Development of a Partial Equilibrium Model of the EU12 Agriculture using Positivistic Mathematical Programming

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Abstract
In order to respond to the current pressures on agriculture in the EU, the industry will have to go through fundamental structural change. Economic modelling provides the framework for understanding such changes. Mathematical programming is probably the most robust of all the modelling approaches notwithstanding several criticisms of the technique. Economists have long understood that profit maximisation is not the only objective of farmers. Although there are techniques to incorporate other objectives there does not exist a statistically rigorous method for estimating an appropriate objective functions. This problem also occurs at national and international levels of aggregation. This paper presents a new approach to modelling national and international production and trade through partial equilibrium and the use of a new development called positivistic mathematical programming. The non-linear element of the objective function representing the partial equilibrium is estimated using past observations on supply, consumption and prices. Further, the paper also presents an original parameterisation of the demand curve that allows perfect competition to be simulated within the framework of a single mathematical model. Such a methodology is an advancement over methods that are currently in use.

Key Words: Mathematical programming, Positivistic mathematical programming, partial equilibrium, international trade, policy analysis.

Introduction

Agriculture in Europe has undergone extensive change over the last fifty years through technological change. During the last twenty years policy changes such as the CAP reform have had major impacts on farming practices. These changes are set to continue with the introduction of the AGENDA 2000 reforms and the reduction of prices to the world level. Therefore, is important to understand in advance the potential impact of such policies in order to reduce the negative impacts of this economic transition.

Models have long been used by economists as an input for planning economic activities and for predicting the outcomes of choices made (McCarl and Spreen, 1980). Several methodologies have been developed to formulate such models. For instance, input-output analysis has been used in which the entire economy and, particularly, linkages between sectors are of interest. However, to simulate the effects of new policies and the adoption of new technologies, mathematical programming has been shown to be a powerful analytical tool (see Blitzer *et al.* (1975) for a review of such approaches).

Mathematical programming can claim several advantageous over other econometric techniques. Econometric models rely upon estimating coefficients in equations describing the situation modelled through observed results. With the adoption of new policy, it is not possible to obtain estimates of parameters reflecting the impact on specific variables within the model. Mathematical programming, however, embodies a causal system of the functioning of each firm (or farm) and the inter-relationships between different enterprises (dairy, beef, sheep and arable) across all firms. This

method is therefore not susceptible to problems from extrapolating explanatory variables beyond the range of observed results.

Mathematical programming models may also be used to estimate the behaviour of firms (in this study, farms) within the sector while explicitly considering the market demand for products and the supply of inputs (Apland, Jonasson and Öhlmér, 1994). These models are particularly suitable to modelling research covering several areas of expertise (in this case, genetics, nutrition and economics) as alternative production systems, and market conditions can be postulated simultaneously in a model.

Large-scale, price-exogenous, linear programming models have been used extensively in agricultural economics to simulate the impact of alternative farming practices and policies on the agricultural sector. These models, by including the assumption of fixed prices or quantities, thereby ignore the important interaction between these variables. As an individual the farmer cannot affect the price of a given product. When considered as an aggregate of individuals within a competitive framework, the assumption of exogenous prices is no longer tenable.

Amongst the first to show how the problem of partial equilibrium could be solved through mathematical programming was Samuelson (1952). Takayama and Judge (1964a, 1964b) extended Samuelson's approach by using quadratic programming to determine the spatial distribution of prices, production, resource use and consumption. This was achieved by assuming linear, price-dependent, demand and supply functions. Duloy and Norton (1975) approximated the quadratic objective function, using separable programming with a linear function, thus enabling a robust algorithm such as the simplex method to be used. For an overview of the formulation and economic interpretation of partial equilibrium models in mathematical programming, see McCarl and Spreen (1980).

All the above formulations assume linear, price-dependent, supply and demand functions. This enables the objective function to be written as a quadratic function. However, they do not allow for non-linear supply and demand functions. Martin (1972) describes three approaches to solving this problem. In the first approach, an ordinary linear programming model is successively solved for different prices until the results reach partial or near partial equilibrium. The second and third approaches are similar in that they require the solution of only one linear programming model. The demand and supply curves are represented as step functions. Each step of each demand and supply curve is represented as a column vector in the linear program. These column vectors are constrained by row vectors to be less than or equal to the quantities accounted for by the steps being represented. This approach, however, represents a monopolistic market and not a competitive one. The objective function represents a sum of stepped prices (costs) multiplied by the quantity of each step up to the equilibrium instead of the equilibrium prices (costs) multiplied by the equilibrium quantity. To adjust for this discrepancy artificial prices (costs) may be used in the objective function or prices (costs) may be used directly in the stepped demand and supply functions after the solution of the linear programme. Both alternatives then require further calculations to ascertain the true value of the objective function as well as the revenues for individual producers. Martin then proposes a formulation of the problem to determine these values within the linear programme itself.

