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An Economic Analysis Of The Efficiency And Sustainability Of Fertilization Programs At Level Of Operational Systems Of Soft Wheat In Umbria

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Abstract

This study analyzes the fertilization strategies in the perspective of the efficiency analysis. The analysis is conducted at farm level and framed into the conceptualization of the relationship between the decisional and operational systems (Sébillotte, Allain 1991). The conceptual framework emphasizes the importance of the response function approach, of the sustainability principles (Pretty, 2008) and of the organizational dimensions. Data on soft wheat were collected from FADN system. Data Envelopment Analysis indicates the importance of the operational systems organizational factors in determining the crop efficiency. The evidence suggests to consider the objectives of the fertilization program in the context of the organizational dimensions of the operational system.

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Keywords: DEA; fertilization; sustainability.

1. Introduction

Agricultural economists and agronomist used for long time two different conceptualization and methodologies to approach the fertilization problem (Paris, 1981). A key point is represented by the fact that while agronomist normally conducted fertilization experiments with a few combinations of nutrients and many replication, the

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agricultural economists used a few combination with many replications. As a consequence the approach of the two disciplines to the analyses of the response functions (or production functions) crucially differ (Paris, 1981, pp. 46-47; Paris, 1992a).

The objective of this paper is to analyze the fertilization strategy in a real farming context. To the purpose of this study we define the fertilization strategy as the amount of the main nutrients used in productive agricultural context. This operational definition allows one to investigate the management of the fertilization with respect to a set of decision normally made by the farmers. We assume that this farm perspective is useful to identify the patterns of the economic and managerial behaviors of the famers and then to make some attempts to evaluate these behavior with respect to the main objectives of the fertilization strategy: the efficiency and the implementation of sustainable technology. The fertilization management is currently facing many challenges under the perspective of the sustainability, the simplest way to take into account the need for introducing sustainable technology. However this view has to be contrasted with both the necessity of implementing a technology adequate to sustain the achievement of other objectives – e.g. sufficient yields, for example .and with the identification of the real pattern of farmer behavior.

2. Objective and method

The aim of this chapter is to address two general problematic area in the field of the fertilization management: a) how the fertilization strategies influence the efficiency of a given crop under an economic point of view; and b) how economic, organizational and environmental variables influence in turn the fertilization management decisions.

Firstly, we propose a conceptual framework which seems reasonably account for the rationale of the questions mentioned. Then we carried out an empirical investigation after having specified the tow general question for soft wheat case study. This crop provides an interesting example of the management problem to be solved in the farming context. The data were collected at the Farm Accountancy Data Network of the European Union (FADN-RICA) About the two crop in Umbria (year 2012).

We analyze the data according to two lines of investigation:

a) crop efficiency analysis, by through Data Envelopment Analysis (DEA);

b) analysis of the influence of economic, organizational and environmental variables, by through simple logistic regression.

Efficiency analysis is central to the analysis of the fertilization strategy both under an economic and technical point of view (Paris, 1992a; Paris, 1992b). DEA is a mathematical programming model applied to observational data providing empirical estimates of input-output relations and efficiency analysis (Charnes, Cooper, and Rhodes, 1978).

The sampled farms (Decision Making Units, DMU, in the DEA language) are sistematically compared in order to ascertain their efficiency degree. An unit is considered efficient if further units in the sample do not exist which are able to produce a larger amount of output with the same level of inputs or use a smaller amount of inputs, production the same level of output.

The analysis was carried out by a two stages process (Fried et al. 1999, 2002) which allows to define best practices frontiers. The efficiency degrees estimated are defined with respect to these frontiers. The method allows to weight the efficiency ratio (output/input) regardless the input and output prices, and according to a maximization procedure that consider each farm in the best evaluation perspective. Furthermore, it is important to point out that the analysis is largely data-oriented and does not requires specific assumption in terms of theoretical background.

3. Conceptual framework

The production response to the level of use of a given fertilizer traditionally is the central problem considered in the field of fertilization management. Agricultural Economists conceptualized this issue in terms of the laws of the productivity seeking to meet the point of view of the Agronomists. In this context the early approach in Agricultural Economics contended that the well-known von Liebig hypothesis implied a linear response and a plateau model (LRP). The hypothesis of linearity was challenged by Paris (1992a) who argued that the LRP has to be thought of as just a first approximation. Starting from the original formulation of von Liebig, Paris (1992a, p. 1019) stated that the so von Liebig hypothesis conveys both the notion of non-substitution between nutrients and of yield plateau.

