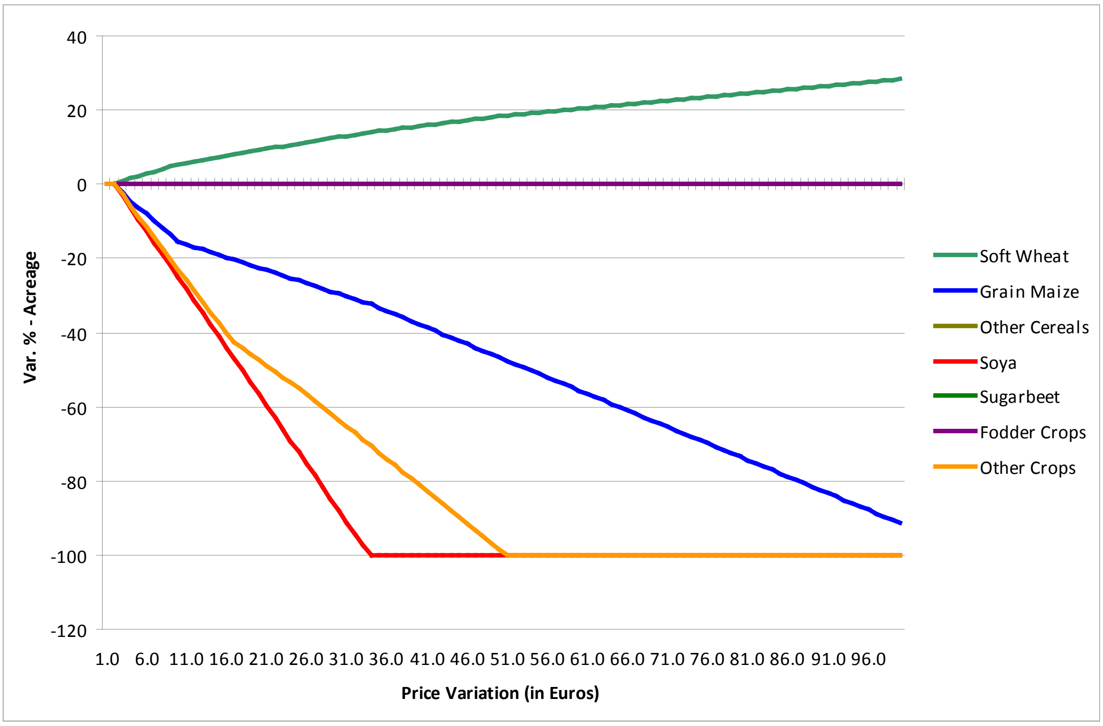
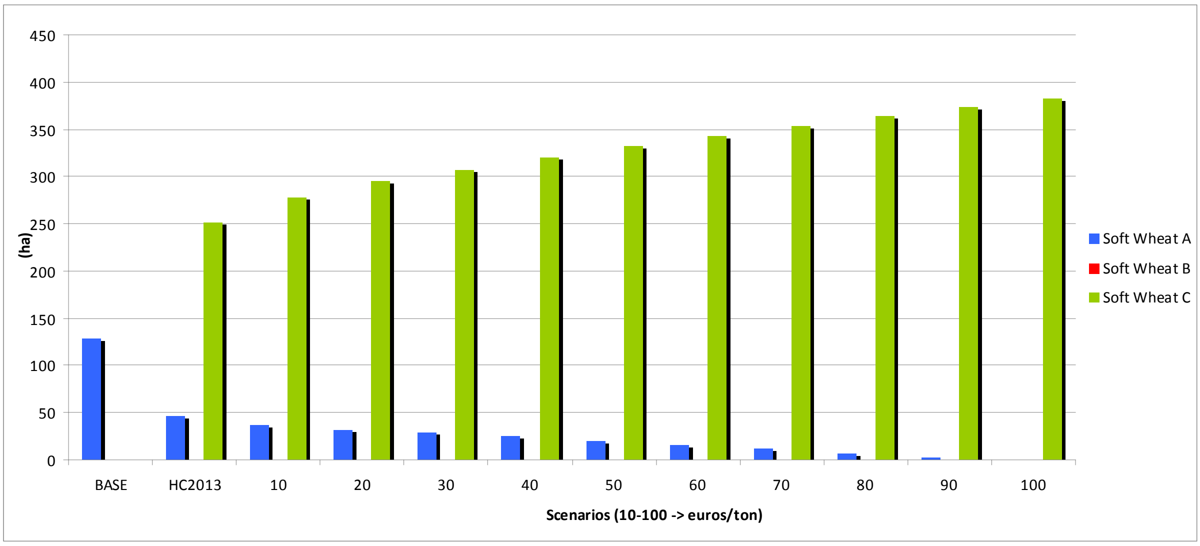


Figure 16: Acreage evolution of the three soft wheat technologies changing the prices (soft wheat technology A - farms)



3.2.3 Farms with soft wheat technology B

The farms with soft wheat B have demonstrated a certain resistance to change the technology by moving to technology C. Figure 18 shows an important increase in the more productive soft wheat (C) and a reduction in the acreage growing soft wheat B, but without the disappearance of this production even at an increase of 100 euros/ton.

The competition with other crops is not different from the other results: grain maize, soya and sugar beet are the crops that suffer most from the price increase of soft wheat; the hectares dedicated to fodder crops don't change very much due to the rotation constraints that maintain the ratio with cereals around the value observed in the initial situation.

Figure 17: Three technologies of soft wheat evolution changing the prices (soft wheat technology B - farms)

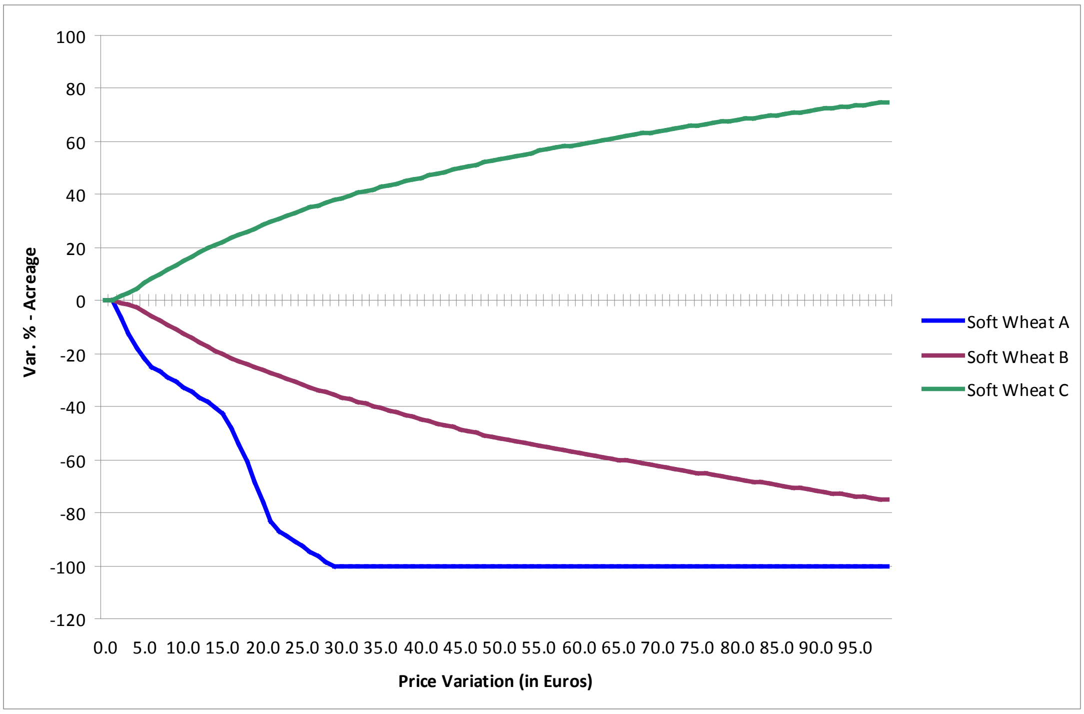


Figure 18: Three technologies of soft wheat evolution changing the prices wrt maize and soya (soft wheat technology B - farms)

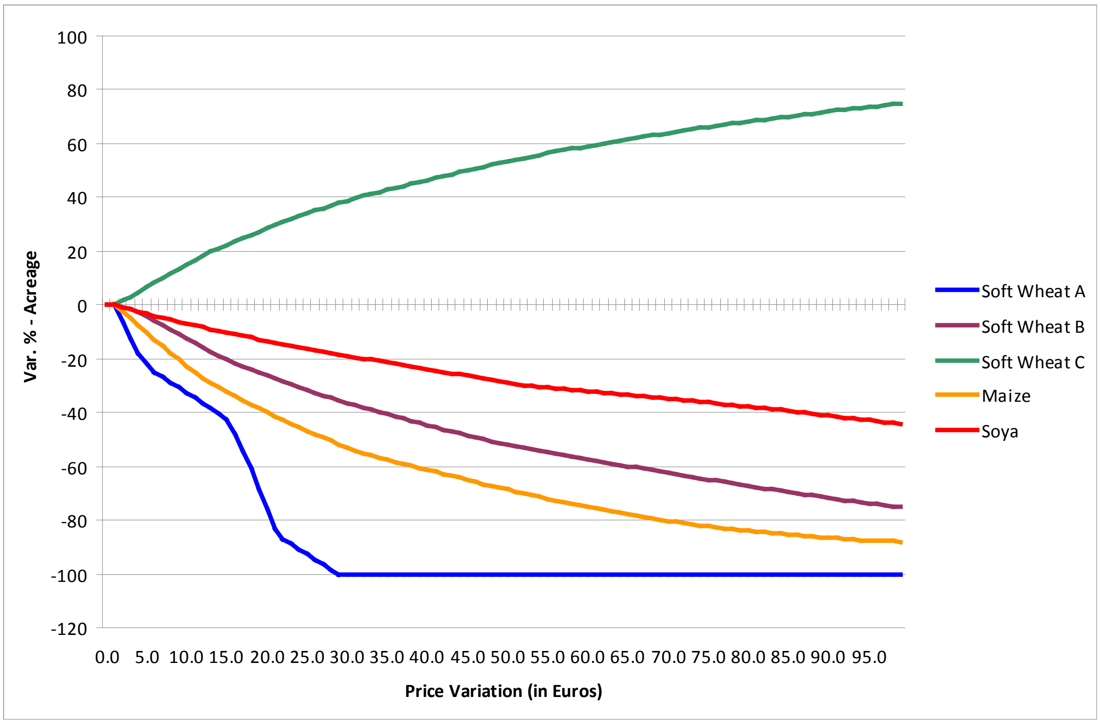


Figure 19: Production plan dynamics according to soft wheat price variation (soft wheat technology B - farms)

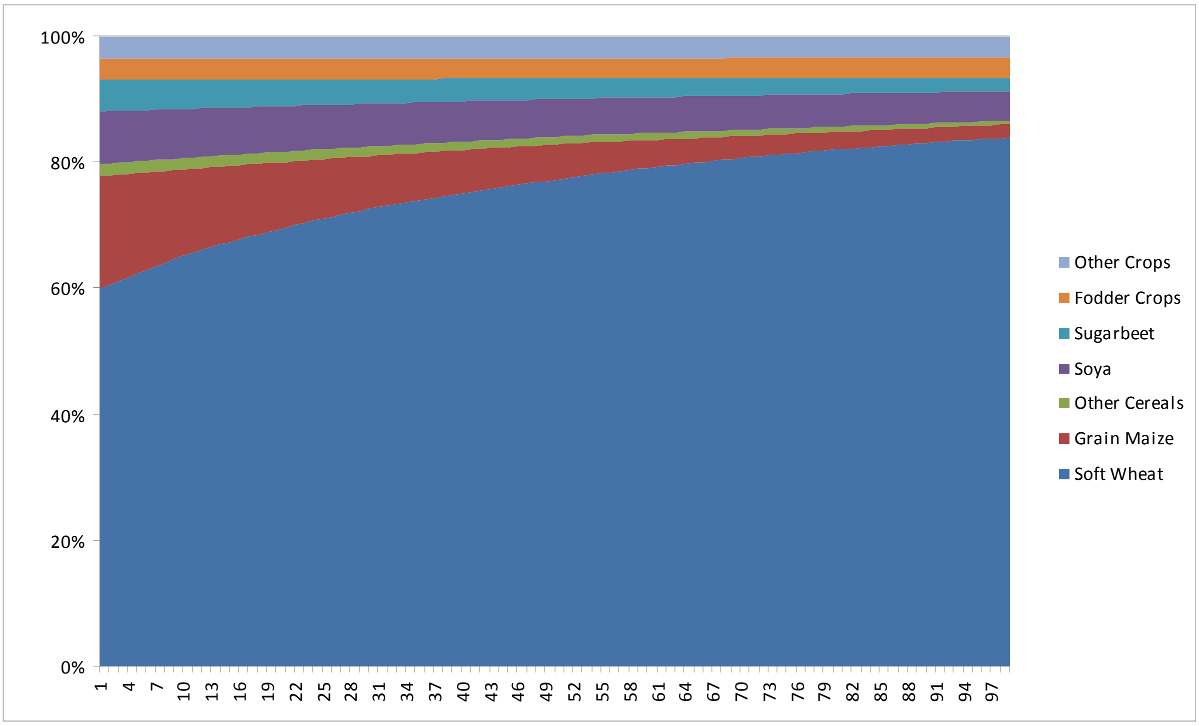


Figure 20: Percentage variation of the groups of crops changing the prices wrt the reference scenario (soft wheat technology B - farms)

