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The MacSharry Challenge: A Farm Simulation Study

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ABSTRACT

A mathematical programming model is used to investigate the effects of the MacSharry Common Agricultural Policy (CAP) reform on crop yields, rotations, and tillage systems of a representative Italian farm. Both professional and small producer regimes are evaluated. The results of the simulation show the profound impact of the policy changes on farm income and land value. No-tillage is introduced to compensate for lower returns, with a strong reductive effect on crop yields. Overall, farm returns are maximized under the professional support regime.

THE MACSHARRY CHALLENGE: A FARM SIMULATION STUDY

Introduction

In May 1992, the European Community (EC) Council adopted the "MacSharry Plan," the most ambitious reform of the Common Agricultural Policy (CAP) to date. One of its main features is the drastic reduction in the level of guaranteed prices, to be completed within three marketing years, 1993/94 to 1995/96. In the case of wheat, for example, the intervention price has to be cut by 38.83 percent, the target price by 51.42 percent, and the threshold price by 30.08 percent. Wheat and corn institutional price changes are summarized in Table 1. A system of payments has been introduced to compensate farmers for the loss of income caused by the reduction of prices. Payments have been set on a per-hectare basis and are not related to current levels of output. In establishing the aid to be paid to producers, member states can choose between an individual production unit or a regional system (EC Council 1992a). In the first case, for each farm a historical average yield has been defined for all program crops (cereals, protein crops, and oilseeds). In the latter case, member states have drawn up

Table 1. EC institutional prices for wheat and corn, 1991/92-1995/96

	Target Price		Intervention Price		Threshold Price	
Marketing Year	Wheat	Corn	Wheat	Corn	Wheat	Corn
			(ECU/ton)			
1991/92[a]	233.26	212.33	168.55	168.55	228.67	207.74
1992/93[a]	226.47	206.16	163.49	163.49	221.68	201.37
1993/94[b]	130	130	117	117	175	175
1994/95[b]	120	120	108	108	165	165
1995/96[b]	110	110	100	100	155	155

[a]EC Commission (1993).
[b]EC Council (1992a)

rationalization plans for their territories; in each region, homogeneous production areas have been identified; in each area, a historical average yield has been calculated for all program crops, based on the average of three of the last five marketing years, 1986/87 to 1990/91, with the exclusion of the lowest and the highest figures. This average yield is the basis for translating the EC compensatory amount into a local per-hectare payment. A 15 percent mandatory set-aside has also been introduced as a prerequisite for program participation. The set-aside is rotational, with a 5-year time span between two consecutive set-asides on the same piece of land; a very efficient system with, probably, very limited slippage effects (Barbero and Zezza 1993).[1]

Interestingly, the new policy differentiates between farmers classified as *small* producers, when they farm an area equivalent to an annual production of no more than 92 tons of cereals, and farmers classified as *professional* producers, when their farmed area is larger. Based on the EC average cereal yield, a small producer holding should not exceed 20 hectares. Small producers are exempted from the set-aside requirement and can receive the compensatory payments on the whole farmed area, although the level of income support differs from that granted to professional producers.[2] However, they have the option of choosing the regular scheme, should this be to their advantage, with the same supply control obligations applied to professional producers.

This set of policy changes is expected to have profound implications on the EC agricultural sector. Of particular concern, especially for the EC's trading partners, is whether this reform will manage to limit cereal production. An answer to this question requires addressing two distinct issues: first, how land allocation will change because of the MacSharry Plan; and, second, how unit yields will change because of the reform. Of these two questions, the second appears the most problematic. In particular, it is clear that it cannot be tackled by econometric analysis of historical data. This is because the MacSharry Plan represents a drastic and innovative departure from past EC policies, one that has changed the framework within which production decisions are made.

To gain insight into the likely consequences of this policy reform, alternative methodologies need to be explored. In this paper, a first (admittedly small) step in this direction is taken. Specifically, a mathematical simulation model of a farm that represents specific production conditions in Northern Italy is constructed. The emphasis is on modeling the farm-level effects of the MacSharry Plan. The model is solved under alternative policy scenarios, in order to study how acreage response and crop yields will be affected by the policy reform, and to determine the impact of these changes on farm income and the shadow price of fixed assets. Parenthetically, the impact on cropping patterns, rotations, and production techniques will also be evaluated.

The Farm Setting

The model is meant to be representative of a crop farm located in Emilia-Romagna, Italy, a region that lies in the southern part of the Po Valley.[3] The Po Valley is the most productive agricultural area in the country, and an important EC grain-producing basin. The size of crop-producing farms in the Po Valley is about 20 hectares (Piccinini 1989), three times larger than the national average; specifically, it is assumed that the gross farm size of the representative farm is 25 hectares, with five hectares used for the homestead, roads, drainage ways, equipment shelters, and other nonagricultural purposes. It is also assumed that the land is owned entirely by a full-time, self-employed farmer, who can count on some extra help from his family and, when needed, hired labor, and custom operations.