An alternative methodology has been developed for this study. The demand and supply curves are included in the formulation of the problem through non-linear functions. Further, these curves are calibrated in such a way as to reproduce the observed results under the base scenario using an extension of the Positive Mathematical Programming (PMP) technique proposed by Howitt (1995).

Positive Mathematical Programming is a technique that allows the modeller to construct a non-linear objective function that will reproduce the observed results. Further, to add economic rigour to the technique economic phenomena are ascribed to these non-linear objective functions such as yield functions or variable cost functions. The methodology relies upon the fact that the observed result lies on the boundary of the feasible region (in the case of agriculture this is generally true as all land is utilised).

Despite its' attraction this technique has one fundamental flaw. With only one observed set of results it is possible to construct an infinite number of non-linear curves that 'calibrate' the model and hence any economic interpretation placed on these functions is completely without justification.

It is clear from this reasoning that modellers cannot use a single observation (or fit more parameters than there are observations) to estimate functions representing economic phenomena. In this paper an extension of the PMP approach has been used that incorporates historical data in determining supply and demand functions. Although this approach is more justifiable than the original there are still some assumptions that cannot be wholly justified. As yet the use of several observations in determining economic functions within a mathematical modelling framework in a rigorous manner remains under-exploited.

Methodology

Modelling objectives
In constructing a model of the EU agriculture several broad criteria were set as objectives. These objectives were:

(i)   To encompass initially all EU12 member states;
(ii)   to simulate most of the predominant forms of current agricultural production in the above EU countries;
(iii)   to predict international trade including the simulation of the rest of the world; and,
(iv)   to provide a modelling framework that permits detailed specifications for regional analysis and the inclusion of market and economic scenarios within the model's internal structure.

Although the model was originally constructed to include the EU12 the framework developed here can easily be used to encompass more countries as they join the EU and as the relevant data becomes available. In simulating the predominant forms of agriculture within the model the question of aggregation must be addressed. Several factors affect such a decision such as data requirements and their availability and model size. Therefore, it was decided to simulate the EU12 at the regional (NUTS 1) level in order to reduce the size of the final model. The final model simulates the

production of 37 different agricultural activities in each of 87 different regions giving a total of 3219 activities. To satisfy the objective of simulating international trade it was decided to construct a partial equilibrium model with functions representing the following economic phenomena:

      (i)   demand and supply functions for regional production;

      (ii)   functions representing the national consumption with respect to national price; and,

      (iii)   functions representing imports and exports with respect to international and national prices.

The decision not to simulate inter-regional trade was taken as this data was not obtainable.

Data Sources
The model requires a considerable amount of data. Primarily, the model requires estimates of yields, costs, prices, livestock numbers and the actual production at a regional level (NUTS 1) for the EU12 countries. These data have been provided by using the FADN (Farm Accounting Data Network). The information on the relevant agricultural policies have been taken from the literature. Finally, the model requires estimation of demand functions and import/export data. Unfortunately, this type of data do not exist at the regional level, however, it was possible to obtain national level data from the r-cade European database available from Durham (UK).

However, there were considerable problems with the quality of the FADN data. In many instances data were missing, for example the areas, the yields and the variable costs would exist for a particular region whilst the prices would not. Moreover the most common problem was that of reliable data. In one instance the price reported by the FADN for potatoes in the Cataluña region of Spain was 88133ECU/t whilst in the Castilla y León region the price was recorded as 386ECU/t. To compensate for the deficiencies in the data set several assumptions had to be made:

      i)   all the data below the 10th percentile and above the 90th percentile were changed to the values of the 10th and 90th percentiles in order to remove the obviously incredible outliers; and

      ii)   the missing data were replaced with national averages (or the EU12 average in some cases).

However, it must be pointed out that the data used were still subject to enormous variation. These problems with the data are the single most significant impediment to the use of the proposed model.