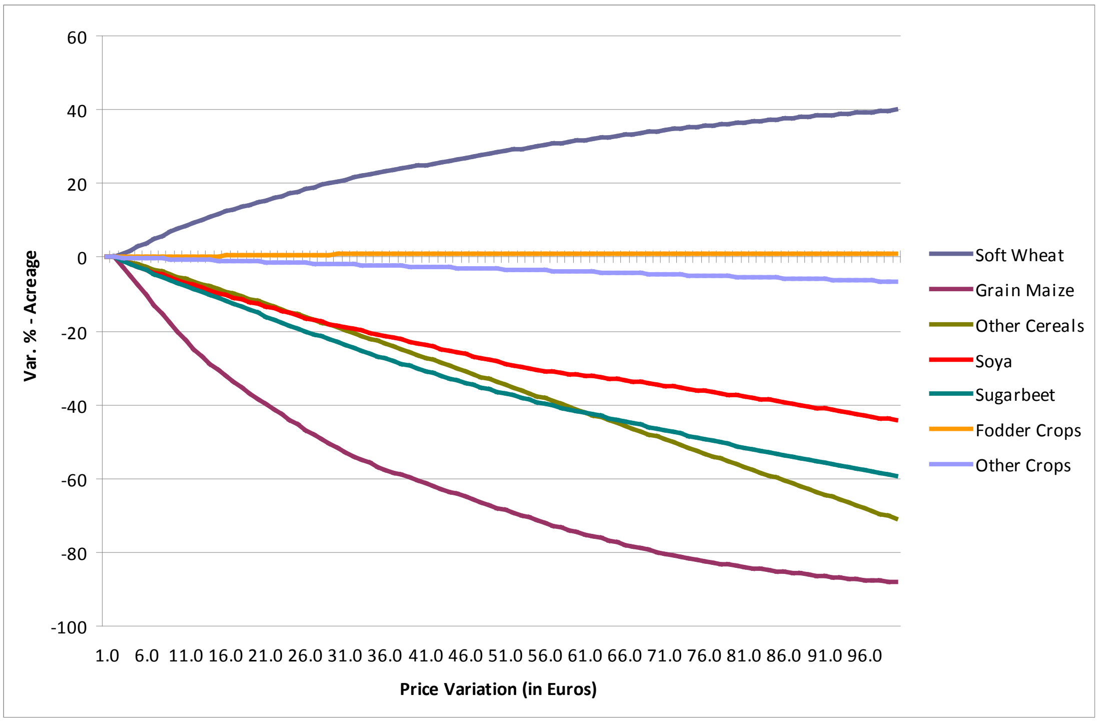
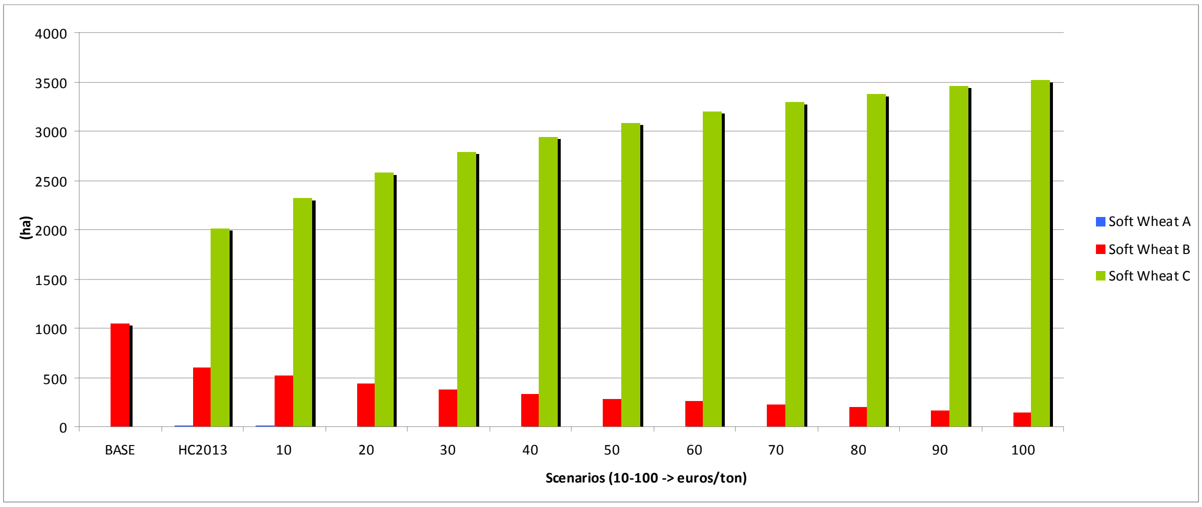


Figure 21: Acreage evolution of the three soft wheat technologies changing the prices (soft wheat technology B - farms)



3.2.4 Farms with soft wheat technology C

The positive variation in soft wheat price has produced a strong incentive to invest in soft wheat stimulating the technology more efficient in term of costs and yields. Technology C prevails over the other ones allowing a higher profitability to the farms. On the farms where technology C is present, the price rise produced an increase in this type of soft wheat confirming the relative high profitability of this crop with respect to the other crops.

Figure 22: Three technologies of soft wheat evolution changing the prices (soft wheat technology C - farms)

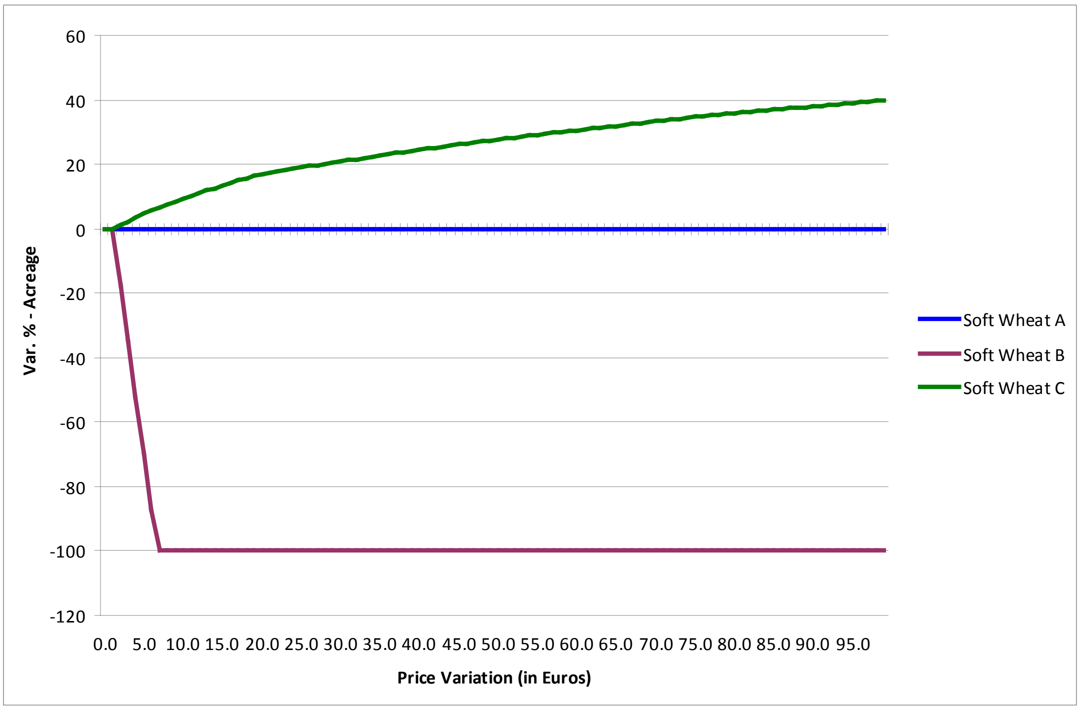


Figure 23: Three technologies of soft wheat evolution changing the prices wrt maize and soya (soft wheat technology C - farms)

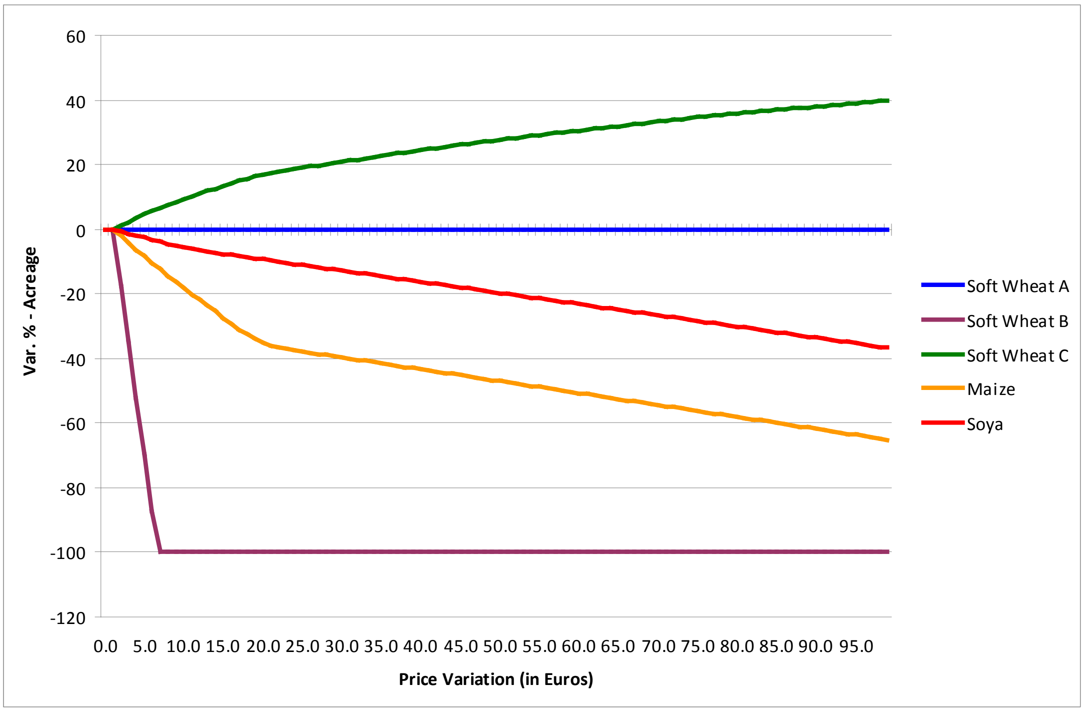


Figure 24: Production plan dynamics according to soft wheat price variation (soft wheat technology C - farms)

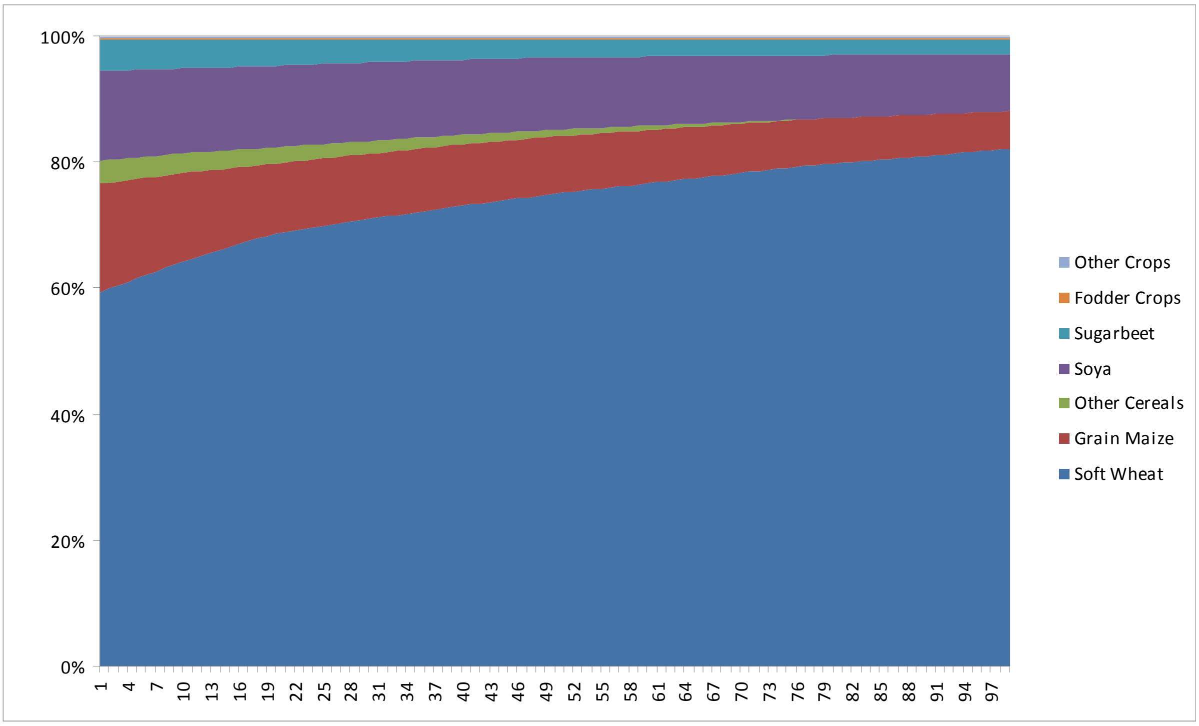


Figure 25: Percentage variation of the groups of crops changing the prices wrt the reference scenario (soft wheat technology C - farms)