In this paper, the effects of policy changes on the representative farm are investigated under both professional and small producer regimes. For this purpose, the model is solved for both scenarios, and the diverse effects of the two support regimes on farm operations are thus evaluated.[4]

Theoretical Framework and Data

The simulated effects of policy changes on crop allocations and yield response are bound to depend crucially on technological assumptions. In this paper, a simple model that captures what appear to be the essential features of a typical Northern Italian crop farm is developed. First, production decisions, as a choice between alternative techniques as well as between alternative crops, are modeled. Within each technique, the requirement of most variable inputs (such as labor, machinery, seeds, pesticides, etc.) is fixed for any given amount of land. The only input that can be used in variable proportions is fertilizer. Therefore, for a given production technique, expected output for crop i, labelled Y_i, can be written as follows:

$$Y_i = \left[\min\{\, t_i,\ \alpha L_i,\ \beta Z_i \,\}\right] \cdot g_i(X_i) \tag{1}$$

where $\{t_i, L_i, Z_i, X_i\}$ are land, labor, other variable inputs, and fertilizers, respectively, allocated to crop i.

Clearly, for any chosen technique, the amount of fertilization is what determines the expected level of production for any given amount of land (i.e., yields). In addition, constant returns to scale in all inputs are assumed, which means that the production level obtainable on a given field (or farm) can be replicated on other fields (or farms). Therefore, yields, which are defined as $y_i \equiv Y_i/t_i$, can be written as:

$$y_i = g_i(x_i) \tag{2}$$

where $x_i \equiv X_i/t_i$ is the level of fertilizer per unit of land, and obviously the level of labor and other inputs per unit of land will be constant, i.e., $l_i \equiv L_i/t_i = 1/\alpha$ and $z_i \equiv Z_i/t_i = 1/\beta$.

Whereas these two assumptions may be deemed too restrictive, it should be borne in mind that they hold for any given technique; then, further generality is introduced by allowing farmers to choose among techniques. With due approximation, this modelling framework is meant to be representative of ordinary farm operations. Producers' decisions generally involve choosing among crops and, for each crop, the definition of a specific farming system, with well-defined levels of inputs use and mechanization; however, fertilizer application cannot be decided a priori, since it is strongly influenced by agronomic and weather conditions as well as economic considerations.

At any rate, it is clear that the combination of the above assumptions would imply that a farmer maximizing (expected) profit will devote all his land to the one crop and the one technique that give the highest returns. Although sometimes observed, this complete specialization is not a characteristic feature among farms in the region investigated. One explanation for crop diversification is inherently dynamic: multiple cultures allow crop rotation on a given land, and this rotational structure is desirable because it improves yields. For example, other things being equal, wheat yields are greater if wheat follows soybeans rather than if wheat follows wheat. To account for this observation, and to make explicit the fact that the farmer can choose among alternative techniques, the yield response function of equation (2) can be rewritten as:

$$y_{is}^{\delta\epsilon} = g_{is}^{\delta\epsilon}(x_{is}^{\delta\epsilon}) \tag{3}$$

Therefore, in this formulation $y_{is}^{\delta\epsilon}$ is the yield of crop i grown with cropping system δ on a field that in the previous year was allocated to crop s grown with a farming system ϵ, and $x_{is}^{\delta\epsilon}$ is the corresponding amount of fertilizer per hectare.

The dynamic feature introduced by the rotational assumption suggests a dynamic programming approach to our simulation of the effects of the policy reform. However, because the long-run effects of the policy changes are of greater interest than the short-term dynamics, a simpler approach is adopted carrying out an extended version of the rotational structure formalized by Throsby (1967) and developed by El-Nazer and McCarl (1986). In this approach, a timeless equilibrium solution is identified as a continuously repeatable crop pattern, i.e., a sustainable rotation.

Given the above, and assuming that N crops can be grown, each with M alternative techniques, the farm decision problem can be represented as:

$$\underset{t_{is}^{\delta\epsilon},\, x_{is}^{\delta\epsilon},\, HL}{Max} \left\{ \sum_{\delta=1}^{M} \sum_{\epsilon=1}^{M} \sum_{i=1}^{N} \sum_{s=1}^{N} t_{is}^{\delta\epsilon} \cdot \Pi_{is}^{\delta\epsilon} - w \cdot HL \right\} \tag{4}$$

where $t_{is}^{\delta\epsilon}$ denotes land allocated to crop i grown with cropping system δ on a field that in the previous year was allocated to crop s grown with farming system ϵ, w is the wage rate for hired labor, HL is total hired labor, and the unit (per hectare) return for this allocation, labelled $\Pi_{is}^{\delta\epsilon}$, is defined as:

$$\Pi_{is}^{\delta\epsilon} \equiv p_i \cdot g_{is}^{\delta\epsilon} (x_{is}^{\delta\epsilon}) - r \cdot x_{is}^{\delta\epsilon} - Q_{is}^{\delta\epsilon} - K_{is}^{\delta\epsilon} \tag{5}$$

where p_i is output price for crop i, r is the price of fertilizer, $x_{is}^{\delta\epsilon}$ is the amount of fertilizer used, $Q_{is}^{\delta\epsilon}$ is the unit (per hectare) direct cost (corresponding to the input vector z), and $K_{is}^{\delta\epsilon}$ denotes imputed costs (e.g., administration, management, or depreciation on fixed capital).