Model Structure
The model is aggregated at three basic levels. At the lowest level of aggregation regions (corresponding to the EU specified NUTS 1 regions) are simulated with the basic limiting constraint of land availability as well as supply/demand constraints for various commodities. These regions when taken collectively form the national level models, which include constraints related to the different agricultural policies for each state. Finally, all these models are linked through simulation of international trade and EU policy.

The key developments of the model include simulation of international trade using an appropriate import/export structure. For each country and each production activity the following equation has been used:

National consumption = National production + Imports – Exports   (1)

Because import/export data was only available at the national level it was not possible to construct a balanced import export structure at a regional level; therefore, for each country non-linear functions were estimated, using econometric techniques on past data, for each of the separate commodities in the model. In the case of national agricultural production separate consumption equations were estimated for each region. All the equations were then calibrated using a variant on the PMP (Positive Mathematical Programming) technique, which allows the model to reproduce the observed results. The national consumption and production in any one country were assumed to be a function of regional prices. The imports and exports for a commodity were assumed to be the function of national and international prices. The model can therefore be described as a static, partial equilibrium, single valued expectation model and it has been constructed using ordinary linear programming techniques but includes linearised non-linear functions.

For all products included in the model, prices and demand are to be determined endogenously under several assumptions. The estimated price of a product within an individual region is constant, whether the product is home produced or imported, although prices in different states may differ. The simulation of home consumption provides the necessary supply curve. The non-linear curves are estimated using a non-linear optimization program which minimizes the sum of squared deviations from observed points under the conditions that the curve passes through the observed value for the period being modelled and that the differential of this curve is equal to the differential of the PMP estimated curves. That is:

$$\text{Min} \quad \sum \left(f(x_i - \beta) - \alpha - h(p_i) \right)^2 \quad (2)$$

Subject to

$$f(\bar{x}) = \bar{p} - \beta \quad (3)$$

$$\frac{d(f(\bar{x}))}{dx} = \bar{p} - \bar{c} - \gamma \quad (4)$$

where $f(x_i - \beta) - \alpha$ is the non-linear function of the set of past production x_i minus scaling factors α, β to allow for differences in the data sets used (FADN and r-cade), that is both the prices and quantities do not necessarily match.

$h(p_i)$ a function of the set of observed prices

$\bar{x}$ is the observed value of x (or quantity produced, imported, exported, consumed)

$\bar{p}$ is the observed price (at the current time)

$\bar{c}$ is the observed cost (at the current time)

γ is the parameter defined using the PMP methodology. The vector γ is defined as:

$$\gamma = (\bar{p} - \bar{c})' - A'\lambda \quad (5)$$

where A is the matrix of input-output coefficients of the pre-calibrated model (e.g. without the inclusion of the non-linear functions and only the production constraints and the balance constraint (1))

λ is the vector of dual values associated with the pre-calibrated model.

The set of functions h(p) are defined separately for the production, consumption, imports and exports:

For production $\qquad h(p) = p \qquad$ for each region $\qquad$ (6)

For consumption $\quad h(p) = \sum w_i p_i \qquad$ for each region i in each member state $\qquad$ (7)

$$\sum w_i = 1 \qquad (8)$$

For imports/exports $\qquad h(p) = \sum w_i p_i - \sum u_j p_j \qquad$ for each region i in a given member state and for all regions j in the model $\qquad$ (9)

$$\sum w_i = 1 \qquad (10)$$

$$\sum u_j = 1 \qquad (11)$$

Finally price was defined as function of quantity as follows:

$$h(p) = ae^{-bx} \qquad (12)$$

In this manner the demand curves have been estimated and calibrated using past observations. This technique is distinct from PMP which, uses only one observation to calibrate the model (effectively giving zero degrees of freedom). This new technique is referred to as Positivistic Mathematical Programming (PosMP).

Linearisation of Demand and Supply Curves
The production level and the price all of the crops and livestock activities are arrived at by estimating the equilibrium between supply and demand through linearisation of the demand functions. The calibrated demand functions, estimated above were split into linear segments. The supply functions in this instance are estimated econometrically using the r-cade data and calibrated using a variant of the PMP methodology. Import and export demand curves as well have been estimated using the r-cade data and the demand, supply, import and export elements of the model are constrained as in equation (1). In summary the demand curves are a function of regional prices; the supply curves are a function of the national prices (a weighted average of all regional prices); the import curves are a function of the national and international prices; and, the export curves are also a function of the national and international prices.