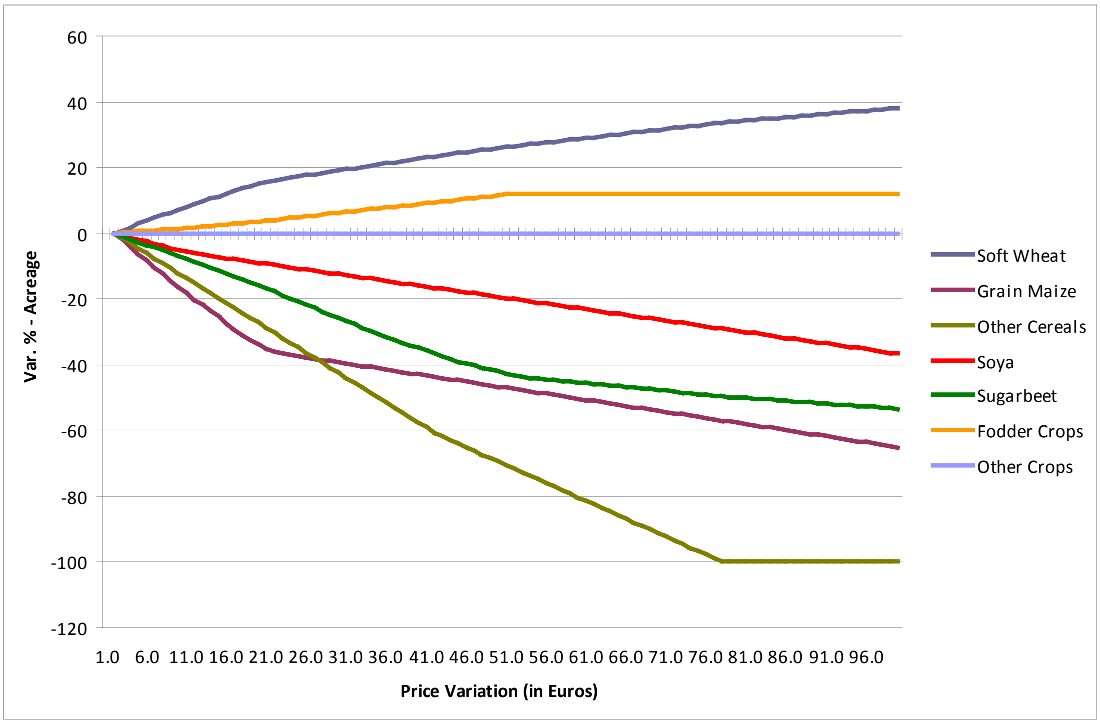
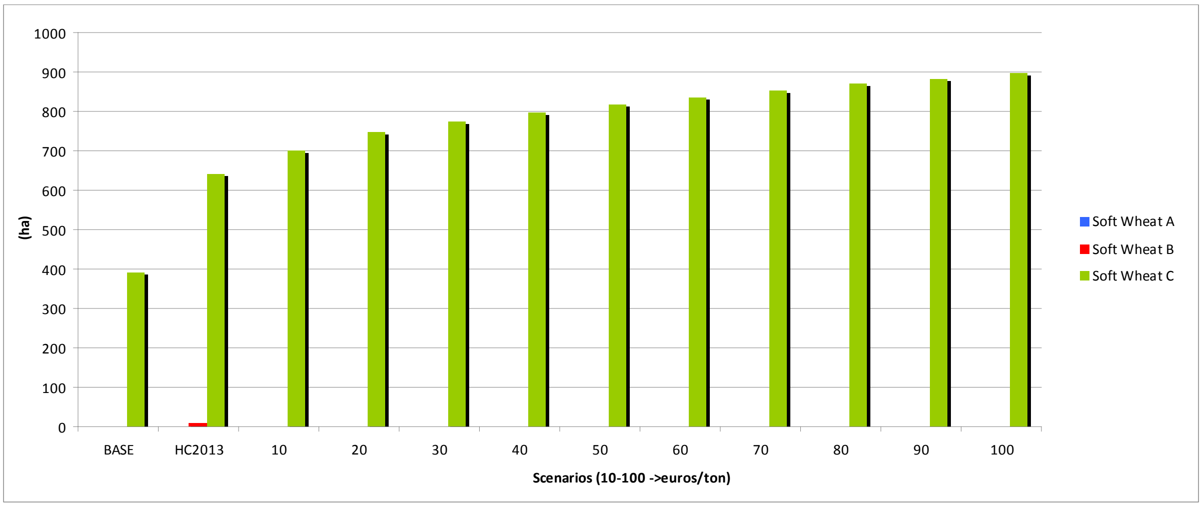


Figure 26: Acreage evolution of the three soft wheat technologies changing the prices (soft wheat technology C - farms)



3.3 Maize

3.3.1 Entire sample

The sensitivity analysis carried out with respect to maize production has revealed in part the same results as those obtained for soft wheat. Also in this case the production was divided in three technology levels according to three yield ranges identified within the Veneto sample. The results presented in this section are related to the total sample and each group of farms differentiated on the basis of the type of technology with which the maize is produced.

In general terms, technology B seems to be the least attractive when each farmer can change the production technology moving to the more profitable type. Figure 27 shows the response of the three different technologies for maize increasing the prices up to +100 euros/ton. The hectares invested in technology C increase considerably while technology A and B decrease. After reaching an increase of 80 euros/ton, maize produced with technology B disappears from the regional production plan leaving maize A and C.

Figure 27: Three technologies of maize evolution changing the prices (all farms)

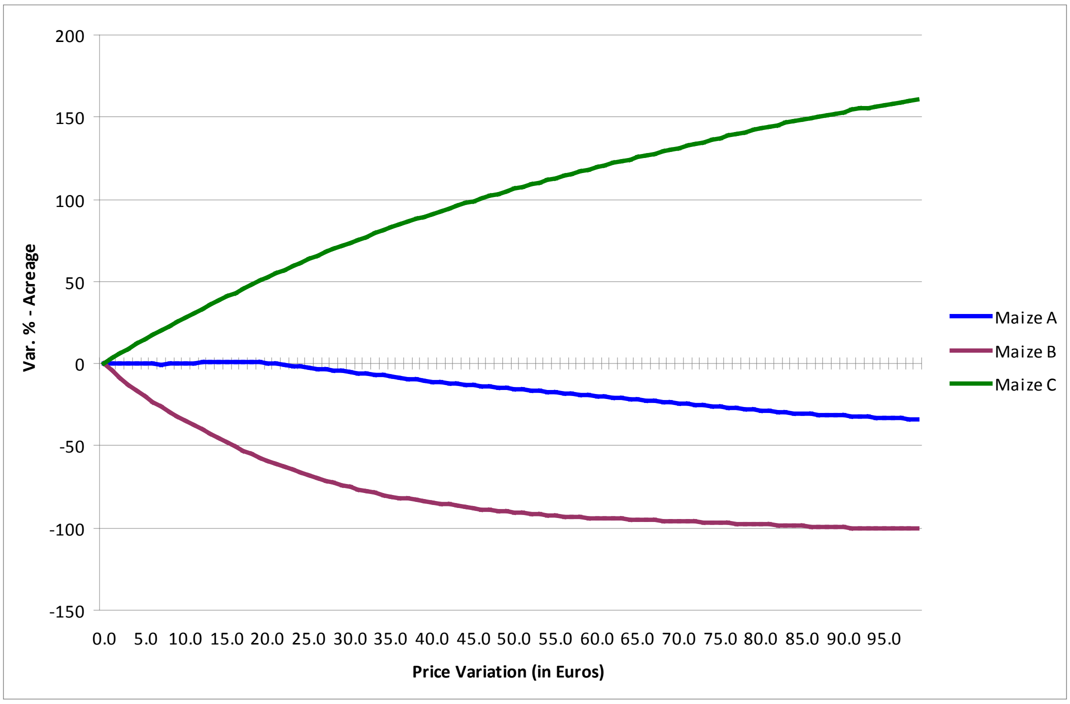
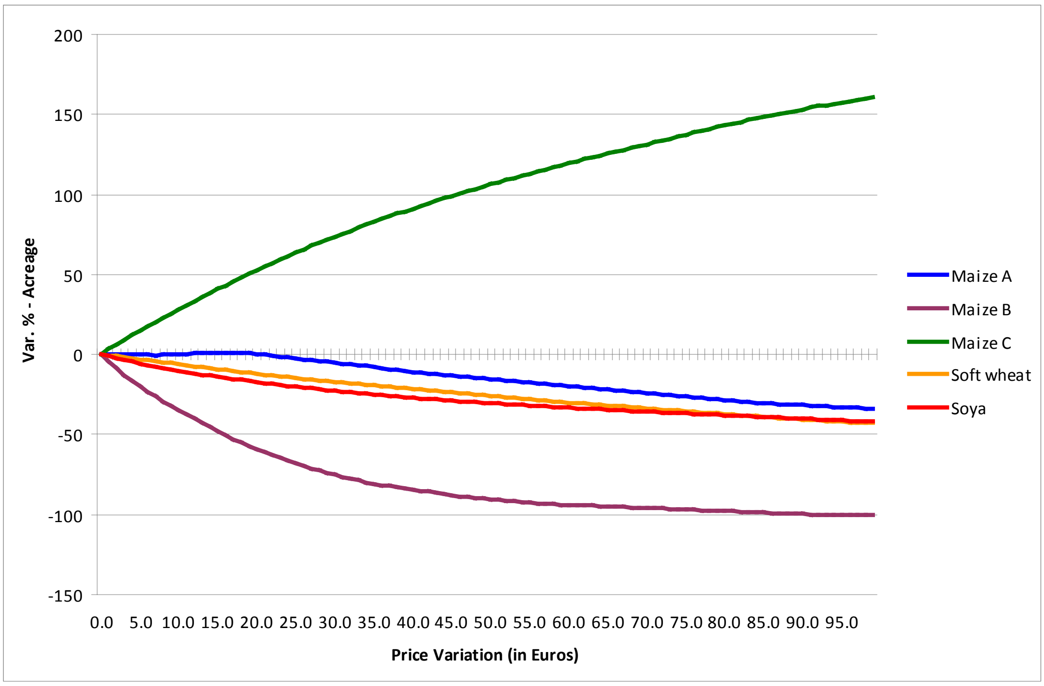


Figure 28: Three technologies of maize evolution changing the prices wrt maize and soya (all farms)



The modification of the market conditions for maize induces a strong competition between maize and other crops. In particular, when the maize price increases the surface that loses most in term of hectares is the soft wheat, which confirms the strict relationship between the two crops. Indeed, also when the market price modification affected soft wheat, the crop that reacted more to this new market scenario was the maize. The two crops within the model can be considered substitutes in the regional production plan.

The other crops remain substantially stable, only soya reveals a certain negative dynamic when the maize price increase. Also in this case, the response is very similar to that highlighted for the soft wheat simulations revealing a cross relationship captured by the model from the observed information. The calibration process through the reconstruction of the Q matrix permits the economic relationship among crops to be defined. Furthermore, the PMP process shows certain stability even if the basic dataset is submitted to modifications in order to take into account the different technologies used for the simulation phase.