The debate on sustainable agriculture challenged the strictly „input-output" setting of the problem of fertilization and to some extent has an impact on the role of economic efficiency in solving the managerial problem related. The reduction of the amount of fertilization quantities is becoming a necessary management principles (Beddington, 2010), but this implies on the one hand to change basic productivity relationship in the management approach and, on the other hand, to develop appropriate conceptual framework to draw innovated management principles. based on It is usually recognized that agriculture has huge impacts on natural systems because of the long trend term toward industrialization (van der Ploeg, 2008), On the other hand, scholar emphasize the inherent unicity of the agricultural sector as it directly affect many assets on which in turn relies (Pretty, Bharucha, 2014, pp. 575-1576).

Agricultural systems are artificial in nature and exhibit distinctive properties which sharply characterize them with respect to the natural ecosystems. Sustainable agroecosystems are thought of as seeking to shift some of these properties towards natural systems, without significant trade-off productivity (Pretty, Barucha, 2014, p. 1575).

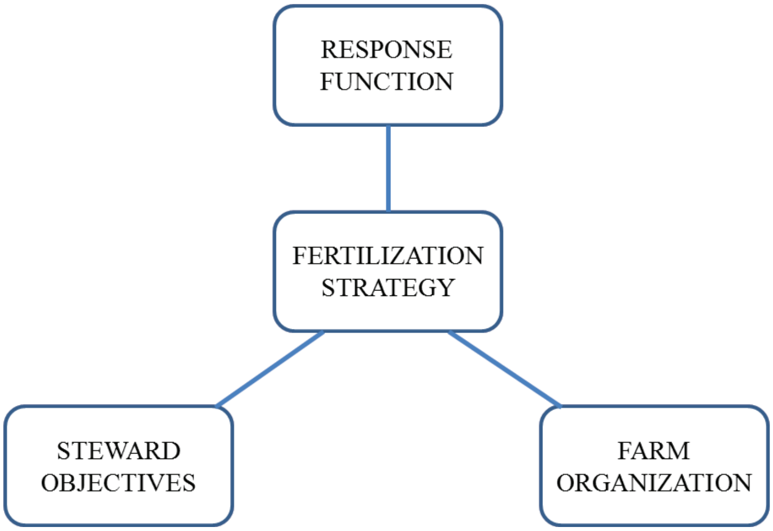

Figure 1. Determinants of the fertilization strategy

The Figure 1 summarizes the analysis developed indicating that the fertilization strategy is based upon an efficiency criterion drawn from the response function approach, it is shaped by the stewardship principles in the sense that the sustainable intensification and it is framed in the organizational dimensions.

4. Empirical analysis

The objective of the empirical analysis is to investigate the fertilization program at the farm level. The rational form this approach is based on two considerations: a) it offers a significant evidence on how the fertilization management principles (efficiency, stewardship based) are implemented; b) it allows one to identifies how the decision made by the farmers are shaped by the organizational framework.

Sèbillotte and Allain (1991, pp. 81-82) pointed out that an operational system in farming ensure the execution of the all the types of operations (productive, administrative etc.) by the entrepreneur. The operational system is particularly relevant in the implementation of the productive processes and establishes causal nexuses between the set of the needs (agronomic, ergonomic and economic) and the way to carry out the productive operations and the performance (Sébillotte, Allain, 1991, p. 82)

