Modelling New EU Agricultural Policies: Global Guidelines, Local Strategies

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Abstract

The Common Agricultural Policy (CAP) has evolved throughout time reflecting the continuously changing concerns of European societies and its rural areas. The Mid-Term Review of the CAP, agreed on June 2003, represents a complete change in the way the EU support the farm sector. On the one hand, "decoupling" will make EU farmers more competitive and market oriented and, on the other hand, "cross-compliance" will ensure the respect of environmental, food safety and animal welfare standards. There is less emphasis on market and income support measures within Pillar 1 and an increasing importance of rural development programs.

One of the particularities of the new CAP is that Member States have several options to implement the single payment scheme. That means that the CAP sets up the general guidelines but it will be for Member States and regions to decide the specific measures to adopt. The versatile nature of the new CAP will lead to a multiplicity of support schemes, rising the interest of developing economic tools flexible enough to take into account the different features and concerns of the rural areas. This motivates the aim of this paper to develop a methodology aimed to guide the design of regional or local strategies in the Spanish farming systems.

The need to collect comprehensive field data is a serious limitation of traditional farm modelling methodologies to perform evaluation on a global scale. Most of existing analyses are restricted to the evaluation of impacts in limited areas making it difficult to establish general conclusions. In this context, the development of methodologies adapted to work with the limited databases available and that can be applied to diverse situations are highly valuable.

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In this paper we propose a methodological framework to assess the environmental and socio-economic impacts of different policy option in a large number of farming systems representing the heterogeneous characteristics that can be found throughout the Spanish territory. In this sense, we develop a positive mathematical programming model that allows us to simulate farmers' behaviour under alternative policy scenarios. One of the main limitations of positive mathematical programming is that available options to the farmers are limited to the observed activities in the actual situation. We propose a cost transfer approach which allow us to overcome this difficulty.

The model interface allows friendly use and easy replication to a large number of rural areas. This modelling approach allows us to evaluate environmental and socio-economic impacts of different agricultural policy scenarios. Chosen scenarios focus on some recently envisaged policy alternatives, such as the cross-compliance option in the Agenda 2000 and the decoupling scheme in the Mid Term Review of the CAP. Model results allow us to suggest that this modelling approach may be used as a management tool to assist the design of regional programs of measures within the CAP.

Keywords: policy impact analysis, positive mathematical programming, CAP reform.

Introduction

The Common Agricultural Policy (CAP) has evolved throughout time reflecting the continuously changing concerns of European societies and its rural areas. The reform of the CAP agreed on June 2003 completely changes the way the EU supports its farm sector. The key elements of the new CAP are:

- "decoupling": a single payment scheme (SPS) for EU farmers, independent from production; partial decoupling may apply to prevent abandonment of production,
- "cross-compliance" : this payment will be linked to the respect of environmental, food safety and animal welfare standards, as well as the requirement to keep all farmland in good agricultural and environmental condition,
- "rural policy": a strengthened rural development policy,
- "modulation": a reduction in direct payments for bigger farms to finance the new rural development policy,
- "financial discipline": mechanism to prevent spending exceeding the ceiling.

On the one hand, "decoupling" will make EU farmers more competitive and market oriented and, on the other hand, "cross-compliance" will ensure the respect of environmental, food safety and animal welfare standards. The SPS applies to the main market sectors, including ce-

reals, meat and milk. The tobacco, olive oil and cotton sector will be added to the system in 2006.

Member States have a considerable degree of flexibility, either to implement the single payment scheme, to develop environmental standards or to establish rural development programs. The versatile nature of the new CAP will lead to a multiplicity of support schemes, rising the interest of developing economic tools flexible enough to take into account the different features and concerns of the rural areas. This motivates the aim of this paper to develop a methodology aimed to guide the design of regional or local strategies in the Spanish farming systems.

The development of this meta-model faces several challenges. First, is that this simulation tool should accommodate the wide range of different situations that can be found throughout the Spanish farming systems. Second, it should be adapted to exploit available data sources. Third, it should show friendly use and allow easy replication in a large number of agricultural regions. Forth and most important, it should simulate the endogenous strategies adopted by farmers to deal with this new institutional context and convey useful information to the policy maker.