The required entry in the objective function is the total revenue which is equal to the equilibrium price multiplied by equilibrium the quantity (costs are assumed to remain constant and are therefore ignored). This rectangular area can be calculated as the area under the demand curve to the left of the equilibrium price 'A$_1$' plus the area below the demand curve and below the equilibrium price 'A$_2$' minus the total area under the demand curve 'A'. As the total area 'A' stays constant the entry in the objective function (maximisation) is;

$$-\sum_i A_{1i} - \sum_i A_{2i} \qquad \text{for each product i} \qquad (13)$$

To approximate these areas, the area under the demand curve is segmented horizontally for area A$_1$ and vertically for area A$_2$ between two predefined lower and upper limits on both the price and the quantity (these limits are chosen to encompass the most extreme scenarios). The segments are chosen in such a way that the difference in prices between the upper and the lower point of any two segments are equal. This difference is referred to as the price gap. Clearly the smaller the price gap the more the segments and, the greater the accuracy of determining the equilibrium.

At this point it is necessary to state the conditions that must hold for this approach to work. The demand function has to be integrable and that its integral is convex. The imposition of these conditions ensures that, in the solution of the linear programming model, the basis will be dominated by those segments with the largest area. In the case of area 'A$_1$' such segments start from the left of the diagram and for area 'A$_2$' the relevant segments are from the bottom of the diagram. Each of the horizontal segments has a complementary vertical segment (e.g. those segments that contain the same common part of the demand curve as their boundary). These complementary segments are constrained so that the vertical segment belongs to (likewise does not belong to) area A$_1$ and that the horizontal segment does not belong to (likewise does belong to) area A$_2$. Alternatively if the equilibrium occurs in these segments, then the area to the left of the equilibrium on the horizontal segment belongs to the area A$_1$ (thus the area to the right does not) and the area below the equilibrium on the vertical segment belongs to the area A$_2$ (thus the area above does not). Hence these values can be approximated using the trapezoid rule by;

$$A_{1i} = \sum_{j=1}^{n-1} (P_{\max i} + (0.5 - j)PG)DL_{ij} \qquad \text{for each product i} \qquad (14)$$

$$A_{2i} = \sum_{j=1}^{n-1} 0.5PG(D_{i,n-j} + D_{i,n+1-j})DU_{i,n-j}/DG_{ij} \quad \text{for each i} \qquad (15)$$

where $P_{\max}$ is the maximum price;
PG is the pre-determined price gap for each linearised section of the curve; DG_j is the change in the demand between prices P_j and P_{j+1} on the linearised demand curve;
D_j is the demand at each point of the linearised demand curve;
n-1 are the number of linear segments; and
DL_j and DU_j are defined as the lower and upper demand gaps where;

$$DL_{i,j} + DU_{i,n-j} = DG_{ij} \qquad\qquad j = 1,\dots,\text{n-1 and for each i} \qquad (16)$$

Hence if all of the 'j'th complementary segments of the demand curve are below the equilibrium point without containing it, then $DL_{i,j} = DG_{ij}$ and $DU_{i,n-j} = 0$. Similarly, if all of the the 'j'th complimentary segments of the demand curve are above the equilibrium point without containing it, then $DL_{i,j} = 0$ and $DU_{i,n-j} = DG_{ij}$. The total production 'DEM$_i$', therefore, is;

$$D_{\min i} + \sum_{j=1}^{n-1} DL_{ij} = DEM_i \qquad\qquad \text{for each product I} \qquad (17)$$

where Dmin$_I$ is the predetermined lower bound on quantity.

Finally, total production of each product is set to equal the total demand; hence;

$$\sum_j \sum_k Y_{ijk} * A_{ijk} = DEM_{ijk} \qquad\qquad \text{for each product I} \qquad (18)$$

where Y_{ijk} are yields of crop I in region j and member state k; and, A_{ijk} is the corresponding area grown.