Figure 29: Production plan dynamics according to maize price variation (all farms)

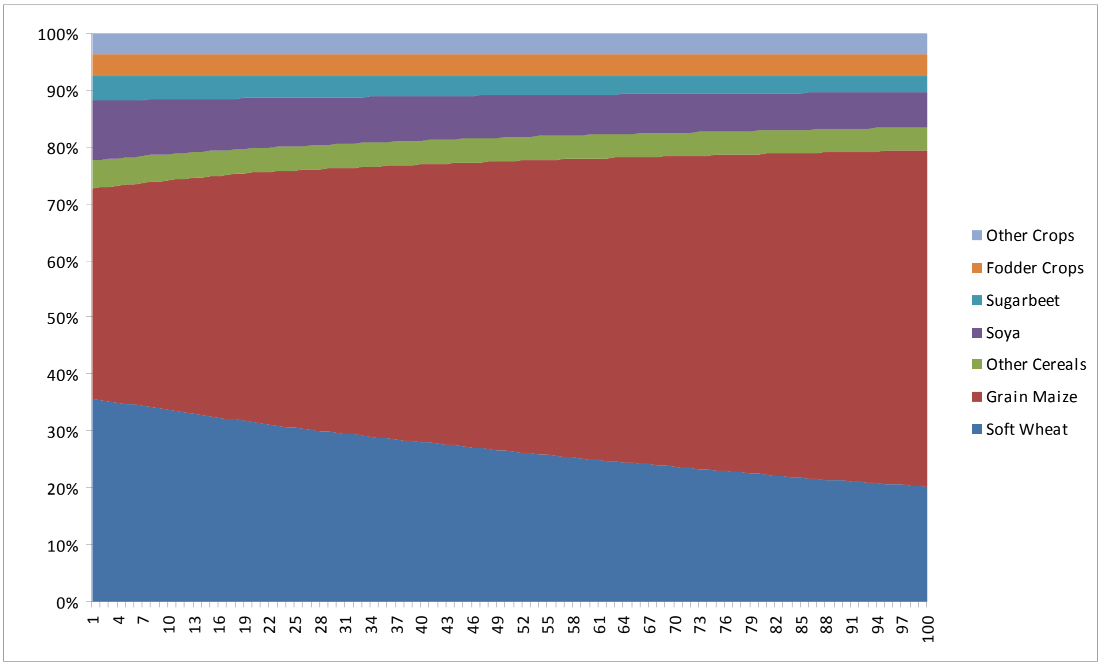


Figure 30: Percentage variation of the groups of crops changing the prices wrt the reference scenario (all farms)

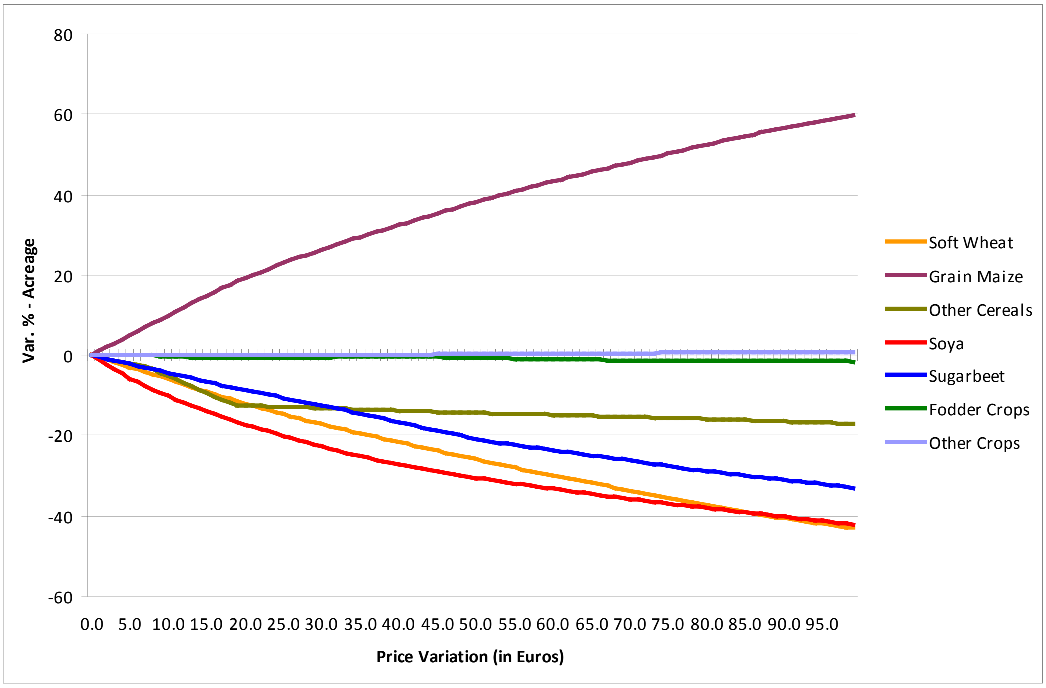
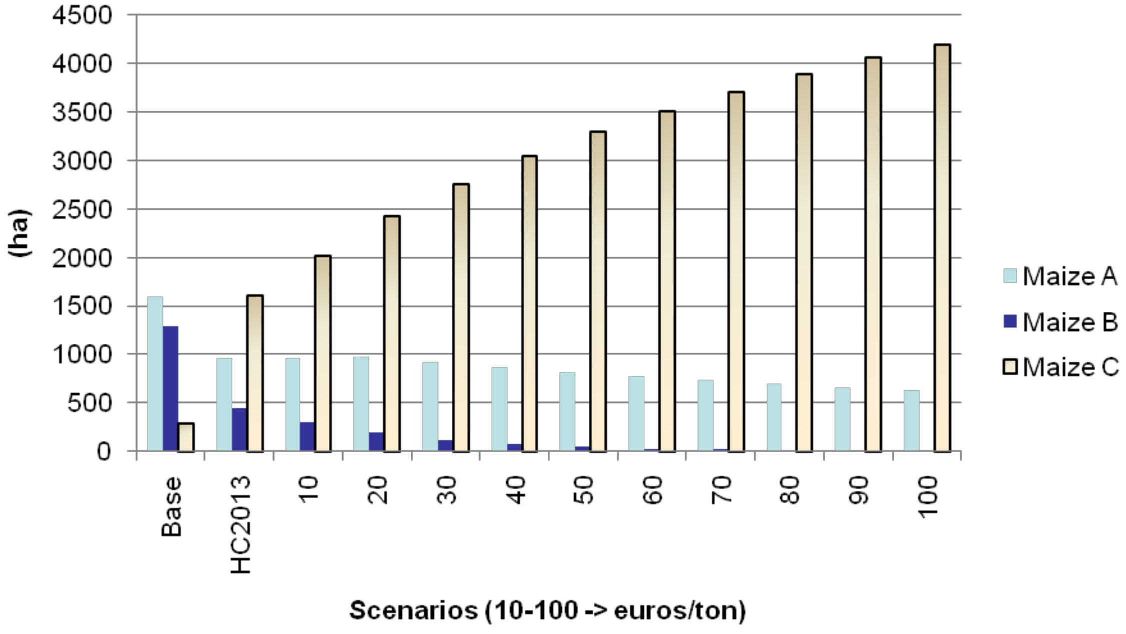


Figure 31: Acreage evolution of the three maize technologies changing the prices (all farms)



3.3.2 Farms with Maize technology A

Figure 32: Three technologies of maize evolution changing the prices (maize technology A - farms)

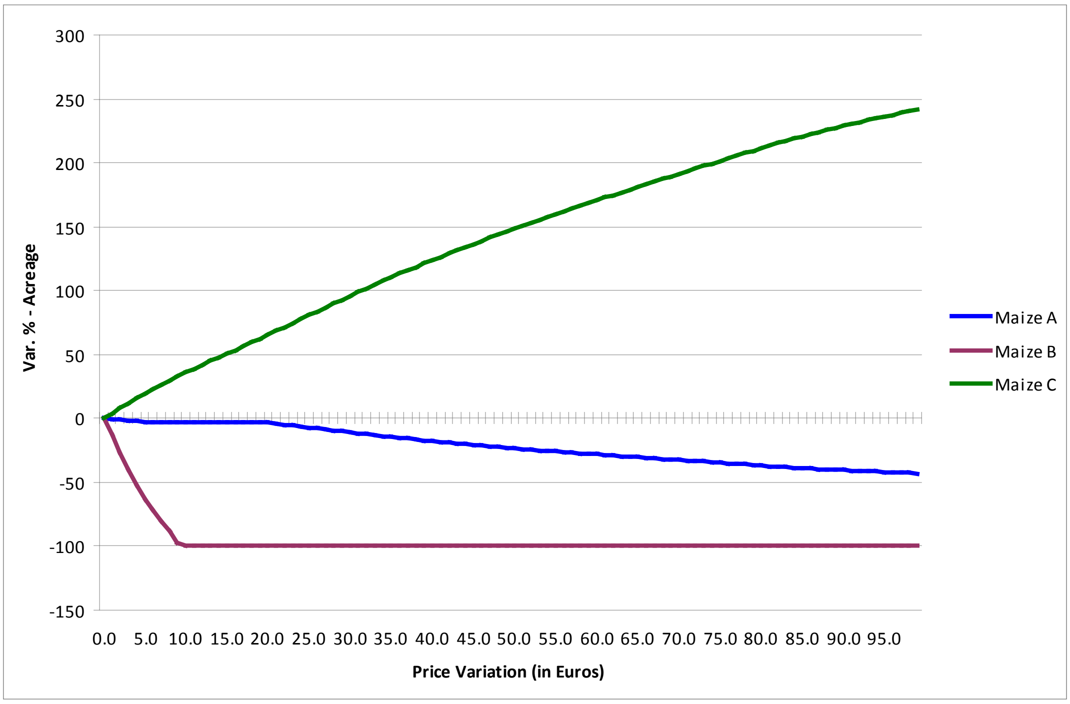


Figure 33: Three technologies of maize evolution changing the prices wrt soft wheat and soya (maize technology A - farms)

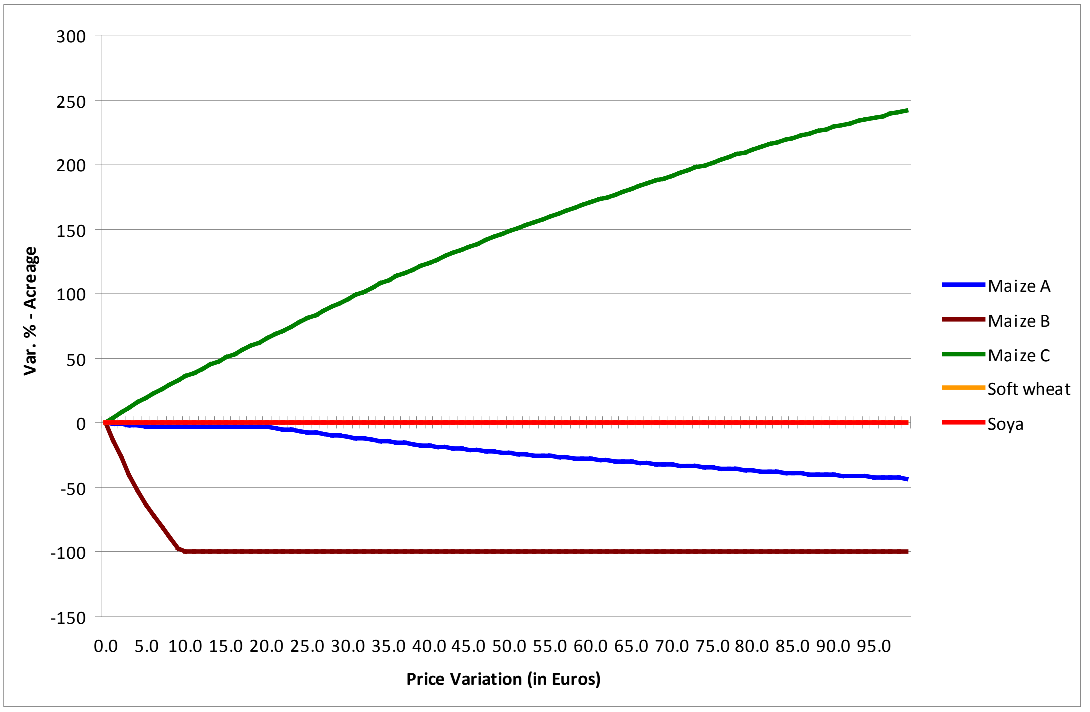


Figure 34: Production plan dynamics according to maize price variation (maize technology A - farms)