The constraints for this maximization problem are as follows:

$$\sum_{\delta=1}^{M} \sum_{\epsilon=1}^{M} \sum_{i=1}^{N} \sum_{s=1}^{N} t_{is}^{\delta\epsilon} \leq T \tag{6}$$

$$\sum_{\delta=1}^{M} \sum_{i=1}^{N} t_{is}^{\delta\epsilon} - \sum_{\theta=1}^{M} \sum_{u=1}^{N} t_{su}^{\epsilon\theta} \leq 0 \tag{7}$$

$$\sum_{\delta=1}^{M} \sum_{\epsilon=1}^{M} \sum_{i=1}^{N} \sum_{s=1}^{N} t_{is}^{\delta\epsilon} \cdot l_{is,q}^{\delta\epsilon} \leq FL_q + HL_q \tag{8}$$

$$t_{is}^{\delta\epsilon} , x_{is}^{\delta\epsilon} , HL \geq 0 \tag{9}$$

Hence, equation (6) is the land availability constraint, where T is the total available farm land. Equation (7) represents the rotational constraint, which holds for all possible N x M combinations of crops and techniques. And, equation (8) is the labor constraint, where $l_{is,q}^{\delta\epsilon}$ is unit (per hectare) labor requirement in season q (spring, summer, autumn), FL_q is family labor availability in season q, and HL_q is hired labor in season q, such that total hired labor for the year is:

$$HL \equiv \sum_{q=1}^{3} HL_q \tag{10}$$

In this modeling structure, once the optimal input levels, hence the optimal crop yields, have been determined, the acreage allocation has linear constraints only. Consequently, the main feature of a linear program (i.e., discontinuous response) holds and becomes manifest in the results, with discrete changes in optimal rotations and tillage systems. For the reasons given above, this outcome seems to represent a reasonable approximation of real farm operations and producers' behavior.

Crucial to the solution of the farm model illustrated above is the specification of the yield function. Paris (1992) presents a thorough overview of the fertilization problem, considers alternative functional forms, and provides evidence in support of the "von Liebig" formulation. The experimental data available to this simulation, however, is in terms of the "Mitscherlich" formulation, and essentially only in terms of response to nitrogen fertilization for given (normal) levels of other nutrients. Specifically, the following modified version of the "Mitscherlich" formulation (Giardini L. 1992; Giardini and Borin 1985; Giardini et al. 1988) was used:

$$y_i \equiv g_i\,(x_i) = A_i \cdot \frac{\left[1 - 10^{-c_i(b_i + x_i)}\right] \cdot 10^{-k_i(b_i + x_i)^2}}{1 + 10^{[1 - c_i(b_i + x_i)]}} \tag{11}$$

where the parameter A_i determines the maximum yield (yield plateau) for crop i, and the term multiplying A_i is a "relative yield response" function, which depends on the level x_i of applied nitrogen through crop-specific parameters c_i, b_i and k_i.

Four crops are allowed in the farm: wheat, sugar beets, soybeans, and corn. For each crop, there are three possible production techniques. These are best characterized by the tillage system adopted: traditional tillage (TT), the moldboard plow soil preparation; reduced tillage (RT), a quicker and simpler seedbed preparation; and no-tillage (NT), no preplant tillage.[5]

Under the modeling procedure illustrated above, with the possibility of choosing between three tillage systems and four crops, and with one-year influence on yields of the preceding crop, 112 two-year rotation activities ($t_{is}^{\delta\kappa}$) were defined.[6] Field operations, input, and labor requirements for each activity were determined upon consultation with agronomists at the Institute of Agronomy of the University of Bologna. Consequently, production costs for each activity were calculated based on data from the Institute of Farm Accounting of the same university.

The response function parameters $\{A_i, c_i, b_i, k_i\}$ are not readily available from experimental data for all production techniques and all rotational sequences. Rather, these parameters can be obtained, at best, only for "normal" levels of other variables, for each crop considered. To proceed, we approximate the technique-specific and rotation-specific effects by adjusting the plateau parameter. Thus, we substitute $A_{is}^{\delta\kappa}$ for A_i in equation (11), whereas the other parameters are common to all rotations and to all techniques (for a given crop i). Appropriate values for these parameters were selected based on experimental evidence and expert opinion in collaboration with the Institute of Agronomy of the University of Padova. Graphical displays of yield response curves are provided in Figures 1 and 2. For wheat, the residual effect of the preceding crop's tillage system is specifically illustrated. In case of wheat and sugar beets, an upper bound to the level of nitrogen application had

