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Alternative Cropping Patterns of Cypriot Farming and their Impact on the Level of Externalities

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Abstract

Agriculture's multifunctional character is highly related to the prevailing farming systems in a region. This means that the cropping pattern and input use are expected to determine, to a degree, agriculture's externalities, both on the environment and on rural development. The purpose of this study is to examine the impact on the level of externalities by changes on the cropping pattern in Cyprus. Alternative cropping scenarios for Cypriot agriculture are developed by means of a parametric programming model, using technical and economic data for the main crops in the country. The results indicate that cereal crops are expected to prevail if an extensive pattern of agriculture is to be adopted substituting tree crops, vines and vegetables. Due to the low input requirements of cereal crops, especially in agrochemicals and irrigation water, substantial environmental benefits are expected if such a scenario is adopted. However, labor in the agricultural sector is expected to be reduced and the remaining farmers will ameliorate their individual incomes. Hence, the adoption of an extensive cropping pattern depends on the implementation of rural development measures, which should concentrate on alternative labor and income sources, otherwise rural areas in the country will be faced to depopulation.

Key words: Cypriot agriculture, cropping pattern, parametric programming, agriculture's multifunctionality, extensification, externalities.

1. Introduction

Agriculture is a multifunctional sector as, apart from its primary role of producing food and fiber, it performs a wide range of environmental, economic and social functions in the form of public goods and externalities (FAO, 1999; Romstad et al., 2000). These non-traded goods and services, except from food safety, are classified into effects on the environment and effects on rural amenities (OECD, 2001).

Agriculture's impact on the environment is positive in preserving farm biodiversity and sustaining landscapes. Pollution of surface and underground water resources from non-point sources (Hitchens et al., 1978; Thampapillai and Sinden, 1979; Burton και Martin, 1987; Pretty et al., 2000) and pressure on water reserves because of intensive irrigation (Hall et al., 2004) are some of the most important negative externalities of the farming sector. These are more explicit in the European Union (EU) due to the intensive farming systems that prevail in the continent.

The farming sector's role is also important in maintaining rural amenities and vivid a vivid countryside. Especially in mountainous and less-favored areas, where rural economy is not diversified, agriculture has been the main, or only, source of income and employment for centuries. This particular development process has formulated a unique cultural environment in EU rural areas, which encompasses features referred to as the agricultural cultural heritage. Society traditionally views peasants as responsible for safeguarding these features, therefore implying interest in keeping rural areas alive. In this context, the farming profession is endowed with non-use values, which provide arguments for retaining protectionism in the sector.

A positive approach of multifunctionality recognizes that policy measures are essential in order to maintain non-traded outputs of agriculture, if society values these outputs. However, the achievement of a certain level of them is a difficult task, as it is closely associated to the production of marketed goods (Allaire and Dupeuble, 2002; Hediger and Lehmann, 2003).

The choice and enforcement of appropriate measures for non-traded goods and services has been a critical issue in the agricultural policy agenda during the past few years. Within the World Trade Organization (WTO), "opponents" and "friends" of multifunctionality highlight conflicting perspectives. USA and the CAIRNS group proclaim that non-traded goods and services can be produced by other sectors of the economy, thus agriculture's multifunctionality is merely a disguise for keeping in force price policy measures that distort markets. The EU, on the other hand, stress the importance of safeguarding the parametric programming model is described along with the technical and economic data used. The results are reported in the following section. The paper ends with a discussion of the results of the empirical analysis.

2. The farming sector in Cyprus

The farming sector in Cyprus accounts for 3.1% of the GDP, 6.7% of employment in the country and 21.2% of exports (Ministry of Agriculture, Natural Resources and Environment, 2008). The country's 44776 farms cultivate, on average, 3.5 hectares (ha) approximately and are mainly specialized in crop production. The fundamental problem of Cypriot agriculture is the management of water resources, as only 23% of farmland is irrigated, but irrigation water consumption accounts for 70% of total annual water use on the island.

Agriculture on the island is characterized by the predominance of a wide range of crops which are categorized into four main types: tree crops, vines, vegetables – potatoes and cereals. The main tree crops on the island are citrus fruit, olive trees, fruit trees and nut trees; vines include both table and wine grapes; cereals include both crops for animal feed as well as grain crops. Apart from cereals, the other three types of farming exhibit high agrochemical input requirements, thus they impose threats on ecosystems and on water resources. The crop structure in Cyprus is affected by climate conditions, available natural resources and infrastructure, human capital, as well as farm policy. These factors also determine the level of input use, employment in agriculture and economic performance of the farms.