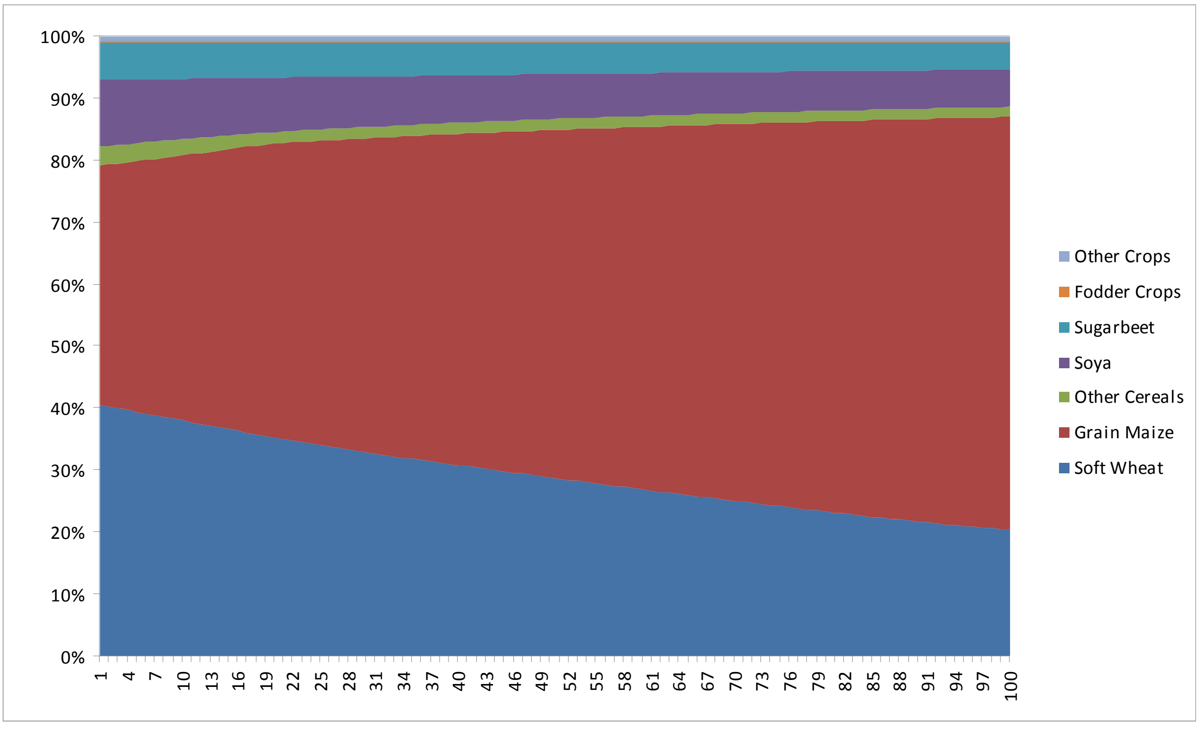


Figure 35: Percentage variation of the groups of crops changing the prices wrt the reference scenario (maize technology A - farms)

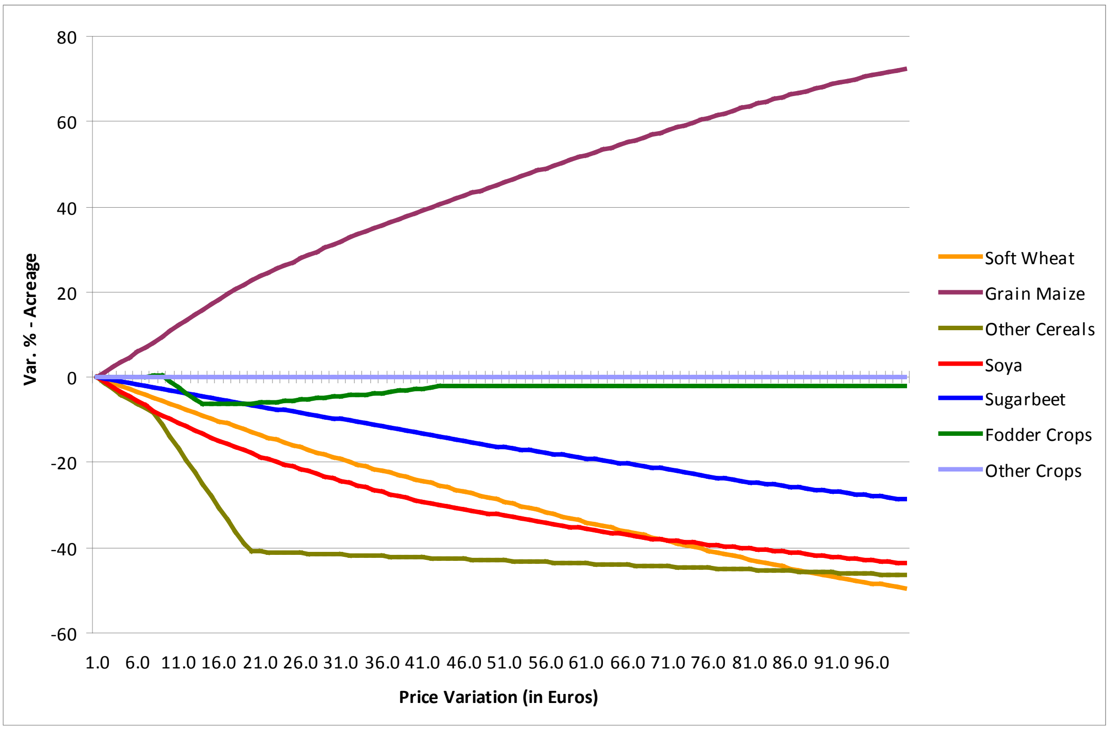
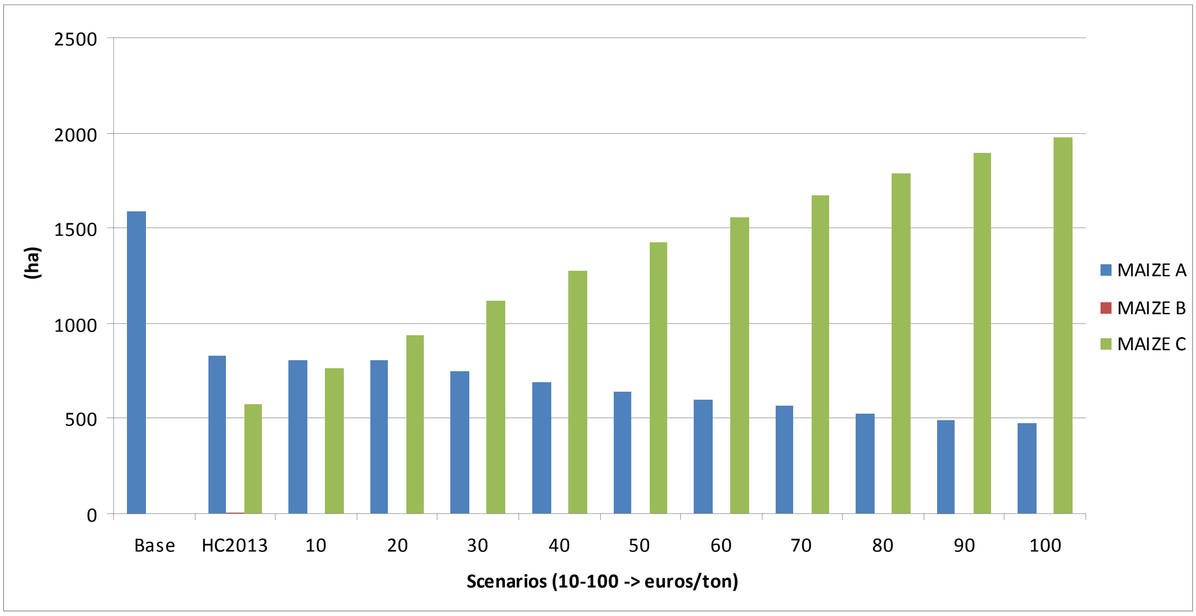


Figure 36: Acreage evolution of the three maize technologies changing the prices (maize technology A - farms)



3.3.3 Farms with Maize technology B

Figure 37: Three technologies of maize evolution changing the prices (maize technology B - farms)

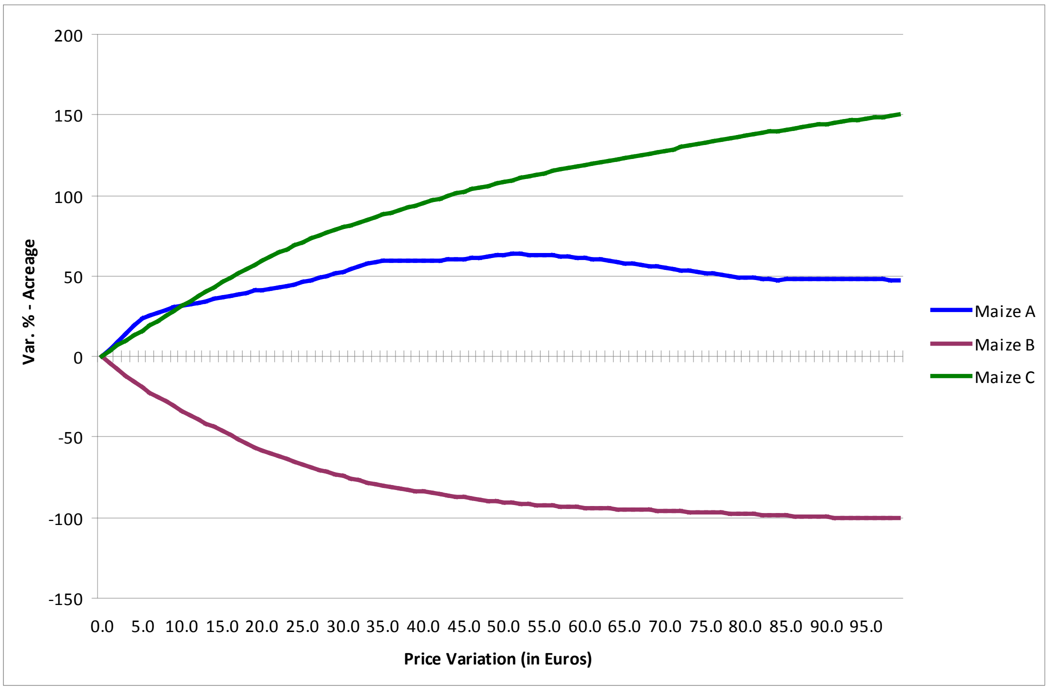


Figure 38: Three technologies of maize evolution changing the prices wrt soft wheat and soya (maize technology B - farms)

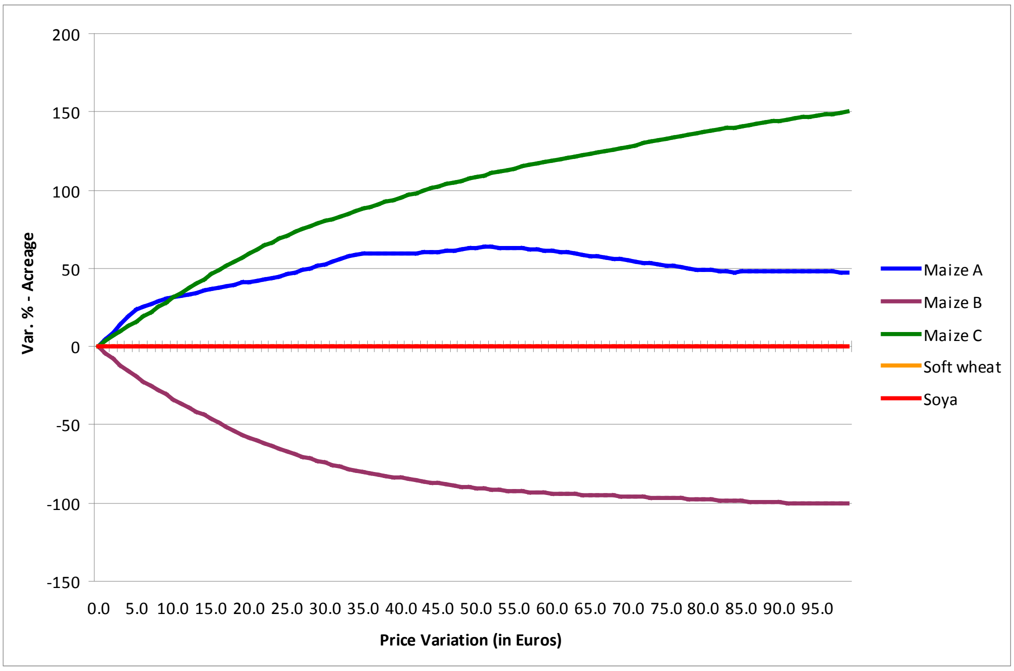


Figure 39: Production plan dynamics according to maize price variation (maize technology B - farms)