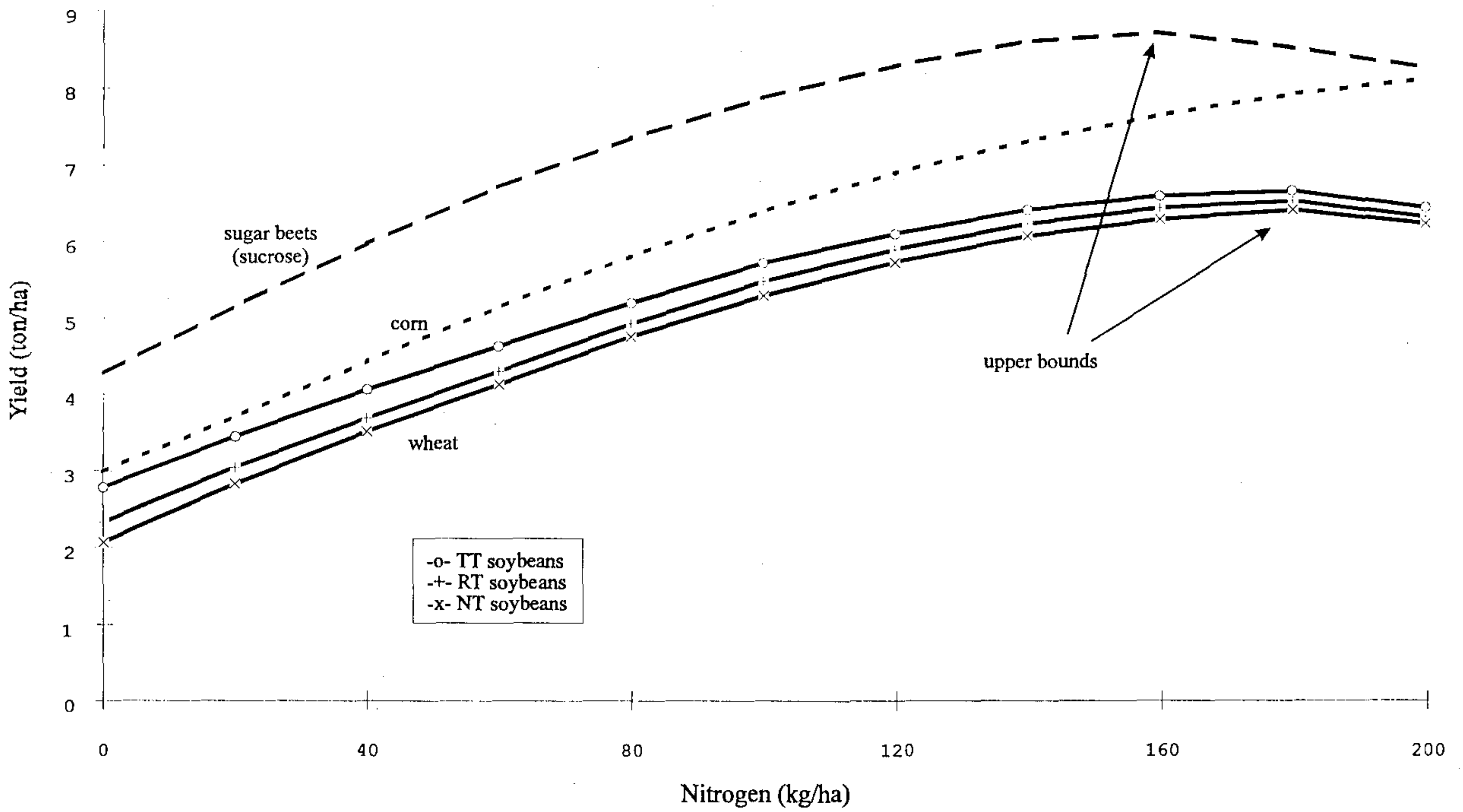

Figure 1. Yield response to nitrogen fertilization for RT wheat following soybeans, TT sugar beets, and TT corn.