Input use in agriculture can be varied in several ways. The first option involves the substitution of existing crops by others with different input requirements. The introduction of new crops in a region usually aims at the achievement of policy and development objectives, inter alia more satisfactory incomes, if the new crops are of high demand in markets, and environmental protection, if fertilizer and pesticide requirements of the new crops are lower. The second includes the introduction of input use restrictions, such as reduction in nitrogen use or even the set aside scheme. These restrictions are often imposed by specific policy measures which entail compensations for potential income losses. The third involves changes in farming practices and the introduction of new farming methods, such as organic and integrated farming. Although their environmental benefits are substantial, such farming practices are not always appropriate for all regions; hence, their adoption is more than often limited in regions where current farming practices prevail for long periods. A fourth option involves restructuring the cropping pattern by maintaining current farming practices. In this case, crops with low requirements in detrimental inputs, such as nitrogen and herbicides, substitute intensive crops in terms of agrochemical use. Nevertheless, the former crops are usually more extensive in terms of labor use.

In Mediterranean countries, including Cyprus, where a broad range of crops and cropping patterns on farm level exists, the most interesting of the aforementioned options is the fourth (Psychoudakis et al., 2002) for four reasons. First, EU legislation on water resources management (Water Framework Directive, NATURA Web) points to the examination of linkages between agriculture and pressure on water resources. It is, then, expected that the mitigation of adverse environmental effects of agriculture can be achieved by expanding crops with low input requirements. Second, changing the crop pattern by maintaining existing crops is a realistic option, as they are usually well-adapted to climate and soil conditions on local level, as well as to existing infrastructure. Third, the introduction of new crops, if possible, is not expected to substitute existing crops in a high degree, therefore bringing about only marginal changes. Fourth, it not expected that current farming practices can be changed in the short run.

An extensification of the cropping pattern would bring about a reduction in fertiliser, pesticide and herbicide use, which in turn is directly linked to the mitigation of negative effects on the environment. On the other hand, reduced input use is expected to adversely affect farm incomes and labor. It is, therefore, straightforward that restructuring the cropping pattern not only affects the level of production of food and fibre, but also the level of agriculture's externalities, which compose the multifunctional character of agriculture. In the remainder of this paper is examined the degree to which the introduction of alternative extensive farming patterns affects agrochemical use, irrigation water use as well as farm incomes and employment. Such changes, in turn, are expected to affect the level of agriculture's externalities, particularly environmental pressures, contribution to rural development and avoiding depopulation, as well as the sustainment of farm incomes and the preservation of non-use values of farming.

3. The parametric programming approach

Mathematical programming is the conventional method, employed in order to examine the possibilities of restructuring the existing cropping patterns. In particular, parametric programming determines the cropping patterns that maximize the objective goal, given various levels of availability for one or more inputs. Manos et al. (2009) present a wide range of studies using mathematical programming approaches in agriculture. The implementation of the parametric programming model in this application requires technical and economic indices of all the types of farming in Cyprus which are based on published data from the Census of Agriculture carried out in 2003 (Statistical Service, 2005) and the seventh edition of the Norm Input-Output Data for the main crops and livestock enterprises in Cyprus (Markou and Papadavid, 2007). These technical and economic indicators included:

- Monthly labor requirements for each crop.
- Capital expenditures for agrochemicals (including pesticides, fertilizers and herbicides) and irrigation water for each crop, which are parametrized in the model of parametric programming.
- Gross margin of each crop, defined as gross return (value of production) less variable production cost (including seeds, agrochemicals, fuel, irrigation water, hired machinery labor). The subsidies provided are not considered in the calculation of the value of production; therefore gross margin does not include the result of price policy measures, which cause distortions in the market and lead into an inefficient distribution of the available inputs.

Linear Programming is a mathematical procedure for optimum resource allocation. Linear Programming maximizes or minimizes a linear function of variables (objective function) that are subject to linear inequalities (constraints) and must assume non negative levels.