Because irrigation plays a major role in the Spanish agriculture, our analysis focuses on the Spanish irrigated lands. Irrigated agriculture accounts for a large share of final farming production and still plays an important role in the economic activity within some areas. Besides, agriculture has traditionally been and still is the main water user, accounting for a notable 80% of total water consumption. Moreover, agricultural intensification has led to a significant increase in water abstraction and fertilizers use, giving rise to growing environmental problems. These include lower groundwater and river flow levels as a direct result of water abstraction; increased nitrate, phosphate and pesticide leaching and the pollution of ground and surface waters.

Background

Policy impact analysis in the agricultural sector has traditionally relied on either mathematical programming models or econometric models. Even if econometric techniques have been used for assessing irrigation policies (Moore et al., 1994), programming models have been proven very useful for this purpose because they allows to explicitly model complex technological or institutional constraints. Moreover, the need to simulate policy scenarios far away from pass experience make difficult the application of econometric techniques (Taylor and Howitt, 1993; Gibbons, 1986).

The mathematical programming approach is based on models that reproduce farmer's decisions assuming an optimising behaviour and allow analyse policy changes at a detailed and disaggregated scale. However, most of existing works focus on a more or less concrete empirical application since this approach requires exhaustive and expensive fieldwork and data collection. Varela et al. (1998), for instance, conduct comprehensive field data to assess the socio economic impact of water pricing policies in several irrigation districts. On the other hand, one

of the most severe criticism to conventional mathematical programming is that the modeller is obliged to add arbitrary constraints in order to avoid too specialized solutions and so that the results calibrate to the observed situation. Both characteristics limit the potential of traditional farming models to perform policy evaluation in a relatively large number of areas.

In this context, the well-known positive mathematical programming method (PMP) overcomes some important limitations of traditional mathematical programming and has opened a promising research frontier (Howitt, 1995). Most important in this approach is that it recovers additional information from observed data on farmer's behaviour allowing to automatically calibrate the model to the base situation. In this way, it avoids the need to introduce ad-hoc and non-empirically justified calibration constraints that tight the model to the observed situation. Furthermore, the resulting model is able to respond smoothly to changes in prices or constraints.

This methodology has been very favourably welcome among policy modellers and has given raise to an active research agenda (Bauer et Kasnakoglu, 1990; Arfini, 1996 et 2001; Heckelei and Britz, 1998; Barkaoui et Bultault, 1998; Gohin and Chantreuil, 1999; Graindorge et al., 2000; Júdez et al., 2001).

Paris and Howitt (1998) and Hecklei and Britz (2000) extend the original approach to recover a flexible cost function when there are several observations on farmers´ allocation decisions applying maximum entropy criteria. This approach has established a nexus between programming and econometric techniques.

While the standard method estimates cost or production functions for each land-use activity separately from each other, Röhm and Dabbert (2003) consider in their modelling framework the elasticity of substitution among interrelated crops and develop an empirical regional production model to evaluate agri-environmental programmes. Other recent contribution to PMP is the work of Preckel et al. (2002) who build up a PMP model that permit specifying existing information on the levels of both primal and dual variables. The authors illustrate their method through an evaluation of the impacts of market resistance to genetically modified grains.

One serious limitation in PMP is that model activities are restricted to those existing in the observed situation. Thus, it does not allow considering technology adoption or new activities, even when these might become plausible strategies under certain policy changes. In this paper, we extend the standard approach and propose a cost transfer method to incorporate the possibility of water saving technology adoption and additional crops when simulating farmer's response to new agricultural policies. We build a meta model that can be applied to a wide range or heterogeneous irrigation districts to analyse farmers response to agricultural policies.

Integrating environmental goals in economic models is not an easy task. A major limitation related to agriculture and water quality has been the lack of well-established economic relationships between agricultural practices and water quality. Non-point source pollution is a dynamic and site specific process. Emissions from non-point sources are either impossible to observe or their observation is prohibitively expensive. Hence, the use of agri-environmental indicators (OECD, 2001) is the most common method to integrate environmental concerns in economic analysis.