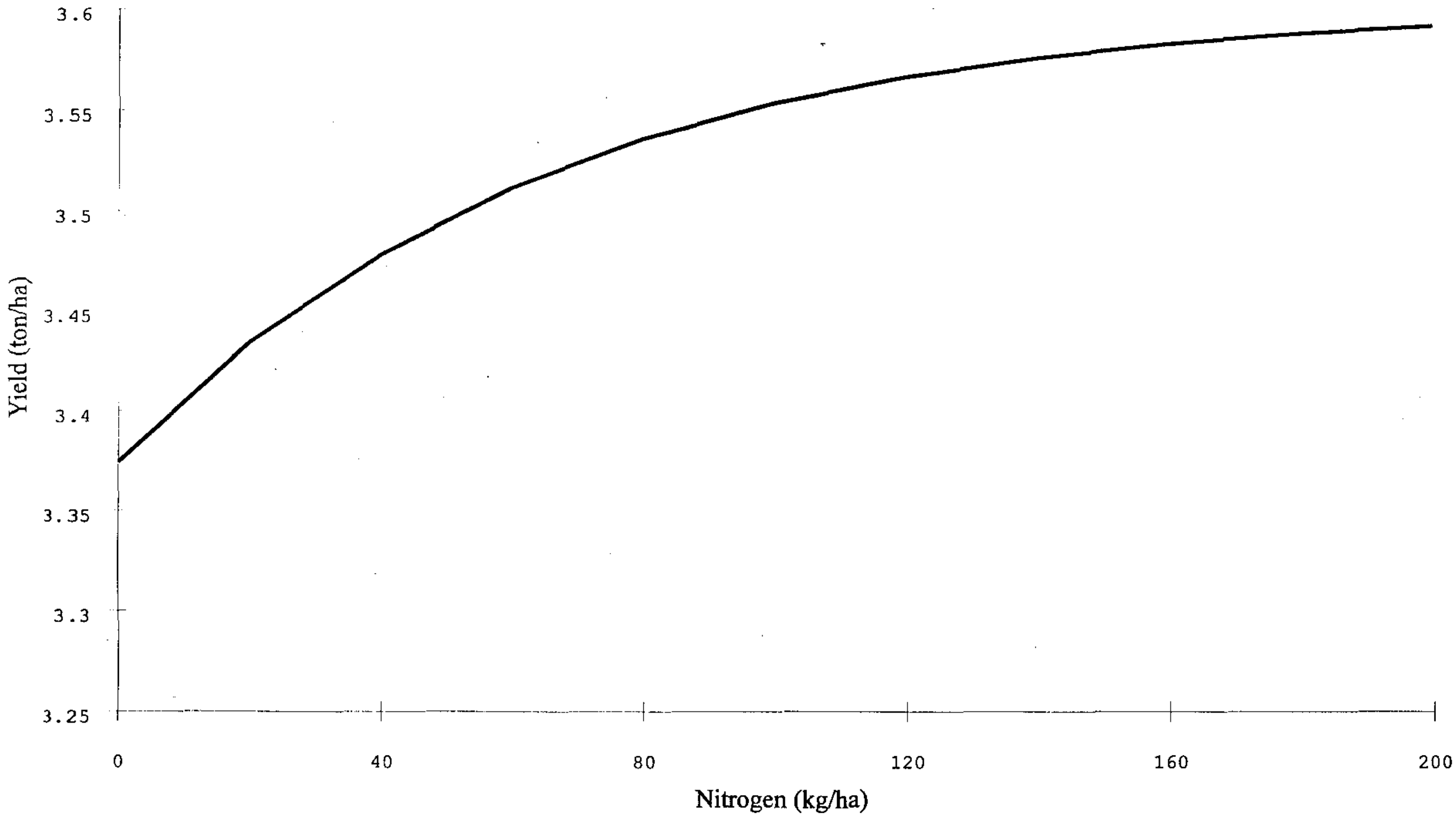

Figure 2. Yield response to nitrogen fertilization for NT soybeans.

to be introduced, for the asymptotic shape of the Mitscherlich function could have resulted in agronomically unfeasible solutions (excessive nitrogen leads to lodging in wheat and a sharp decrease in the sugar content in sugar beets). Based on experimental evidence, the upper limit was fixed at 180 and 150 kg per hectare for wheat and sugar beets, respectively.

Finally, note that the return specification of equation (5) pertains to the prereform situation. The new policy changes introduced with the MacSharry Plan can be captured by writing per-hectare returns for professional producers as:

$$\Pi_{is}^{\delta\epsilon} \equiv \left(1 - R_i\right) \cdot \left[p_i \cdot g_{is}^{\delta\epsilon}\,(x_{is}^{\delta\epsilon}) + C_i - r \cdot x_{is}^{\delta\epsilon} - Q_{is}^{\delta\epsilon}\right] - K_{is}^{\delta\epsilon} + R_i \cdot D \qquad (12)$$

where p_i is now the post-reform output price, R_i is the set-aside requirement, C_i is the per-hectare crop-specific compensatory payment, and D is the net compensation for the set-aside land (EC payment minus due maintenance costs). As previously explained, small producers are granted an optional special regime under the MacSharry Plan, such that they have the option of considering a per-hectare return function of the type:

$$\Pi_{is}^{\delta\epsilon} \equiv p_i \cdot g_{is}^{\delta\epsilon}\,(x_{is}^{\delta\epsilon}) - r \cdot x_{is}^{\delta\epsilon} - Q_{is}^{\delta\epsilon} - K_{is}^{\delta\epsilon} + C \qquad (13)$$

where C is the compensatory payment, which in this case is equal for all program crops.

Crop market prices and compensatory amounts for all program crops are reported in the Appendix.

Results

Reference Solutions

The model outlined in the previous sections was solved for the pre- and the postreform conditions for both small and professional support regimes, providing comparative results for the analysis.

Crop rotations and tillage systems are shown in Table 2. Originally, the best plan is a continuous three-year rotation including RT wheat, followed by TT sugar beets and RT soybeans, and then starting with RT wheat again. This is a common solution in the area of interest, where most grain producers have gradually abandoned the traditional moldboard plow tillage and adopted more rational, cost-saving farming techniques. The policy reforms introduced with the MacSharry Plan leave the rotation unchanged but impose an additional budgetary constraint, forcing the farmer to adopt a less-expensive farming solution. This is achieved with the introduction of no-tillage in wheat and soybean cultivation for the professional producer, and only for wheat in the small producer case.