In terms of algebra, a Linear Programming problem can be stated as:

$$\max(\min) \sum_{j=1}^{M} c_j x_j = Z \quad (1)$$

$$\sum_{j=1}^{M} a_{ij} x_j \leq A_i \quad (2)$$

$$x_j \geq 0 \quad (3)$$

where

$\mathbf{x}_j$ the activities, in this case the number of units (hectare) of the farm type j, $\mathbf{c}_j$ the contribution of each activity $\mathbf{x}_j$ to the objective function (gross margin), **Z** the objective function, α_{ij} represents the requirements per unit (hectare) of farm type j for input i, where its available resource is **A**

The solution produces an optimum combination of activities in terms of cost minimization or output maximization.

The mathematical formulation of the parametric programming model is the same, however, the available resources (A_i) of an input or the gross margin c_j, vary into an acceptable price range, yielding a set of alternative crop plans.

Table 1: Shortened Matrix for the Parametric Programming Model

Objective Function	=	Gross Margin Crop 1 (€/ha)	…	Gross Margin Crop N (€/ha)	Pesticides Fertilizers Herbicides Irrigation
		3938	…	1949	0
Total Land (ha)	√ ≥	1		1	
Irrigated Land (ha)	√ ≥	1	…	1	
Max Acreage Crop 1 (ha)	√ ≥	1			
…			…		
Max Acreage Crop N (ha)	√ ≥			1	
Labor January (hours)	√ ≥	132	…	12	
Labor February (hours)	√ ≥	65	…	15	
…					
Labor November (hours)	√ ≥	12	…	0	
Labor December (hours)	√ ≥	0	…	15	
Value of Pesticides (€)	√ ≥	410	…	110	-1
Value of Fertilizers (€)	√ ≥	1062	…	52	-1
Value of Herbicides (€)	√ ≥	50	…	0	-1
Value of Irrigation Water (€)	√ ≥	1840	…	2484	-1
Capital Cost (€)	√ ≥				1

The matrix simulates current farming practices on the island and includes (Table 1):

- Objective function: The objective function of the model maximizes total gross output.
- Land constraints: Land constraints reflect available cropped land in hectares for each crop. Irrigated land is treated separately. Furthermore, a maximum acreage for each crop is included in the set of the constraints.
- Labor force constraints: Labor constraints (monthly requirements for each crop per hectare, which are based on the published input – output data for the main crops and livestock enterprises in Cyprus) ensure that the amount of labor used is less than or equal to amount of total available family resources.
- Purchase constraints for agrochemicals and irrigation water: It involves the input requirements for pesticides, fertilizers, herbicides and irrigation water

respectively, expressed in euros per hectare, for each crop.

- Total capital constraint for agrochemicals and irrigation water: It includes the total capital expenditures for agrochemicals and irrigation water, expressed in euros per hectare, for each crop. This total variable capital for agrochemicals and irrigation water is parametrized in the model and each subsequent scenario that occurs from the solution of the model results to a more extensive cropping pattern using less capital for agrochemicals and irrigation water. Hence, the effects of the extensification of agricultural production in Cyprus are examined through the reduction of the level of capital availability for purchased agrochemicals and irrigation water inputs.

4. Results of the empirical analysis

The solution of the model, using the SAS 9.0 System software, yields a set of 88 optimal crop plans, out of which fifteen were chosen, by means of a filtering technique (Romero et al., 1989). The fifteen selected optimal solutions (scenarios) are presented in Table 2. The estimated total cropped land of 156,383 hectares is fully used in each scenario. Within the first cropping pattern, which is the most intensive, cereal farming prevails, utilizing 66.0% of the total cropped land of the island, followed by tree crops, vines and vegetables-potatoes that utilize 16.3%, 10.4% and 7.3% of the total cropped land, respectively. The 15th scenario is the most extensive, as cereals utilize 84.0% of the total cropped land of Cyprus, followed by vines, vegetable-potatoes and tree crops, which utilize 9.1%, 4.0% and 2.9% of the total cropped land.