Water pollution by nitrates is by far one of the main environmental problems associated with agricultural activities. Nitrates are highly soluble and migrate easily into groundwater through the soil, making it difficult to establish a link between nitrogen supply and water pollution. One proxy to deal with water pollution is to measure the amount of applied fertilizer.

The model results allow assessing the environmental and socioeconomic impacts of implementing new agricultural policies and convey useful information to policy makers.

Methodology

Given that farming systems and impacts of agricultural policies are highly heterogeneous throughout the Spanish irrigations, models used for analyse agricultural policies need to be disaggregated by region. Hence we have developed a methodology that can be easily applied to a large number of heterogeneous irrigated areas.

Data requirements was another decisive factor for model selection. Given the national scale of this study, we wanted to exploit available information as possible and limit the need to collect new field data. The positive mathematical programming approach, first developed by Howitt (1995), appeared as a suitable option. Compared to conventional mathematical programming, the main advantages of this approach are an exact representation of the reference situation, lower data requirements and a smooth response of model results to continuous changes in exogenous parameters when the model is used for analysis of policy changes.

One of the main disadvantages of positive mathematical programming (PMP) is that available options to the farmers are limited to the observed activities in the base-year situation. To overcome this difficulty, we have extended the standard PMP approach in order to allow the incorporation of new production activities and irrigation technologies. We propose a cost transfer approach which allows us to simulate the adoption of new irrigation technologies and the switch from irrigated to dryland crops.

The PMP method to calibrate mathematical programming models to observed activity levels typically involves a two-step procedure for implementation. In the first step, we solve a conventional programming model bounded to observed activity levels by calibration constraints. In the second step, we use information contained in dual values of the calibration constraints in order to specify a non-linear objective function such that, once the calibration constraints are removed, the new programming model reproduces almost exactly the observed activity levels.

The calibration model can be compactly written (*j* denotes the crop type, *r* the irrigation technique and *i* the resource type):

Max
$$Z = \sum_j \sum_r \left(p_j \, y_{jr} - c_{jr} \right) x_{jr} \tag{1}$$

subject to
$$\sum_j \sum_r a_{ijr} \, x_{jr} \quad \leq \quad b_i \, ; \qquad i = 1,2,\cdots,m \tag{2}$$

$$x_{jr} \geq 0; \; j = 1,2,\cdots,n \quad r = 1,2,\cdots,s \tag{3}$$

$$x_{jr} \leq x_{jr}^{0}\,(1+\varepsilon) \tag{4}$$

where Z denotes the objective function value, c is a (n × 1) vector of variable cost per unit of activity; x is a (n × 1) vector of production activity levels; p and y are vectors of (expected) output prices and yields, respectively, a_{ij} represents a (m × n) matrix of coefficients in resource/policy constraints, b_i is a (m × 1) vector of available resource quantities, x^0 is a (n × 1) vector of observed production activity levels and ε denotes a vector of small positive numbers.

The objective function maximizes net farm income. Net income is defined as total sales value minus irrigation costs and other variable costs. Resource constraints include constraints on total cropland available, total irrigation water available and agricultural policy.

The addition of the calibration constraints forces the optimal solution of the linear programming model to almost perfectly reproduce the observed base-year activity levels x^0. The solution of the linear model allows us to obtain the dual values associated to the calibration constraints, which give us extra information about the cost functions.

The first order conditions for profit maximization are:

$$\left(p_j\, y_{jr} - c_{jr} + \sum_{i=1}^{m} \lambda_i\, a_{ijr} - \mu_{jr} \right)_{x_{jr}=x_{jr}^{*}} = 0 \qquad \forall\, j,r \,/\, x_{jr}^{*} \neq 0 \tag{5}$$

$$\left(b_i - \sum_{j=1}^{n} a_{ijr}\, x_{jr} \right)_{x_{jr}=x_{jr}^{*}} = 0 \qquad \forall\, i \,/\, \lambda_i \neq 0 \tag{6}$$

$$\left(x_{jr}^{0}\,(1+\varepsilon) - x_{jr} \right)_{x_{jr}=x_{jr}^{*}} = 0 \qquad \forall\, j,r \,/\, \mu_{jr} \neq 0 \tag{7}$$

where λ_i is the dual value for the i resource and μ_{jr} represent the dual values associated to the calibration constraints.