The linear programming matrix for this formulation is shown in Table 1

Table 1 The linear programming matrix for estimating the equilibrium price and demand

DL_1	DL_2	...	DL_n	DU_1	DU_2	...	DU_n	DEM	A_1	A_2	Area		RHS
*	*	...	*						-1			=	0
				*	*	...	*			-1		=	0
1				1								=	DG_1
	1				1							=	DG_2
		...				...						...	...
			1				1					=	DG_n
1	1	...	1					-1				=	-Dmin
								1			-yield	=	0

It is worth noting that the areas A_1 and A_2 should include the area under the demand curve and to the left of the lowest demand, and the area under the demand curve and below the lowest price respectively, in order to calculate the total output. However, these additional areas are constant (obtainable using integration of the demand curve) and therefore do not need to be included in the formulation of the model. Further, the estimations of the areas are clearly approximations.

To appreciate how this methodology works, it is necessary to understand that the model is determining the level of the total output and production. The equilibrium price can then be calculated by dividing output by production. Further, both areas A_1 and A_2 are assumed to be convex curves with respect to changes in demand (or price). That is the value of A_1 increases at a diminishing rate as the demand increases. Similarly A_2 decreases at an increasing rate as the demand increases. This is clearly true if the demand curve is concave over the linearised section of the curve.

Activities Included in the Model
The activities included in the model are listed below and comprise 23 cropping activities and 14 livestock activities.

Cropping Activities
1. Soft wheat
2. Durum wheat
3. Barley
4. Rye
5. Oats
6. Grain maize
7. Rice
8. Other cereals
9. Potatoes
10. Sugar beet
11. Colza
12. Sunflower
13. Soya
14. Fodder dried vegetables
15. Fodderbeet
16. Fodder maize
17. Temporary grass
18. Permanent meadow
19. Other forage plants
20. Set-aside
21. Quality wine
22. Table wine
23. Olives

Livestock activities
1. Calves for fattening
2. Cattle under 1 year
3. Male cattle of 1-2 years
4. Female cattle of 1-2 years
5. Male cattle 2 years and over
6. Breeding heifers
7. Heifers for fattening
8. Dairy cows
9. Other cows
10. Goats
11. Sheep
12. Sows and pigs
13. Piglets
14. Poultry

Constraint Structure of the Model

The major constraint in the model is that the total land used in each region for each activity must be equal to the total land available. The output from each activity is simulated via the yield constraints. In the case of livestock activities, especially the bovine ones, the numbers of animals in each class of animals have been specified as ratios. It has been done in order to represent the relative herd characteristics as they exist in each region. The allocation of fodder crops and pastures are also specified as proportional to the livestock population within a specific region. The costs associated with each activity in the model are included in the objective function. In the case of the pre-calibrated model prices recorded by the FADN have also been included, however, in the final version these prices will be replaced by the supply and demand constraint structure described in the previous section. Finally, the national and the EU policy structures such as milk quotas, set aside requirements and subsidies are superimposed upon the activities in the model.

The general structure of the pre-calibrated model is defined as ;

$$\text{Max} \sum_i \sum_j \left(Y_{ij}P_{ij} + S_j - C_{ij}\right)A_{ij} + \sum_i \sum_j \left(Q_{ij} + T_j\right)L_{ij} - \sum_k h_k(p)H_k - \sum_k h_k(p)I_k + \sum_k h_k(p)E_k \qquad (19)$$

Subject to

$$\sum_j A_{ij} \leq F_i \qquad \forall i \qquad (20)$$

$$\sum_l G_l R_{im} L_{il} - A_m \leq 0 \qquad \forall i, m \qquad (21)$$

$$H_{kj} - \sum_{i \in k} Y_{ij}A_{ij} + E_{kj} - I_{kj} \leq 0 \qquad \forall k, j \qquad (22)$$

$$H_{kj} - \sum_{i \in k} L_{ij} + E_{kj} - I_{kj} \leq 0 \qquad \forall k, j \qquad (23)$$

$$M_i L_{ic} - V_i \leq 0 \quad \forall i \qquad (24)$$

where
  Y_{ij} = Yield (tonnes/ha) of crop j in region i
  P_{ij} = Price (ECUs/tonne) of crop j in region i
  S_j = Subsidy (ECUs/ha) for crop j
  C_{ij} = Cost (ECUs/ha) of crop j in region i
  A_{ij} = Area (ha) of crop j grown in region i
  Q_{ij} = Gross margin (ECUs/head) of livestock j on region i
  T_j = Subsidy (ECUs/head) of livestock j
  L_{ij} = Livestock numbers j in region i
  $h_k(p)$ are the various functions of price defined in section 2.2
  H_k = Consumption (tonnes) in country k
  I_k = Imports (tonnes) into country k
  E_k = Exports (tonnes) from country k
  G_l = Livestock equivalent units for livestock l
  R_{im} = Requirements (ha) for a livestock unit of fodder crop m in region i
  A_m = Area (ha) grown of fodder crop m
  M_i = Milk yield (litres/cow) in region i
  L_{ic} = Numbers of milking cows in region i
  V_i = Milk quota (litres) in region i

The remaining constraints in the pre-calibration model are as defined according to the PMP methodology. The non-linear production, consumption, import and export curves were then estimated and implemented according to the procedure and methodology outlined in the previous sections.