It is clear from the results that cereal predominate in all selected scenarios; in addition, their acreage is expected to increase from 103,326 to 131,458 hectares (increase by 27.2%) when available capital for agrochemicals and irrigation water is decreased. Such a result is expected, as cereal crops are non-irrigated and their agrochemical input requirements are quite low. The restructuring of cropping patterns indicates that cereals will substitute tree crops, vines and vegetables-potatoes, introducing an extensive agricultural system. The acreage of the tree crops is reducing between the 1st and 15th scenario by 82.1%, from 25434 to 4547 hectares, while the acreage of vegetables and potatoes is expected to be reduced by 45.4%, from 11341 to 6191 hectares. The smallest reduction between the 1st and 15th scenario is expected to occur in the acreage of vines, which is reduced by 12.7%, from 16246 to 14187 hectares.

Table 2: Selected Cropping Patterns (Scenarios)

Scenarios	Cropped Land in Hectares (ha)					Gross Margin per ha
	Tree crops	Vines	Vegetables Potatoes	Cereals	Total	
1	25434	16246	11341	103362	156383	2601
2	21164	16246	11341	107632	156383	2478
3	12504	12848	11341	119690	156383	2226
4	12504	9103	9708	125068	156383	2120
5	11408	9569	9774	125632	156383	2039
6	10130	10847	9774	125632	156383	1909
7	9926	11110	8887	126460	156383	1830
8	9889	13628	6361	126505	156383	1738
9	9889	13628	5773	127093	156383	1632
10	9266	13985	5729	127403	156383	1537
11	8931	14020	5823	127609	156383	1435
12	8750	14074	5823	127736	156383	1393
13	5229	14074	5823	131257	156383	1106
14	4847	14150	5928	131458	156383	1018
15	4547	14187	6191	131458	156383	930

The impact of restructuring and extensification of the crop patterns on farm income is determinative. Gross margin per hectare decreases, while shifting from the 1st to the 15th scenario, by 64.2%. In the 1st cropping pattern it occurs that gross margin per hectare is expected to be 2,601 €, while in the last one comes to 930 €. This downward trend of the gross margin per hectare can be justified by the substitution of crops with high gross margin per hectare, like tree crops and vegetables, by others with low gross margin per hectare, like cereals and feed crops.

Capital expenditures per hectare for agrochemicals (pesticides, fertilizers, herbicides) and irrigation water, as well as the annual irrigation water consumption (m3/ha) are reported in Table 3 for each of the fifteen selected cropping patterns. The results indicate that the total cost of agrochemicals is reduced between the 1st and 15th scenario by almost 51%, from 406.4 to 198.1 € per hectare, indicating substantial changes in the level of intensification of the alternative cropping patterns. In particular, the cost of pesticides presents the highest reduction between 1st and 15th scenario by 68.0%, followed by the cost of fertilizers and herbicides, which are reduced by 41.7% and 37.7%, respectively. The cost of irrigation water is reduced by 86.4%, from 199.9 to 27.2 € per hectare, while its use is expected to be reduced by 80.1%, from 954.8 to 189.6 m^3 per hectare; hence, such changes in the cropping pattern are expected to mitigate agriculture's pressures on Cypriot water resources, which is considered a vital contribution to the protection of water resources in Cyprus.

Table 3: Cost of Agrochemicals and Irrigation Water per Hectare and Annual Water Requirements per Hectare for Alternative Cropping Patterns

Scenarios	Cost of Pesticides (€)	Cost of Fertilizers (€)	Cost of Herbicides (€)	Cost of Irrigation Water (€)	Annual Irrigation Water Requirements (m^3)
1	157.9	184.0	64.5	199.9	954.8
2	142.2	165.1	53.9	165.6	805.8
3	119.0	135.5	39.1	110.9	567.7
4	100.8	129.2	36.7	98.3	499.4
5	91.8	126.7	37.0	86.6	451.6
6	77.3	122.4	37.7	74.7	406.8
7	71.3	120.0	37.4	69.8	377.5
8	69.9	114.2	37.2	65.0	327.1
9	63.8	113.7	38.7	57.0	298.1
10	60.1	112.4	38.9	51.0	275.0
11	56.4	109.7	39.1	46.9	262.2
12	55.7	109.5	39.0	45.0	255.6
13	52.0	107.0	39.8	33.5	206.9
14	51.0	106.8	39.8	30.0	195.6
15	50.7	107.2	40.2	27.2	189.6

Employment in agriculture, as well as the achieved gross margin per farmer is presented in the first two columns of Table 4. The findings indicate a 68.4% reduction in the number of the farmers between the 1st and 15th scenario (45,241 to 14,305 farmers). However, the gross margin per farmer increases between the 1st and the 6th scenario from 8,991 to 14,683 € per farmer, remaining, though, on higher level than the gross margin that the farmer achieves in the first two intensive cropping patterns. Hence, it is clear that the restructuring of crops yields higher gross margin per farmer by almost 13%, between the 1st and the 15th optimal solution, which points to an extensive type of farming, with fewer people engaged in the profession, who, nevertheless, will achieve higher incomes, improving, thus, their standard of living.