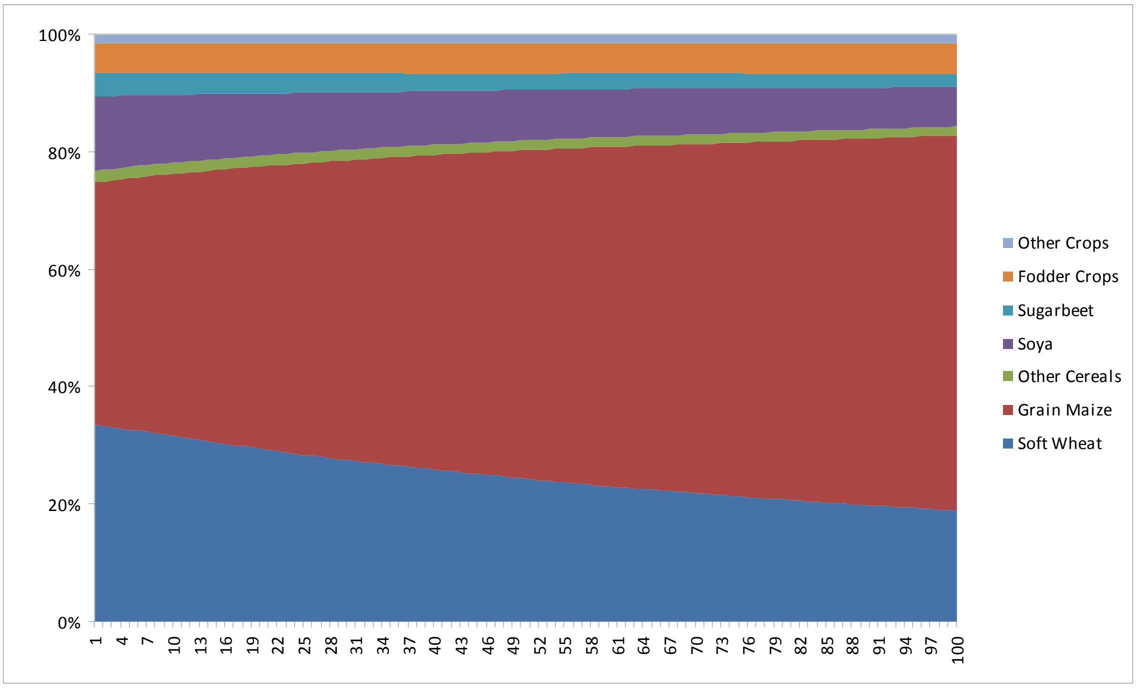


Figure 40: Percentage variation of the groups of crops changing the prices wrt the reference scenario (maize technology A - farms)

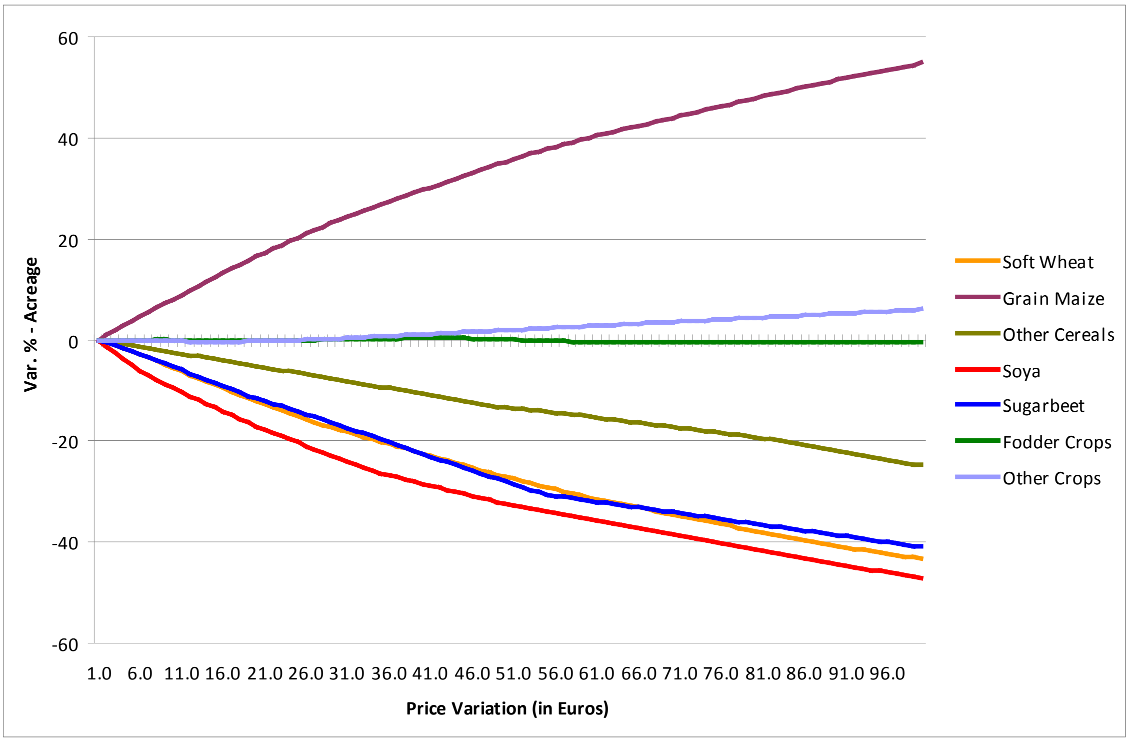
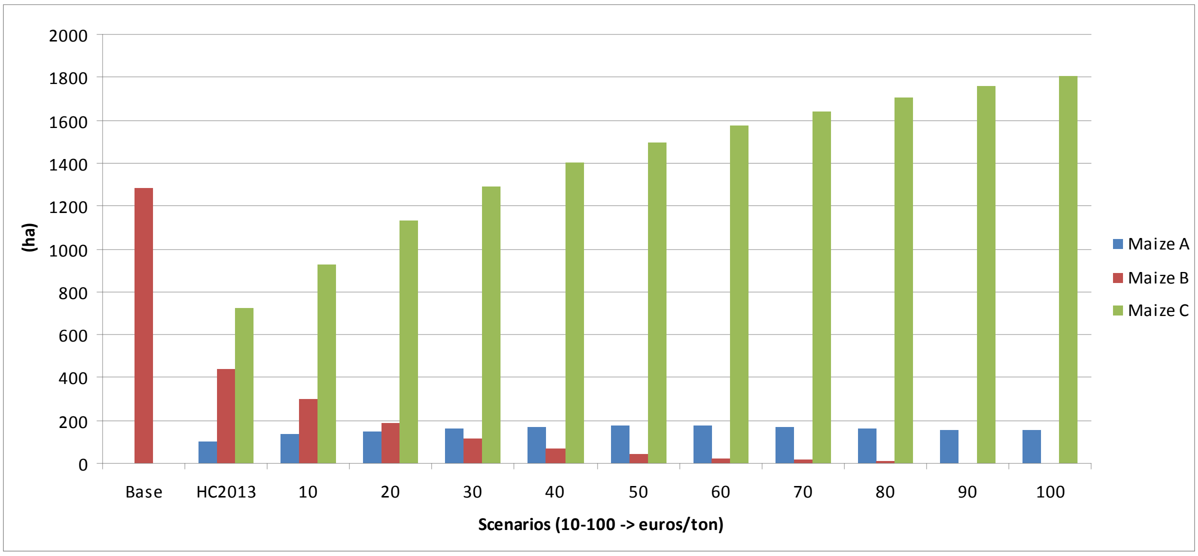


Figure 41: Acreage evolution of the three maize technologies changing the prices (maize technology B - farms)



3.3.4 Farms with Maize technology C

Figure 42: Three technologies of maize evolution changing the prices (maize technology C - farms)

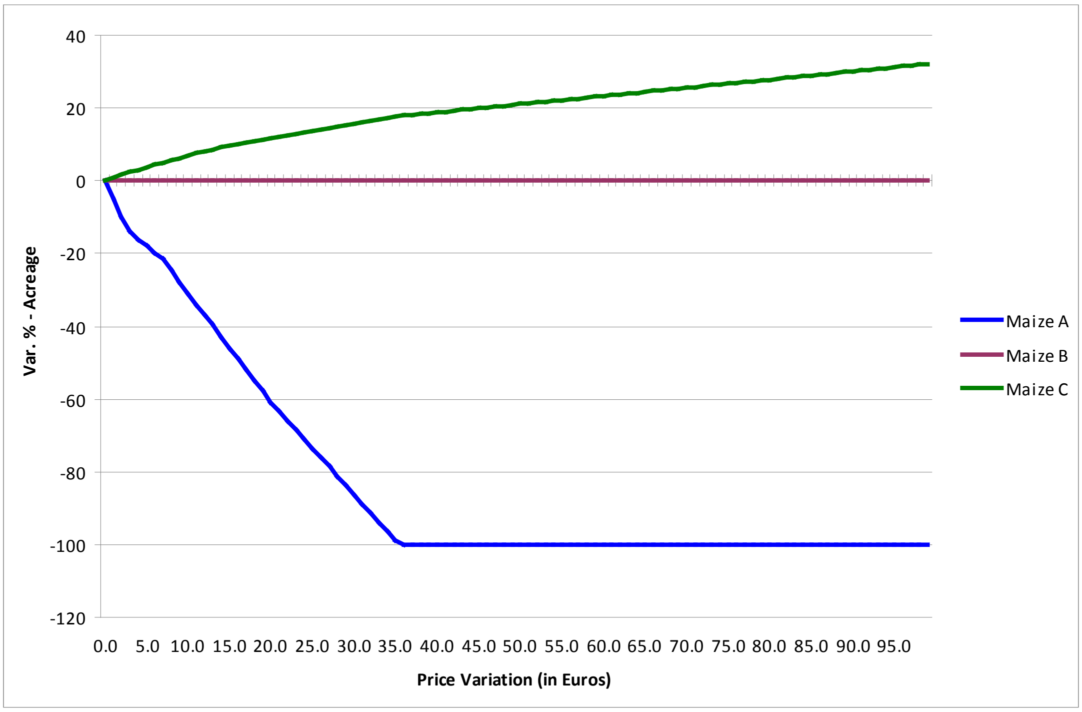


Figure 43: Three technologies of maize evolution changing the prices wrt soft wheat and soya (maize technology C - farms)

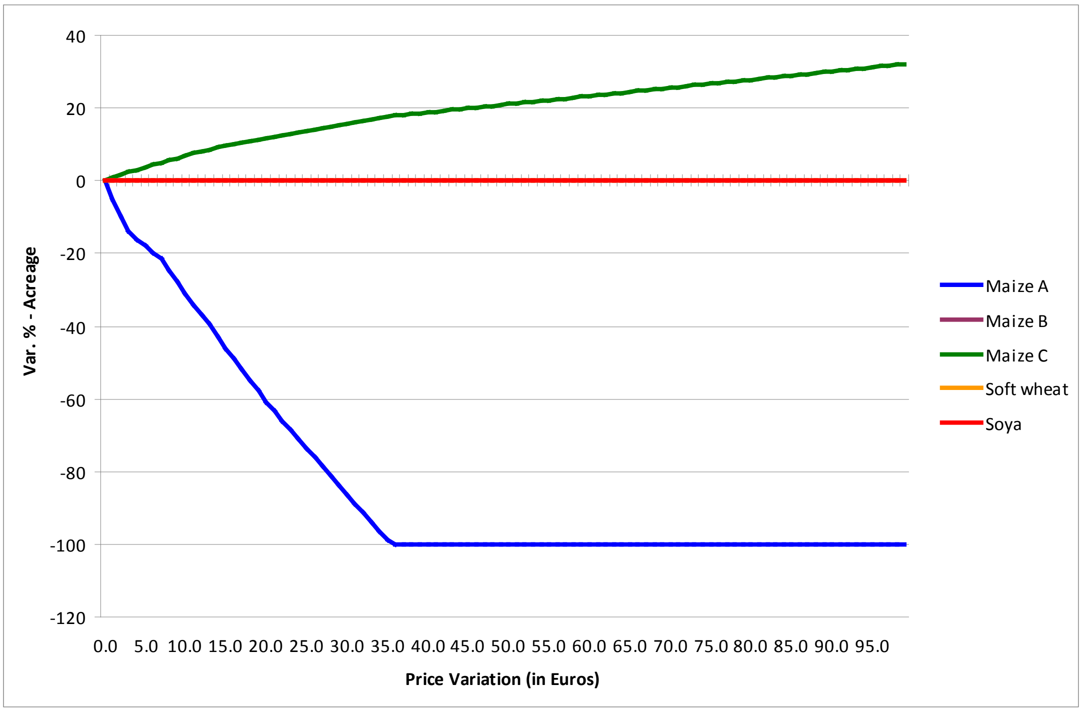


Figure 44: Production plan dynamics according to maize price variation (maize technology C - farms)