The dimensions of the final model are approximately 60000 rows and 50000 columns. Although large the model can be solved relatively quickly on a 533MHz computer. The main problems associated with using the model are the quality of the data used to estimate the calibrated model and the inputting of that data and the changes needed to be made to the model parameters in order to simulate alternative scenarios.

Results from the simulation of the agenda 2000 reform package

Under the base scenario (e.g. using the data from the base year of the model) the model replicates the observed results as expected. The model was then used to simulate agricultural production across the EU12 under the AGENDA 2000 scenario. The salient aspects of this policy are:

(i)   Area aid payments increased by 19 ECU;
(ii)   Compulsory default set aside rate reduced to 10%;
(iii)   Non-crop-specific aid payment cuts for oilseeds to the level of cereals;
(iv)   Aid payments for protein crops fixed at 72 ECU/t;
(v)   Price of skimmed milk cut by 15%;
(vi)   Quota increased by 1.5%;
(vii)   New dairy premia, 17 ECU/t of quota;
(viii) Slaughter premium for all bovine animals of 80 ECU for all animals over 8 months;

Table 2 shows the percentage changes in area for the 23 cropping activities included in the model under the above AGENDA 2000 policies. In general, the changes to production are small. However, with increases in area aid payments this will have the net effect of lowering retail prices for cereals. For oilseed production several large changes have been predicted. Although for countries such as Belgium where there is relatively little production anyway, these changes are in fact comparatively small. Despite a reduction in the area aid payments for oilseeds the prices are expected to remain at or just above current levels.

Table 2   Percentage changes in production areas under the adoption of AGENDA 2000 as predicted by the Eurotools LUAM

	Ger	Fra	Ita	Bel	Lux	Net	Den	Ire	UK	Gre	Spa	Por
Soft wheat	0.20	0.032	-0.03	1.23	-0.25	0.42	-0.27	-0.30	-0.15	0.10	-0.12	1.48
Durum wheat	Na	-0.65	-0.19	Na	Na	Na	Na	Na	-0.46	-0.07	-0.47	-51.85
Barley	-0.09	-0.15	0.04	1.29	-0.20	-0.48	-0.18	-0.63	-0.14	0.02	-0.92	2.48
Rye	-0.05	-0.34	-0.48	1.25	0.35	-0.11	-0.29	Na	0.36	-0.08	-0.88	-3.71
Oats	-0.16	-0.25	-0.13	1.75	0.39	-0.08	0.60	-0.78	-0.03	-0.02	-0.51	2.05
Grain maize	0.22	-0.07	-0.17	1.90	0.31	-0.35	Na	Na	Na	-0.05	-0.40	0.11
Rice	Na	-0.59	0.14	Na	Na	Na	Na	Na	Na	0.21	0.25	2.56
Other cereals	Na	-1.43	-0.03	1.27	Na	Na	Na	Na	-4.03	-13.19	-0.07	1.02
Potatoes	-0.07	-0.15	-0.06	1.73	0.03	-0.08	0.10	-0.57	0.05	-0.01	-0.41	0.38
Sugar beet	-0.08	-0.19	-0.02	1.73	Na	-0.08	0.10	-0.57	0.03	-0.06	-0.28	-3.23
Oilseed rape	0.00	-0.29	28.17	-89.9	-0.50	46.99	0.25	49.41	-0.21	Na	6.37	Na
Sunflower	-0.36	3.12	0.49	Na	Na	Na	Na	Na	Na	0.32	3.55	-60.55
Soya	Na	-1.08	-0.03	Na	Na	Na	Na	Na	Na	0.20	0.04	Na
Fodder vegetables	-0.08	-0.28	-0.07	1.73	0.03	-0.08	0.10	-0.57	0.03	-0.08	-0.91	0.34
Fodderbeet	-0.09	-0.33	-0.06	1.73	0.03	-0.08	0.10	-0.57	0.06	Na	-0.00	0.81
Fodder maize	-0.08	-0.26	-0.02	1.73	0.03	-0.08	Na	-0.57	0.01	-0.04	-0.01	1.35
Temporary grass	-0.09	-0.16	-0.12	1.73	Na	-0.08	0.10	-0.57	0.05	-0.04	-0.15	2.53
Permanent grass	-0.09	-0.29	-0.04	1.73	0.03	-0.08	0.10	-0.57	0.04	-0.01	-0.53	1.20