The first condition (5) can be rewritten:

$$\sum_{i=1}^{n} \lambda_i\, a_{ijr} = p_j\, y_{jr} - c_{jr} - \mu_{jr} \tag{8}$$

In this expression, the left hand side represents the marginal value of resources used for producing a unit of the jr activity while the right hand side can be interpreted as the marginal profit of this activity.

In the second step of the procedure, the vector μ_{jr} is employed to specify a non-linear objective function such that the marginal cost of the model activities are equal to their respective revenues at the base-year activity levels x^0. If we choose a quadratic cost function :

$$CT_{jr} = \alpha_{jr}\, x_{jr} + \beta_{jr}\, x_{jr}^2 \tag{9}$$

using the first order conditions the vector of marginal values μ_{jr} allows us to estimate parameters α_{jr} y β_{jr} for this function, according to:

$$c_{jr} + \mu_{jr} = \alpha_{jr} + 2\,\beta_{jr}\, x_{jr}^0 \tag{10}$$

$$\text{with} \quad c_{jr} = \alpha_{jr} \;\; ; \;\; \alpha_{jr'} = \max\left\{c_{jr}, \left((p_j\, y_{jr} - p_j\, y_{jr'}) + c_{jr'}\right)\right\} \tag{11}$$

where r' represent the subset of irrigation technologies that do not exist in the observed situation but could probably enter the solution if the economic environment change.

Once the cost functions have been derived, we are able to define the non-linear model that allows us to simulate hypothetical agricultural policy scenarios :

$$\text{Max} \qquad \sum_j \sum_r \left(\left(p_j y_{jr}\right) x_{jr} - \left(\alpha_{jr} x_{jr} + \beta_{jr} \left(x_{jr} + \sum_{r'} x_{jr} \right)^2 \right) \right) \tag{12}$$

$$\text{subject to:} \qquad \sum_j \sum_r a_{ijr}\, x_{jr} \;\leq\; b_i \tag{13}$$

$$x_{jr} \;\geq\; 0, \tag{14}$$

This non-linear model reproduces the activity levels observed for the base-year situation and allows us to simulate hypothetical agricultural policy scenarios.

Empirical application

Using this methodological framework, we developed the meta-model APSIM (*Agricultural Policies Simulation Integrated Model*), that allowed easy replication to a wide range of irrigation areas, selected throughout the Spanish territory. Selection criteria have included area size, cropping systems, agronomic and climatic characteristics, water supply system, irrigation methods, etc.

Data sets have been limited to existing data availability. For each irrigation district, information about production activity levels, inputs use per crop, water charges, variable costs per activity, expected crop prices and yields, and agricultural policy subsidies and constraints were available. We also considered total cropland, total irrigated land and water availability.

The model allows us to reproduce the strategies adopted by farmers when a new agricultural policy measure applies. In general, there are three ways that a farmer can respond. First, the farmer can alter the crop mix. Second, the farmer can adopt modern irrigation technolo-

gies. Finally, the farmer can reduce the total irrigated land, increasing the proportion of dryland crops (adopting new activities).

This meta-model allows to analyse the economic and environmental impacts of agricultural policy scenarios. Impacts on cropland allocation, irrigation technologies, water consumption, farm net income, employment and inputs use are assessed. The model have been built using the GAMS modelling language (Brooke et al., 1998) and the model interface allowed us to replicate the model in a easy way.

In order to illustrate the capabilities of this methodological approach to asses the impacts of the CAP reform, we discuss the results obtained for two particular irrigation districts (one located in the Guadiana river basin and the other in the Guadalquivir river basin). In both cases, irrigation is carried out with surface water; the river basin authority takes the mayor responsibility for operation, maintenance and management of the water delivery system; and farmers are charged on a per unit area basis.

The policy options simulated are:

- CAP-1999 : Baseline scenario. It correspond to the Common Agricultural Policy that apply in the region in the year base situation (due to data availability we consider 1999 as the baseline situation)
- SPS-50: Single Payment Scheme (50% subventions decoupled from production).
- SPS-75: Single Payment Scheme (50% subventions decoupled from production). This scenario corresponds to the envisaged option for Spain.
- SPS-100: Single Payment Scheme (full decoupling).