A summary of the simulated effects of the policy changes is presented in Table 3. The deterioration of the farmer's economic situation is evident. For the professional producer, per-hectare

Table 2. Model simulation: Optimal crop rotations and tillage systems

Simulation	Crop	Tillage	Land share (percent)
Prereform	Wheat	RT	0.33
	Sugar beets	TT	0.33
	Soybeans	RT	0.33
Postreform			
Professional Producer	Wheat	NT	0.33
	Sugar beets	TT	0.33
	Soybeans	NT	0.33
Small Producer	Wheat	NT	0.33
	Sugar beets	TT	0.33
	Soybeans	RT	0.33

returns drop by 27 percent and the lower profitability causes a sharp reduction in returns to land, whose shadow price falls by almost one-third of its original value. Family labor never results in a binding constraint in farm operations. Wheat nitrogen application remains unchanged, but the negative effects of no-tillage, both in wheat and in the preceding crop in the rotation (soybeans), determine a 20 percent reduction in its yield. Sugar beets nitrogen use is also unaltered, but its yield drops by 4 percent due to the negative effect of no-tillage on the preceding crop (wheat) in the rotation. For soybeans, the effects of no-tillage and the sharp reduction in nitrogen fertilization are a 12 percent contraction in yields. Similar results characterize the small producer's situation, with a more severe reduction in farm returns and land value and, conversely, a lower decrement in crop yields. No-tillage is responsible for a 10 percent reduction in wheat yields. In the case of soybeans, tillage is maintained at its prereform optimal level; nitrogen fertilization is, again, sharply reduced, but yields decrease by only 2 percent, due to the very low response to nitrogen application.

Table 3. Model simulation: Summary of results

	Prereform	Postreform	
Model Variables		Professional Producer	Small Producer
Obj. Value (000 L/ha)	933.28	683.09	600.04
Land λ (000 L/ha)	933.28	664.95	425.26
Labor λ (000 L/ha)	0.00	0.00	0.00
Crop Yield (ton/ha)			
Wheat	6.61	5.23	5.95
Sugar beets	8.73	8.37	8.37
Soybeans	3.90	3.43	3.81
Nitrogen (kg/ha)			
Wheat	180.00	180.00	180.00
Sugar beets	150.00	150.00	150.00
Soybeans	73.78	18.64	25.43

λ = shadow price.

To summarize, the policy reform introduced with the MacSharry Plan causes a sharp deterioration in farm returns and land values, but leaves the optimal land allocation unchanged. Except for soybeans, nitrogen fertilization rates also remain unchanged, but crop yields are consistently reduced by the introduction of no-tillage farming techniques. These results are very consistent. As budgetary constraints grow, the number of field operations is progressively reduced and crop yields fall due to agronomic changes (e.g., higher soil compaction, more superficial root systems, lower mineralization of the organic matter, lower soil temperature, with delayed plant emergence and size, more difficult weed control, more serious pesticide and disease problems). But given its very low cost, nitrogen application is always maximized for those crops showing a high response to fertilization (wheat and sugar beets), while it is reduced for soybeans, whose response to nitrogen is much lower.

Sensitivity Analysis

In the present study, most of the model's parameters are set as a result of policy decisions. The main objective of this analysis is to understand the full implications and the potential consequences of these changes. In particular, the influence of set-aside requirements, output prices, and the level of the support payments on the optimal solution need to be investigated. These factors, as well as the effects of changing the price of nitrogen, are examined in the following sensitivity analyses: Scenario 1, increase in set-aside requirements; Scenario 2, devaluation of the Lira/ECU conversion rate and, consequently, increases in output prices and support payments; and Scenario 3, increase in the price of nitrogen. Results are presented in Tables 4 and 5.

Scenario 1. Under the provisions of the MacSharry Plan, to maintain the equilibrium between supply and demand and avoid the accumulation of new surpluses at intervention, the EC institutions could decide on an increase in the minimum set-aside requirement (Council of the EC 1992a, p. 14).

In this case, only the effects on the production decisions of the professional farmer are relevant, since no mandatory acreage reduction is required for small producers at the moment.

Clearly, the optimal solution is quite stable to changes in the set-aside area, and for a moderate increase in mandatory land retirements only a small reduction in farm returns occurs (Table 4). A 50 percent increase, hence a 22.5 percent acreage reduction requirement, determines a change in the basis. But in this case, a strong incentive for higher production is introduced: the optimal tillage systems return to their prereform equilibria as do crop nitrogen use and yield levels (with the exclusion of soybeans). On the land in production, the effects of the MacSharry Plan are thus eliminated.

Therefore, the effects of an increase in set-aside requirements are mixed. A greater land retirement would certainly favor further output reductions but, at the same time, higher yields and a probable lower participation rate of small producers in the professional support regime would push in the opposite direction.

Scenario 2. To focus solely on the effects of the MacSharry Plan, the postreform reference solutions were obtained by maintaining the original value of the Lira/ECU conversion rate at the time the policy reform was first introduced. Guaranteed price levels and compensatory payments are set by the EC Institutions in ECU and are to be converted in national currencies using the green ratios. Evidently, alterations in the green parities lead to adjustments of prices and compensatory amounts expressed in national monies. In Italy, this is a very important issue, given the frequent monetary realignments that have led, since the starting time of the MacSharry reform, to a strong devaluation of the green parity of the Lira within the ECU. Then, it seems interesting to investigate the effects of these factors on the optimal solution of the representative farm (Table 4).