	Ger	Fra	Ita	Bel	Lux	Net	Den	Ire	UK	Gre	Spa	Por
Other forage plants	-0.09	-0.21	-0.04	1.73	0.03	Na	0.10	-0.57	0.04	-0.03	-0.22	2.12
Set aside	0.36	0.27	0.36	2.19	0.49	0.37	0.55	-0.12	0.49	0.42	-0.02	2.74
Quality wine	-0.19	-0.38	-0.06	Na	0.03	Na	Na	Na	Na	-0.02	-1.61	1.45
Table wine	Na	0.46	-0.05	Na	Na	Na	Na	Na	Na	-0.05	-0.64	0.86
Olives	Na	-0.10	-0.10	Na	Na	Na	Na	Na	Na	-0.10	-0.10	-0.10

Na = No production recorded

In the case of land used for livestock there are few major changes that have been predicted. Only in Belgium and Portugal are there any significant increases in area. Although the set-aside is to be reduced to 10%, many countries limit this reduction to 5% under special arrangement; therefore, with a limit of 10% on set aside some small increases are expected in all countries except Ireland and Spain where large increases in oilseeds are expected. The production of wine for both quality and table wines decreases in Spain whilst it increases in Portugal.

These results generated by the calibrated version of the model show very few differences from the current pattern of agricultural production in the EU, except in some countries where there is relatively small production of some crops. The changes to regional production patterns were also small although slightly larger than at the national level. The most likely explanation for this outcome is that the EU is close to equilibrium and though prices may change, the demand for each crop remains stable; also, that farmers are reluctant to change production patterns drastically. Both of these aspects are inherent in the model due to its formulation and structure.

Table 3 shows the expected percentage changes to livestock numbers for the EU12 under the adoption of AGENDA 2000 proposals. Slightly greater change is expected for livestock production than for crops. With an increase of 1.5% in milk quota all countries have increased dairy production. Although only Belgium, Luxembourg, UK and Portugal actually increase production by the full extent of 1.5%. The extra payments on male beef animals over 8 months old have restricted the negative impact of increasing dairy production would have on other livestock enterprises that compete for the same land resources. With the exception of some large changes in countries where there are few goats recorded, production of goats is expected to fall slightly across all countries. The major effect of the reforms to the dairy and beef sectors is expected to be a reduction in sheep production. However, this reduction is relatively small (again the large changes reported occur for countries which have a small sheep industry). As no reforms were included for the pig and poultry sectors, and the fact that these two enterprises do not compete for land with the cropping and livestock activities no changes were predicted.

Table 3 Percentage changes in livestock production under the adoption of AGENDA 2000

	Ger	Fra	Ita	Bel	Lux	Net	Den	Ire	UK	Gre	Spa	Por
Beef	-0.02	-0.14	-0.03	0.74	0.03	0.00	0.12	-0.16	0.01	-0.03	-0.13	1.10
Dairy	1.01	0.89	1.27	1.50	1.50	1.11	1.50	0.76	1.50	1.46	0.78	1.5
Goat	-1.71	-1.63	-1.26	Na	Na	-50.42	Na	Na	98.57	-1.83	-0.97	2.86
Sheep	-0.64	-1.42	-0.85	5.62	85.23	-0.96	0.20	-0.95	-0.02	-0.56	-1.44	0.53
Pig	0	0	0	0	0	0	0	0	0	0	0	0
Poultry	0	0	0	0	0	0	0	0	0	0	0	0

Na = No data recorded

Concluding remarks

This paper has demonstrated a methodology for calibrating international sector models using a variant of the PMP methodology, which attempts to overcome the faults of this technique. Further, a novel approach has been adopted to linearise the demand and supply functions within the model in order to endogenously estimate both price and quantity for each region, member state and the international trade between member states.

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