The single farm payment is related to the baseline situation and future prices are assumed stable (except for cotton, in which case the support regime completely changes).

Figures 1 and 2 present some model results on cropland allocation in Guadiana and Guadalquivir irrigation districts respectively. Compared to the baseline situation (CAP 1999 scenario), full decoupling (SPS-100 scenario) induce farmers to change cropping patterns and to reduce the irrigated area. COP irrigated surface decrease and new dryland crops appear. These crop substitution effects are more acute in the Guadalquivir study area where cotton production is very important (CAP reform implies a radical change in the cotton support regime). Also, differences in productivity between irrigated and dryland crops are much higher in the Guadiana area, so the shift to dryland crops is softer in this area than in the Guadalquivir irrigation district.

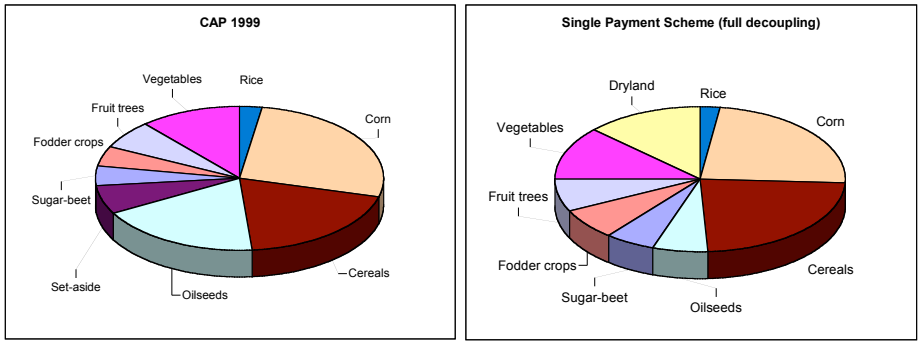

Figure 1. Cropland allocation (Guadiana irrigation district)

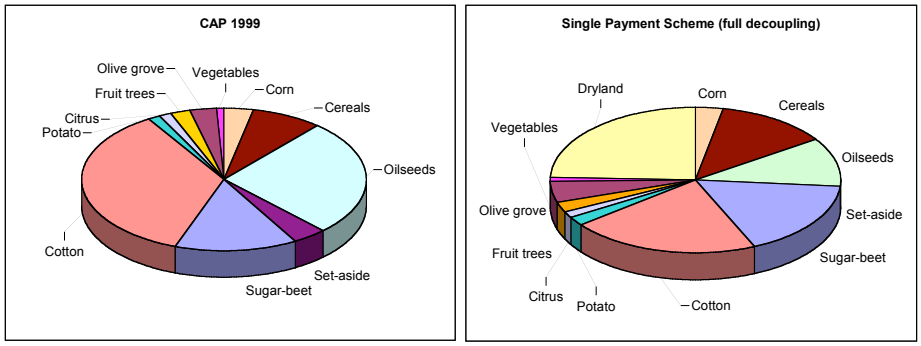

Figure 2. Cropland allocation (Guadalquivir irrigation district)

Table 1. Irrigation technology

	Guadiana Irrigation District				Guadalquivir Irrigation District			
	CAP-99	SPS-50	SPS-75	SPS-100	CAP-99	SPS-50	SPS-75	SPS-100
Dryland	0.00	0.00	4.26	12.94	0.00	10.48	17.20	24.53
Surface irrigation	93.76	93.07	88.59	79.76	93.57	82.40	75.36	67.74
Sprinkler irrigation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Drip irrigation	6.24	6.93	7.15	7.30	6.43	7.12	7.43	7.72

As a consequence, the full decoupling scenario will induce a decrease in water use in both irrigated areas (see Tables 2 and 3). However, impact of decoupling in water use is not straightforward. It depends on cropping patterns and on crop substitution effects. For instance, Table 2 shows that the in the trend on water use is not continuous in the Guadiana irrigation district. Compared to the baseline scenario (CAP-1999), the SPS-50 scenario (mid-decoupling) implies an increase in water consumption (shift from COP irrigated crops to non-COP irrigated crops). In contrast, under the SPS-100 scenario (full-decoupling) we observe a decrease in water consumption (shift from irrigated to dryland crops).