Table 4. Sensitivity analysis: Summary of results for Scenarios 1 and 2

Scenarios	1		2		
Variations	+25	+50	-5	-10	-15
	(percent)		(percent)		
Professional Producer					
Rotation	-	Δ[a]	Δ[b]	Δ[a]	Δ[a]
Obj. Value (000 L/ha)	672.05	689.15	744.54	819.56	874.99
Crop Yield (ton/ha)					
Wheat	5.23	6.61	5.95	6.61	6.61
Sugar beets	8.37	8.73	8.37	8.73	8.73
Soybeans	3.43	3.81	3.82	3.83	3.84
Nitrogen (kg/ha)					
Wheat	180.00	180.00	180.00	180.00	180.00
Sugar beets	150.00	150.00	150.00	150.00	150.00
Soybeans	18.64	25.43	28.71	31.81	34.77
Small Producer					
Rotation			-	-	Δ[a]
Obj. Value (000 L/ha)			667.52	719.86	789.17
Crop Yield (ton/ha)					
Wheat			5.95	5.95	6.61
Sugar beets			8.37	8.37	8.73
Soybeans			3.82	3.83	3.84
Nitrogen (kg/ha)					
Wheat			180.00	180.00	180.00
Sugar beets			150.00	150.00	150.00
Soybeans			28.71	31.81	34.77

(-)/(Δ) same (different) as (from) the postreform reference solution (Table 2).
[a]Three-year RT wheat-TT sugar beets-RT soybeans.
[b]Three-year NT wheat-TT sugar beets-RT soybeans.

As output prices and compensatory payments increase, farm returns rise and the budgetary constraints which had forced the introduction of cost-minimizing farming systems gradually disappear. For a 15 percent devaluation of the Lira, both professional and small producers' input use, rotations, and tillage practices return to the prereform reference optima; again, the effects of the MacSharry Plan are completely eliminated.

Scenario 3. Quite interestingly, the results obtained in the preceding sections show that the decrease in crop yields is generally induced by the reduction in tillage, while nitrogen use, in the case of wheat and sugar beets, is unaffected by the policy changes. If this is the case, it is evident that the cost of nitrogen is not, at the moment, a binding constraint in farm operations. In this context, an evaluation of the effects of a change in the price of nitrogen is of great interest. In this case, the prereform optimum is chosen as the reference solution (Table 5). For a 250 percent nitrogen price increase, the producer maintains the traditional rotation, but no-tillage is introduced for wheat and soybeans; the fertilization level is consistently reduced for wheat and terminated for soybeans. Compared with the reference optimal values, for a 300 percent nitrogen price increase, the average yields for wheat and soybeans drop by 25 and 14 percent, respectively. The total reduction in per-

Table 5. Sensitivity analysis: Summary of results for Scenario 3

Variations	+200	+250	+300
		(percent)	
Rotation	-	Δ[a]	Δ[a]
Obj. Value (000 L/ha)	752.00	600.85	563.40
Crop Yield (ton/ha)			
Wheat	6.60	5.05	4.96
Sugar beets	8.73	8.37	8.37
Soybeans	3.77	3.37	3.37
Nitrogen (kg/ha)			
Wheat	178.67	154.38	145.13
Sugar beets	150.00	150.00	150.00
Soybeans	12.50	0.00	0.00

(-) = same as the prereform reference solution (Table 2).
(Δ) = different from the prereform reference solution.
[a]Three-year NT wheat-TT sugar beets-NT soybeans.

hectare returns is also substantial, almost 40 percent. Clearly, the effects of a strong nitrogen price increase on economic returns, farming systems, and output levels are quite similar to those introduced with the MacSharry policy reform.

Summary and Conclusions

This study has focused on the reform of EC agricultural policy. The consequences of the policy changes on a representative Italian crop farm were investigated by solving a mathematical optimization model, to assess the impact on crop yields, farming systems, and acreage response.

In the results of this simulation, under the new regime of low market prices, mandatory land set-aside, and income support payments, the farmer is unambiguously worse off than before, with an estimated 25 to 30 percent reduction in per-hectare returns. Should the farmer opt for the special support regime granted by the EC to small producers, this reduction would create even more severe results, since the benefits from the absence of set-aside requirements would be more than offset by the reduction in the level of EC income support. Lower returns are a strong incentive to reduce the number of field operations, and the introduction of no-tillage leads to a considerable decrease in crop yields. In particular, wheat and soybean yield reductions were estimated at approximately 20 and 10 percent of their current average values, respectively. A 30 to 40 percent reduction in the value of farmland was also estimated.

The level of farm output is influenced by the particular support regime chosen by the farmer. In the professional producer's case, the land retirement under the mandatory set-aside program strongly reinforces the effect of reduction in yields and determines a consistent decrease in production. Under the small producer regime, no land set-aside is required and the lower yield reductions have only a moderate effect on the level of farm output. Then, assuming that these findings can be extended to a large number of crop farm operations, the effect of the reform on regional grain production is likely to be influenced by the type of producers operating in the area of interest and their preferences for the support regime. Our findings in the area considered in this study, the southern part of the Italian Po Valley, show that the professional regime should be preferred by all crop producers. Therefore, the effect of the reform on the level of aggregate grain production should be significant.