Table 4: Income and Labor in Alternative Cropping Patterns

Scenarios	Number of Farmers	Income per Farmer (€)	Estimated Land (ha) per Farmer	Annual Human Labor (hours) per ha
1	45241	8991	3.5	333.5
2	45043	8603	3.5	292.7
3	26491	13141	5.9	181.7
4	23120	14340	6.8	157.2
5	21889	14567	7.1	151.3
6	20332	14683	7.7	145.6
7	19930	14359	7.8	135.8
8	20914	12996	7.5	133.8
9	19767	12911	7.9	120.8
10	18647	12890	8.4	117.6
11	17634	12726	8.9	105.5
12	17659	12336	8.9	104.2
13	15365	11257	10.2	90.6
14	15012	10604	10.4	87.7
15	14305	10167	10.9	86.4

Farm labor requirements in hours per hectare for each cropping pattern are also presented in Table 4. The restructuring of the cropping pattern through the reduction of agrochemical and water consumption implies a reduction in human labor, which becomes even more significant the more extensive a cropping pattern is. It is estimated that between the 1st and 15th scenario the annual human labor used is reduced by 74.1%, from 333.5 to 86.4 hours per hectare of cropped land. This reduction is the result of the substitution of the tree crops, vines and vegetables and potatoes by cereals, as the latter are less labor-intensive. Cultivated land in hectares per farmer, which is presented at the last column of Table 3, is expected to increase by 7.4 hectares between the 1st and 15th scenario (increase of 211.4%), from 3.5 to 10.9 hectares, a result which verifies that a more extensive cropping pattern implies reduction in the number of farmers on the island.

5. Conclusions/Discussion

The objective of this study was the investigation of the effect of restructuring the existing crop pattern in Cyprus on economic and structural characteristics of the Cypriot agriculture, which, in turn, affect the level of agriculture's externalities. The possibilities of restructuring agriculture in Cyprus were examined with a parametric programming model, where the available variable capital for agrochemicals and irrigation water was parametrized. This procedure yielded fifteen cropping patterns (scenarios), each of which represented an extensification of the production.

The basic characteristic of this restructuring is the introduction and gradual prevalence of cereals, which substitute mainly tree crops. The predominance of such an extensive cropping pattern implies reduced requirements in agrochemicals and irrigation water. A substantial reduction of up to 68% in pesticide use and savings up to 86.4% on irrigation water can be achieved only by expanding the acreage of cereals on the island. Hence, depending on the level of this reduction, the introduction of an extensive cropping plan will mitigate environmental pressures from agriculture, especially on water resources. Nevertheless, this extensification will reduce the economic performance of the farms, as the gross margin is expected to decrease up to 64.2%, as well as the number of the farmers by up to 68.4%. Within this new pattern of farming, farmers that will remain in the sector are expected to achieve higher incomes, because the decrease in farm employment overlaps the corresponding reduction in gross margin.

The aforementioned consequences of changes in the cropping pattern point not only to the achievement of policy objectives concerning environmental protection, but also to socioeconomic changes in rural areas of Cyprus. It is illustrated, then, that the cropping pattern directly affects the multifunctional character of agriculture. Such a development is desirable only if redundant labor force can effectively be absorbed in other sectors of rural economy. Otherwise, the extensification of farming is expected to bring about depopulation in rural areas of Cyprus, which is opposed to the objective of sustaining vivid rural areas through the protection of the multifunctional farming sector. The absorption of farmers leaving agriculture is directly linked to the implementation of rural development measures (Axis III, Reg. 1698/2005) that promote diversification of rural economy. Cultural and environmental features of these regions, which have been formulated by the predominance of agriculture, can be deployed in order to develop alternative sources of employment and income. Such a development strategy would take advantage of features of multifunctional agriculture, thus justifying the continuation of protectionism in the farming sector.

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