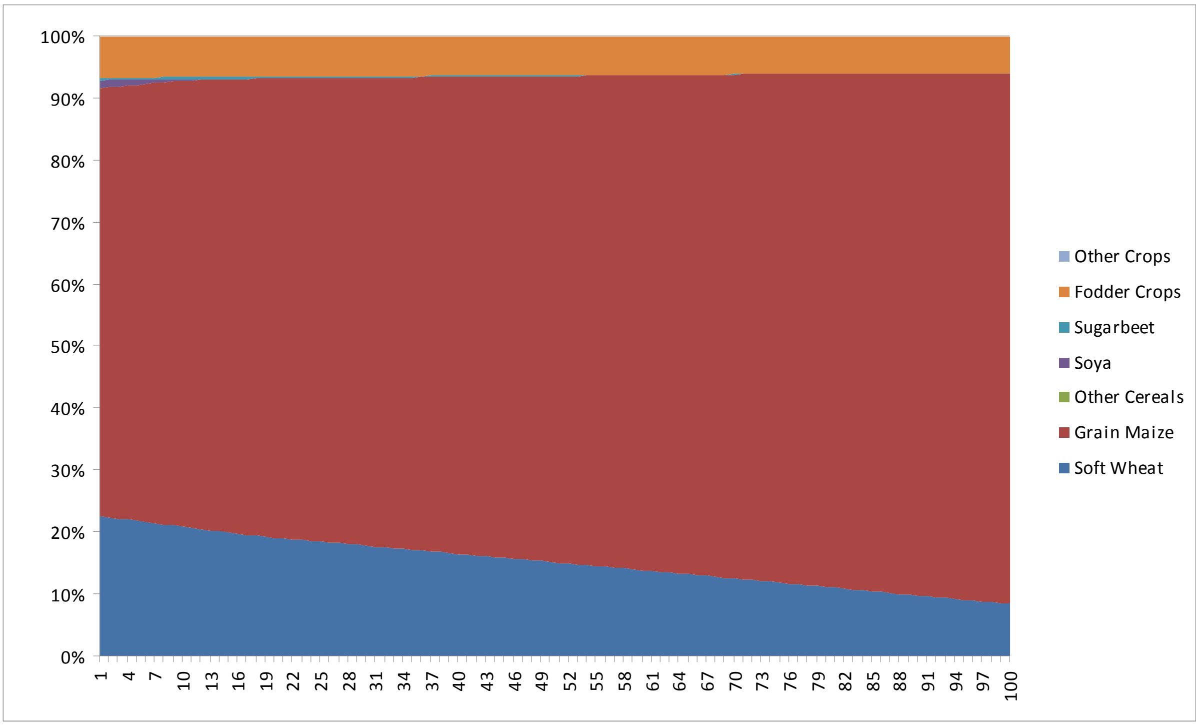


Figure 45: Percentage variation of the groups of crops changing the prices wrt the reference scenario (maize technology C - farms)

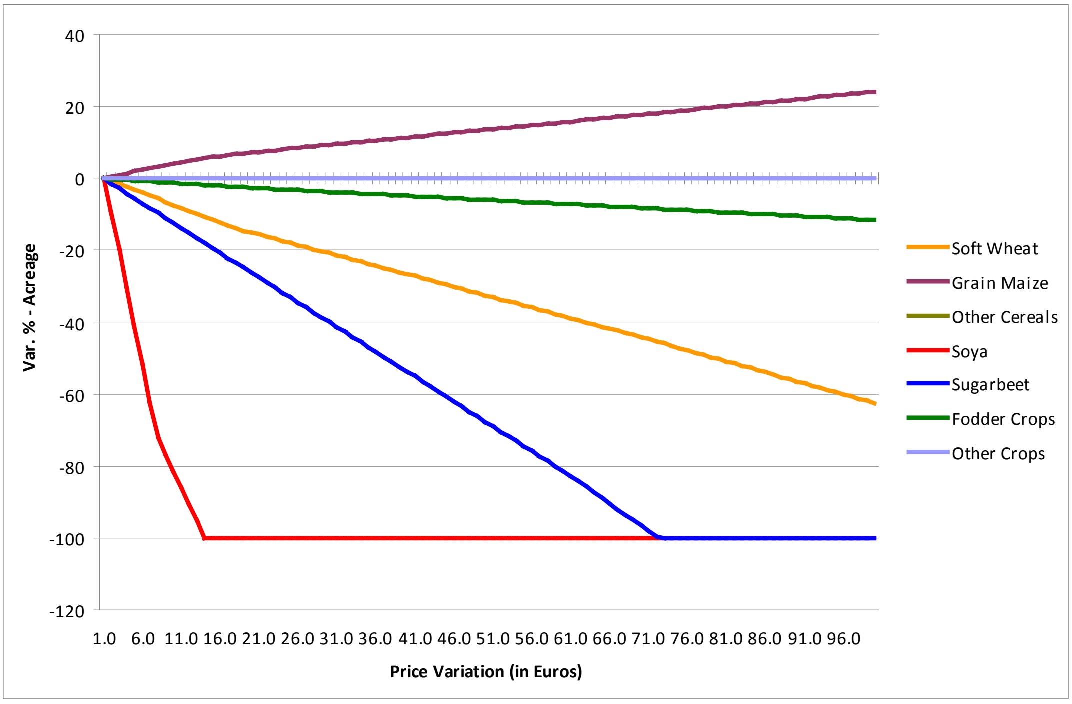
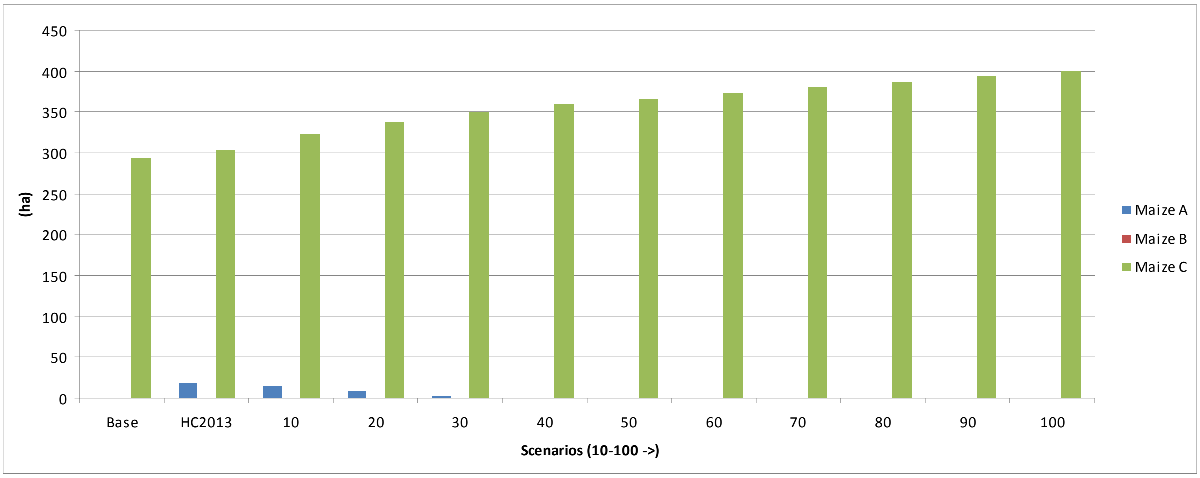


Figure 46: Acreage evolution of the three maize technologies changing the prices (maize technology C - farms)

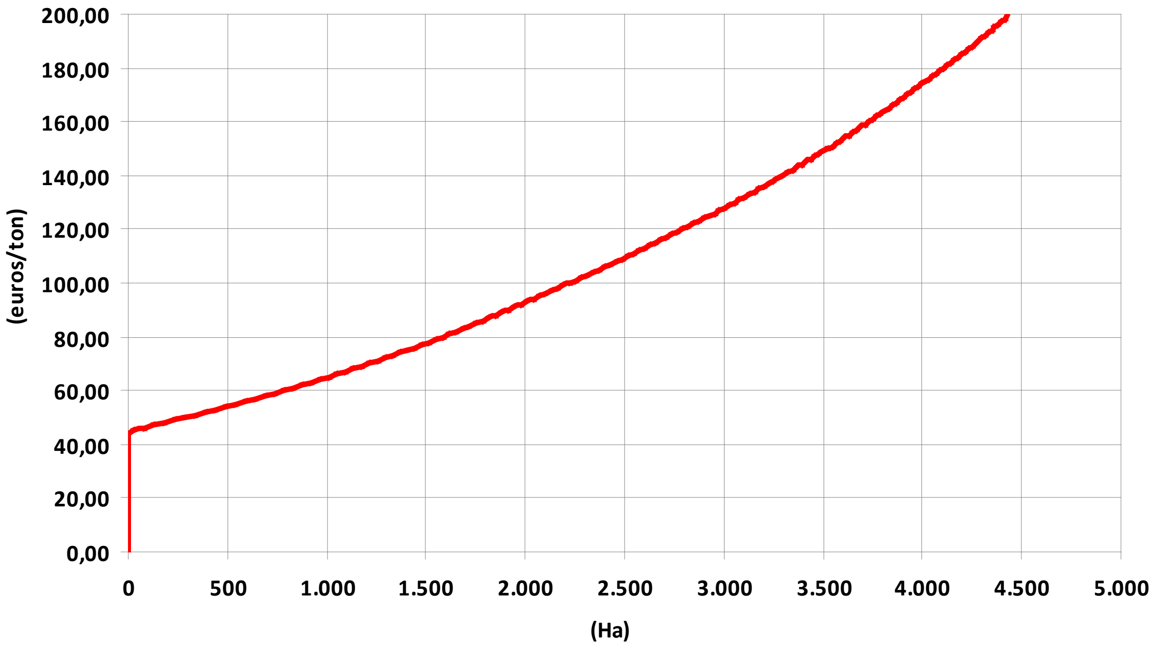


3.4 Results obtained for the latent crop

The simulations concerning the latent product have been developed with respect to a new crop that didn’t exist in the regional production plan. This latent crop is sorghum used for producing ethanol, a variety of sorghum with agroenergy aptitude. The information concerning average yields, price and specific production cost have been collected from a study promoted by the Emilia-Romagna region aiming to evaluate the possibility of building a regional supply chain for this bioethanol.

The results obtained for the Veneto region permit the economic threshold of sorghum to be discussed, that in other words means the prices starting from which sorghum for biomass can be inserted in the production plan of the farms present in the sample. Figure 47 shows the response of the sorghum production decision with respect to its price variation. The graph presents a curve that becomes to increase from a level of 4.5 euros/tons to be considered as the profitable threshold for the crop. The dynamics in prices produce a relevant increase of the acreage for sorghum in the first part of the chart and less in the last part. This means that the farm internal constraints don’t allow a simple expansion of the crop. In particular the rotation constraints and the complementary and substitution relationships within the cost matrix prevent the possibility of the entire farm surface specializing in a single crop. The graphical representation of the simulation results is interesting because it is possible to consider the different production levels with respect to the different price levels, so that for a public institution or a private firm that intends to constitute a supply chain for the sorghum for biomass this graph permits the correct price to pay to the producers to be identified in order to get a given quantity of raw material to process. So, for example, if a certain farmer is interested in planting 2000 hectares of sorghum, the price that should be paid to farms is more or less 90 euros/ton.

Figure 47: Evolution of the sorghum hectares varying the price



The simulation also permits the modification of the relative incidence of sorghum with respect to the other crops in the regional production plan to be identified. Figure 48 highlights that the increase in the incidence of sorghum on the regional production plan is due to a strong reduction in the incidence of maize and wheat productions.

Figure 48: Incidence of each crop on the regional production plan wrt a progressive increase in the sorghum price