The result of the sensitivity analysis shows the farmer's response to changing policy conditions. A devaluation of the green parity (therefore, higher guaranteed prices and compensatory payments), and a substantial increase in the acreage reduction requirement, create a strong incentive for more intensive production and gradually eliminate the effects of the MacSharry reform on farming systems and crop yields. Finally, a higher nitrogen price appears to be a very effective solution for obtaining a consistent output reduction. In the light of this result, it is not unreasonable to think that an alternative approach could have been used to meet the MacSharry goals. For example, a drastic increase in the price of fertilizers could have been introduced. It appears likely that, under such a different scenario, a considerable reduction in the level of production might have been achieved as well.

APPENDIX

The model was first solved under the prereform market conditions. For this purpose, the 1991/92 marketing year was chosen, since necessary farm data for 1992/93 were not yet available. For the base year, crop market prices were recorded from regional farm statistics. Price forecasting for the stabilized market condition following the reform is, at the moment, arbitrary; as a reference, the new intervention level for wheat and corn and the world "reference price" for soybeans were used (EC Council, 1992a, 1992b). In the case of sugar beets, the price (expressed in Lire/kg sucrose, with a 16 percent sugar content) was maintained at the prereform level, since no provision for a reform of the sugar sector is contained in the new plan. All computations were made using the monetary conversion rate existing at the time the MacSharry reform began (1 ECU = 1,761.45 Lire).

Crop market prices

	Prereform (1991/92)	Postreform (1995/96)
	(Lire/kg)	
Wheat	300.00	176,14[a]
Sugar beets	531.25	531.25
Soybeans	600.00	287,12[b]
Corn	280.00	176,14[a]

[a] Intervention price = 100 ECU/ton.
[b] World reference price = 163 ECU/ton.

Given the new policy provisions and the results of the Italian regionalisation plan (MAF 1992), the compensatory payments for the professional producer (C_i), expressed in lire per hectare, resulted in the following:

$C_{(wheat)}$ = regional yield (ton/ha) * compensatory amount (L/ton) =

= 6.119 * 79,265.25 = 485,024

$C_{(corn)}$ = regional yield (ton/ha) * compensatory amount (L/ton) =

= 8.044 * 79,265.25 = 637,610.

$C_{(soybeans)}$ = EC reference amount (L/ha) * conversion factor =

= 632,360.55 * (3.686/2.36) = 987,661

where 3.686 and 2.36 are the regional and EC average yields, respectively. Under the small producer regime, the compensatory payment for all program crops, expressed in lire per hectare, was calculated as follows:

C = all cereals average regional yield (ton/ha) * compensatory amount (L/ton) =

= 6.276 * 79,265.25 = 497,469.

In both cases, no payment is provided for sugar beets, which is not a program crop. Under the original MacSharry provisions, the per-hectare set-aside compensation for the professional producer is equal to the small producer compensatory payment (C). Average maintenance costs for the set-aside land were estimated at 260,000 lire per hectare; therefore, the set-aside net compensation (D) resulted as follows (in lire per hectare):

D = 497,469 - 260,000 = 237,469.

The set-aside requirement is 15 percent for all program crops. Given the rotational obligation, it was assumed that, on average, the set-aside is fully effective, with no slippage effects. All production costs were assumed constant at their prereform market level, for the focus of this study is solely on the effects of the policy reform, abstracting from macroeconomic long-run adjustments. Finally, the model does not include any long-run yield increase due to technological progress. As explained in the text, the MacSharry Plan has altered the productive decision framework and is expected to lead to a considerable reform in production technology. But, at the moment, testable data for the long-term trend of yields for the hypothesized new farming systems is not yet available.

NOTES

1. More recently, a 20 percent fixed set-aside has also been introduced (EC Council 1993), and a rise in set-aside compensation has been proposed. These new features have not been included in the present study, which is focused solely on the original version of the MacSharry Plan.

2. The compensatory payments for professional producers are crop-and-yield specific, while the aid paid to small producers is independent of the mix of crops sown and is referred to as the regional all-cereal average yield.

3. Specifically, this farm is thought of as being within the administrative province of Bologna. Agriculture is an important industry in Emilia Romagna. On a national basis, 25 percent of common wheat, 35 percent of sugar beets, 12 percent of soybeans, and 7 percent of corn are produced in this region (INEA 1991). Within the province of Bologna, grain farms account for more than 70 percent of total existing farms and land harvested of cereals and sugar beets represents about 65 percent of total farmed area (Regione Emilia-Romagna 1992).

4. In particular, the evaluation of the small producer regime is a matter of considerable interest for Italian agriculture, since small family operations represent a vast majority of total national farms (ISTAT 1989).

5. In the case of wheat, only reduced and no-tillage are considered, because in the area of interest most farmers have gradually abandoned the traditional moldboard plow tillage. For a detailed description of the tillage systems adopted in this study, see Giardini G. (1992).

6. Continuous sugar beets was not included as a feasible rotation activity, because of the serious parasite problem and the product quality deterioration it causes.

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