Tables 2 and 3 also show the socioeconomic effects of decoupling. Regarding farm income, we can see that the Single Payment Scheme will imply a gain in farm net income.

Table 2. Comparative results of policy scenarios (Guadiana irrigation district)

Policy scenario	**Water use** (m^3/ha)		**Farm income** (euro/ha)		**Public expenditure** (euro/ha)	
	Total	%	Total	%	Total	%
Baseline scenario (CAP-1999)	6754	100.00	954	100.00	337	100.00
Single Payment Scheme (SPS-50)	7096	105.07	999	104.71	321	95.14
Single Payment Scheme (SPS-75)	6916	102.41	1004	105.31	323	95.67
Single Payment Scheme (SPS-100)	6466	95.74	1004	105.31	337	100.00

Table 3. Comparative results of policy scenarios (Guadalquivir irrigation district)

Policy scenario	**Water use** (m^3/ha)		**Farm income** (euro/ha)		**Public expenditure** (euro/ha)	
	Total	%	Total	%	Total	%
Baseline scenario (CAP-1999)	7173	100.00	1780	100.00	218	100.00
Single Payment Scheme (SPS-50)	6281	87.57	1792	100.63	638	292.95
Single Payment Scheme (SPS-75)	5749	80.15	1842	103.46	710	326.20
Single Payment Scheme (SPS-100)	5188	72.33	1916	107.64	812	372.76

Figure 3 shows a close correlation between fertilizer use and water use. Regarding fertilizers use, model results are highly different for the two irrigation districts. In the Guadiana irrigation district, we appreciate that the amount of fertilizers used undergoes a significant increase when the decoupling percentage increases. This phenomenon can be explained by the crop substitution effect. Actually, there are a close correspondence between crop activities and fertilizer use, and the partial substitution of cotton by other crops with higher nitrate fertilizer requirements can explain this outcome.

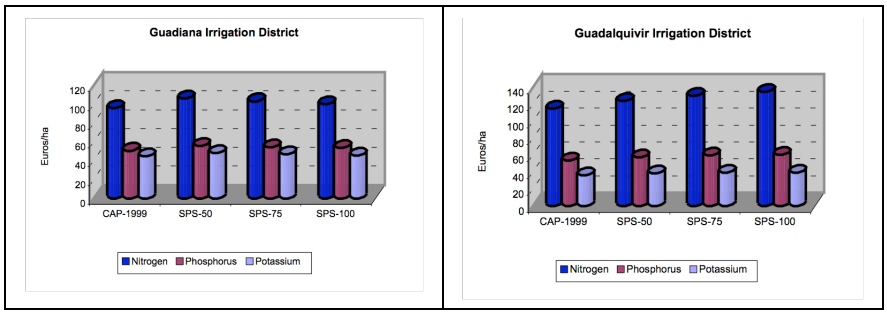

Figure 3. Fertilizers consumption

Concluding remarks

In this paper, we develop a positive mathematical programming model to assess the environmental and socioeconomic impacts of agricultural policies in Spanish irrigated lands. The proposed model allows to simulate farmers' behaviour under different agricultural policy options. Compared to conventional farm modelling methodologies, the positive mathematical programming approach has lower data requirements and can be adapted to work with the limited databases available, making it easier to perform analyses on a global scale. One of the main limitations of positive mathematical programming is that available options to the farmers are limited to the observed activities in the base-year situation. To overcome this difficulty, we propose a cost transfer approach which allows us to simulate the adoption of new production activities and irrigation technologies.

Also important is that model structure has proven great flexibility to incorporate cross-compliance and other CAP requirements. The model interface allows friendly use and easy replication to a large number of irrigation districts, which were selected throughout the Spanish territory.

Finally we have shown through an empirical application that our model results convey specific and detailed information about the impact on environmental indicators, water consumption, crop allocation decisions, technology adoption, farm income, and public expendi-

ture when different scenarios of agricultural policy are considered. These characteristics suggest that this modelling approach may be used as a management tool to analyse the economic and environmental impacts of new agricultural policy measures under the CAP.

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