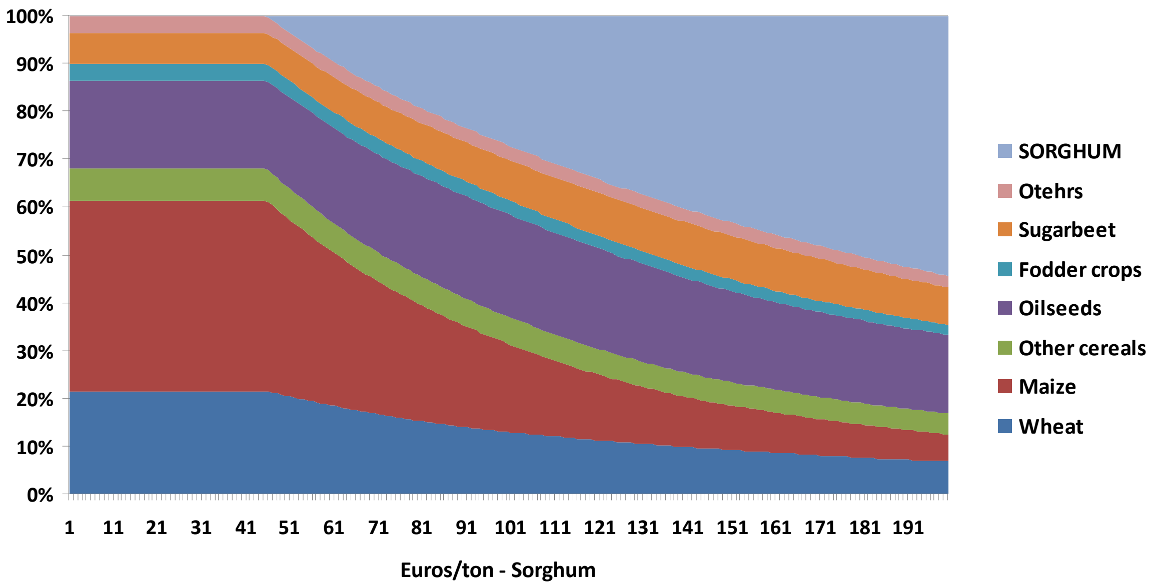
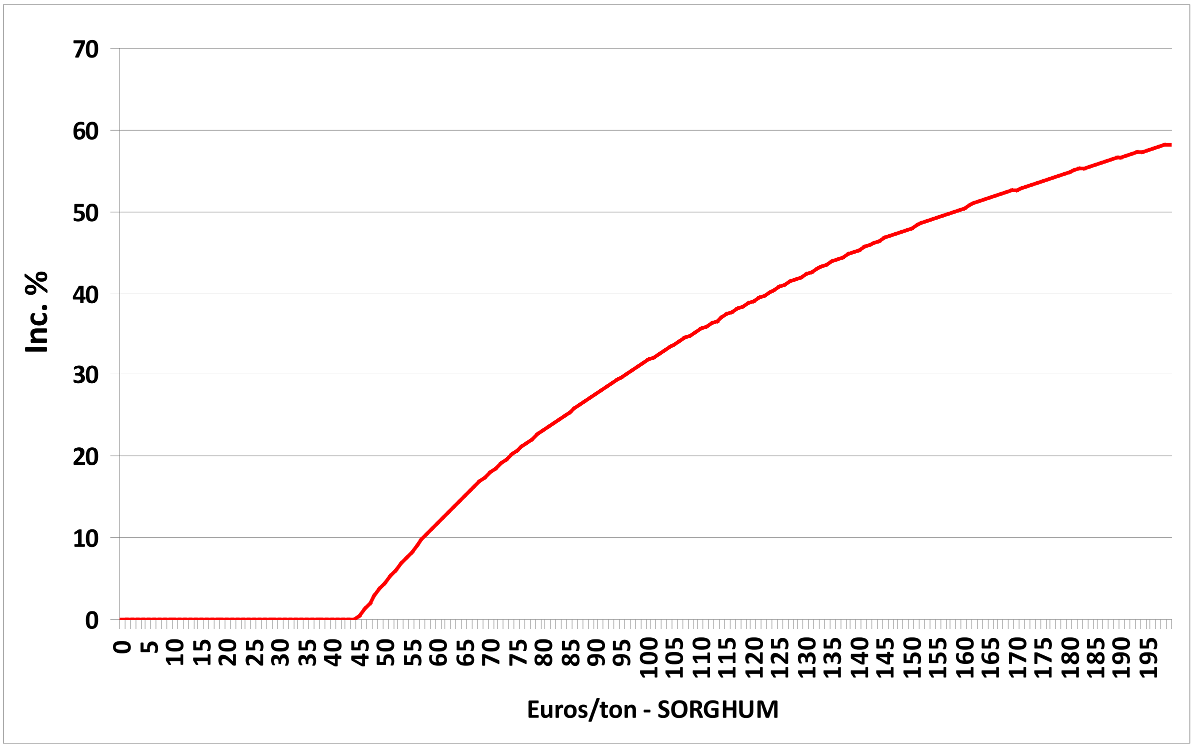
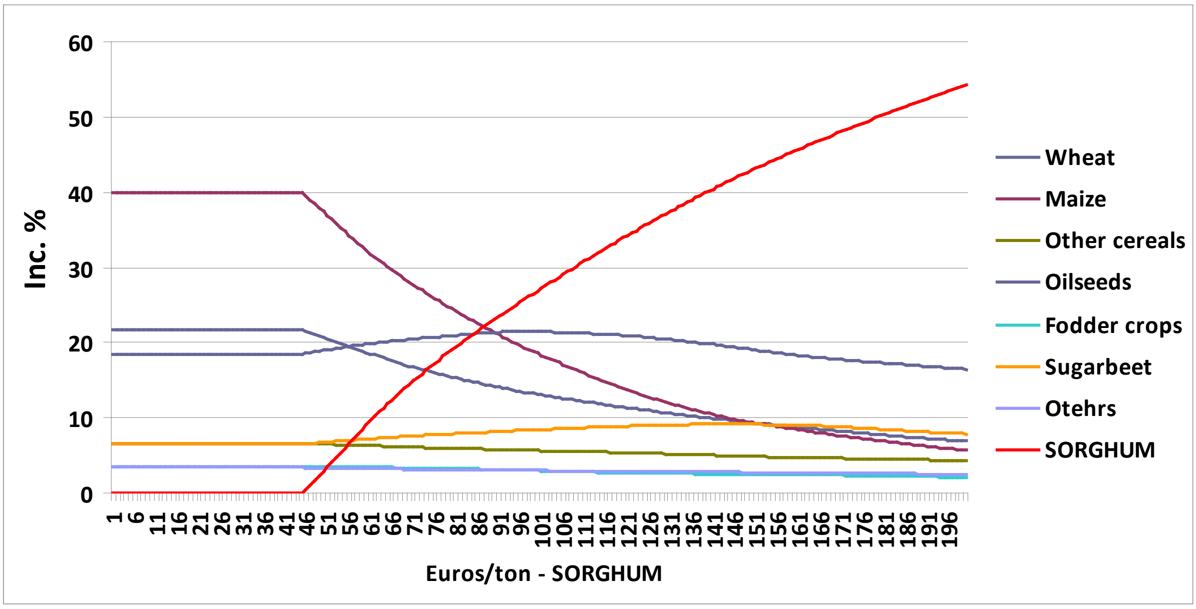


Figure 49: Evolution of the specific sorghum incidence on the regional production plan



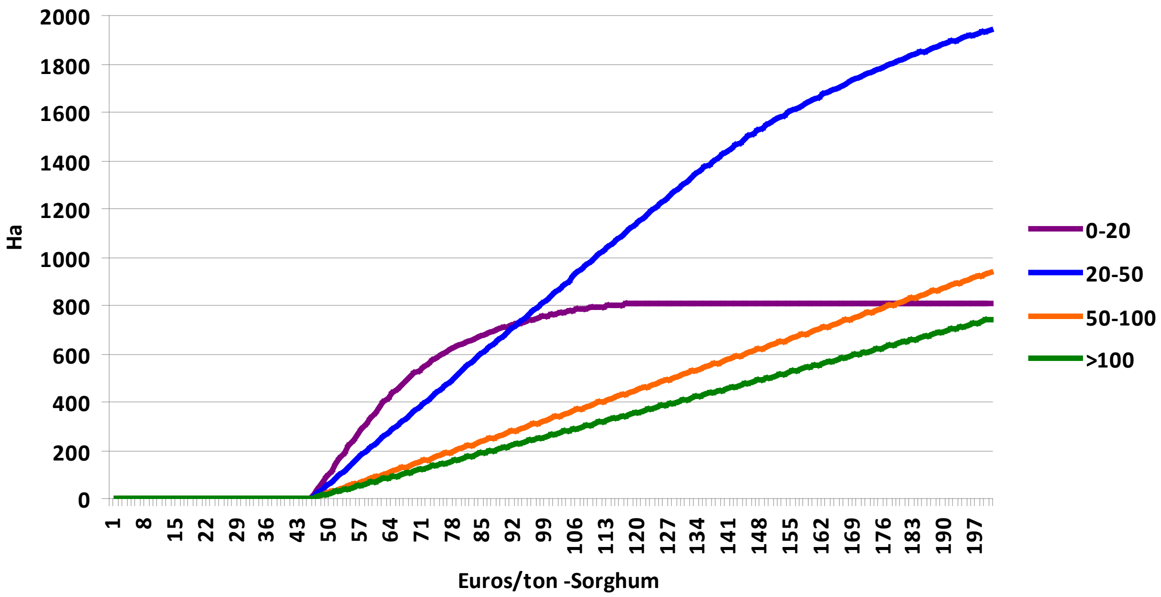
The same discussion as that of figure 48 can be repeated observing figure 50, but with a different perspective that compares the dynamic of the incidence of each crop in relation to the variation in the sorghum price. In the figure, the increase in the incidence of sorghum is evident and corresponds to a reduction in maize and soft wheat, while the other crops have kept roughly the same level as that observed in the basic scenario.

Figure 50: Evolution of the specific incidence of each crop on the regional production plan



The simulation analysis is developed evaluating the individual behaviour farm by farm. The results obtained at the maximum level of detail correspond to the production plan dynamics for each single farm considered in the sample. For this reason it is possible to analyze the results in relation to different dimensions, like the size class of the group of farms considered. Figure 51 presents the evolution of the hectares planted with sorghum with respect to four size classes (0-20 ha, 20-50 ha, 50-100 ha, >100 ha). The most dynamic groups of farms are those with a size less than or equal to 50 ha, which present a strong response to the increase in price; while the farms bigger than 50 ha show a constant positive variation of the surface cultivated with sorghum. It can be said that the small farms can benefit from a new crop that can create the conditions for a notable improvement of the gross margin; in the case of the largest farms, the intensive techniques combined with a more complicated production plan reduce the profitability of introducing the new crop on those farms.

Figure 51: Dynamics of the sorghum hectares in relation to farm size class



Conclusions

The analysis developed in this deliverable focuses on the application of a PMP model on a sample of farms belonging to the FADN for Veneto region, in order to evaluate the capacity and convenience of these farms to change their level of technology when the policy and market scenario change. The PMP model adopted in this framework is the version presented in the previous two deliverables (D6.1 and D6.2) where the calibration phase is carried out without using the specific costs associated with each activity. The model calibrates the basic situation, at the same time estimating the specific costs per crop distinguishing the accounting costs, i.e. the part of total cost identified in the farm accounting books, from the hidden cost, or the part of total cost not easily observed because implicit within the farmer's decision process. The information retrieved by the PMP model is used in the simulation phase for assessing the farm behaviour with respect to some changes in the reference scenario.

The analysis of the effect of environmental changes on farm technology is developed considering the possibility of adopting a different technology for an activity already present in the farm production plan or adopting a technology connected to an activity not present in the basic observation. For the first level of analysis, two crops are considered: soft wheat and maize. Both soft wheat and maize activated in the farm sample were categorized in three classes according to yield levels. In this analysis the yield of a given crop and the related cost constitute the technology associated to that crop. In the simulation, each farm with soft wheat or maize could continue to produce the same crop with the observed technology or modify the basic technology moving towards a new one choosing from the set of technology provided. The second type of analysis is based on the evaluation of the capacity of a group of farms to introduce a new crop in their production plan. This latter analysis intended to verify under which conditions a new technology not included in the sample of farms could appear in the production plan. The crop used for representing the new available technology is sorghum for biomass.

The objective of this work is not to provide useful results for policymakers or for agricultural stakeholders, but is to offer a methodological framework able to analyze the impact of a environmental perturbation, related to agricultural policy or market prices, with respect to the response of farmers in terms of technological adjustment. The traditional PMP models provide results about the effect of alternative scenarios in terms of land allocation and farm economic performances; the model presented in this deliverable also produces information about the modification in farm technology.

The scenarios assumed for the evaluation concern a likely market price evolution for the crops on which we focused our analysis and the introduction of the total decoupling and modulation reinforcement foreseen by the CAP Health Check reform. The simulation introduced the policy interventions and in addition the modification in market price. In regard to the market scenarios, the model developed different cycles of simulation progressively increasing the price related to the selected products, in order to obtain a sensitivity response in the level of production for the different crops and the different identified technologies.

The results obtained for the three different ranges of technology associated to soft wheat and maize highlight that farmers tend to change the level of technology when the price increases and the main process of substitution can be identified between the lowest yield technology and the highest yield technology. The farmers that move to the most productive technology completely abandon the lowest productive technology. The middle level of technology retains a significant part of the production even if the tendency is to substitute this with the most productive technology. This result shows how farmers find it worth investing in new technologies when the level of market prices increases. The change towards new technologies identifies an increase in the rate of production intensity within the group of farms.

If the market price has a role in pushing farmers to changes in farm technology, the agricultural policy mechanisms intervene in modifying the land allocation according to a farm strategy based on the reduction of production costs. The adoption of the total decoupling in all agricultural sectors in combination with a more intensive modulation push the farmer to specialize in the production where he can benefit better from the cost reduction and with a higher productivity. For this reason, total decoupling represents an incentive to reorganize farm production, minimizing the costs and giving priority to the process with high productivity; the new technologies are introduced into the production plan substituting the basic one in response to the new signal from the CAP.

The model applied considering the latent activity, i.e. an activity not present in the production plan of the observed sample of farms, provided a set of information about the profitability of introducing such an activity into the production plan. The model showed the economic threshold starting from which the new activity can be introduced alongside the other productions. This threshold changes according to the type of farm, identifying different levels of profitability for introducing the new crop. This information is useful in order to identify the types of farm that could be more available to introduce the new activity into their production plan and, at territorial level, it is also possible to identify the supply of raw material for agrifood processing. The construction of a new supply chain based, as in our example, on the biomass produced by sorghum, involves a feasibility analysis that is conducted to find the relationship between price levels and the related level of production. The PMP model and related simulation analysis allow the production level to be discovered for each type of farm and for each territorial area according to the different price levels of the crop.

In conclusion, the PMP model adopted in this framework of analysis has captured the fundamental economic information about the specific production costs for each level of technology in order to evaluate the response of the FADN farms in terms of technology change with respect to modifications in the reference environment. The model can be used for evaluating the capacity of a new technology to be adopted by the farms belonging to a specific type or a given territory, providing information about the economic thresholds associated to the new technology. In terms of policy interest, the model provides information about the productive recombination of the farm production plan and about the attitude of each farmer to adapt his production system to the new CAP framework.

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