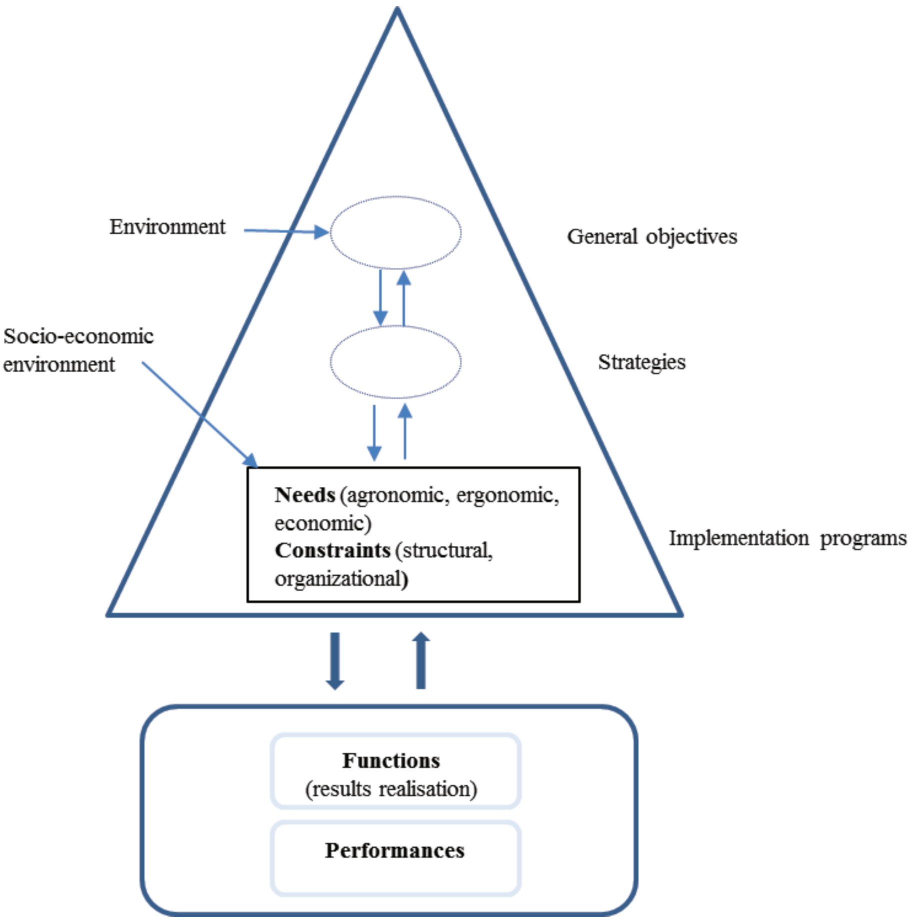

Figure 2. Decision and Operational systems (from Sébillotte, Allain, 1991, p. 83)

The Figure 2 illustrates the relationship between the decisional systems – internally articulated -, the strategies level and the implementation program. The figures shows as the level of strategies *has to deal with a complex set of needs and constraints in order to specify the implementation programs.* The real content and configuration of the production process (*functions*, in the figure) and their performance thus directly depend upon the formulation of the implementation programs. Accordingly, we consider the fertilization strategies and their potential evolution towards a more sustainable content under this perspective. To carry out an empirical analysis at farm level implies to deal with the outcomes of the systemic relations depicted in the Figure 2.

We used FADN data and concentrates on farms activities in Umbria region (Central Italy). This implied to deal with a huge variability of climate and soil-based factors. We tried to capture the influence of these variables by a) specifying proxy variables available in the database (altitude, geographic coordinates and soil average characteristics); b) for the soft wheat, considering the homogeneity of the vocation in the regional territory.

The initial model includes four inputs (land, labour, capital and other inputs) and one output (gross product of the crop considered: soft wheat and sunflower). We assumed variable return of scale, i.e. we assume that the return of the productive processes increases (decreases) at a variable rate when all the input increase (decrease).

After having obtained the level of efficiency we considered the fertilization strategies together with the influence of further farm factors. Actually, scholars (Fried et al. 1999, 2002; Coelli et al. 1998; Muniz 2002) pointed out that the economic environment in which the DMU operate can influence their performance. For example, factors not directly controlled by the management may have a negative influence on the evaluation of efficient performance. In the field.of our study it may be the case of not sustainabilty strategies imposed to farmers. Following Coelli et al. (1998) we considered four factors held to be able to explain the efficiency differences among the studied units (see Table 2):

i) *Altitude* (m. o.l.s), as it is a proxy of critical weather characteristics (like temperatures) having direct influence on the crop;

ii) *Age of the entrepreneuer*, as a proxy of the farmer experience; the variable is dichotomic and assumes value 1 if the farmer is a "young" farmer according to the FADN classification, and value 0 if it is not "young";

iii) Importance of the crop in the farming system, the idea is that the greater is the importance of the crop, the more important is the performance of process; we consider the percentage of the farm UAL used by the crop

iv) Fertilization strategy, we summarize the strategy by considering the amounts (Kg./Ha) of Nitrogen, Phosphorus and Potassium used in the process.

Table 1. Factors explaining the levels of the crop efficiency

Variable	Label	Unit of measurement
Altitude	Alt	m. o.l.s.
Age of the enterpreneur	Young	
Percentage of the UAL of Soft Wheat on the total farm‟s UAL	UAL_SWheat	(%)
Amount of Nitrogen distributed	N	Kg/Ha
Amount of Phosphorus distributed	P	Kg/Ha
Amount of Potassium distributed	K	Kg/Ha

Source: authors

The subsequent step is to use the coefficients estimated by through the truncated regression to correct the original input data eliminating the effects of the variables considered and then obtain the new, corrected levels of input. Then we simply calculate again the level of inefficiency of all the farm by moving from the corrected input data.

The number of the farms considered is 212. We run the DEA estimation across all these units. The level of efficiency estimated are presented in the Table 2. We considered the technical efficiency in the case of constant and variable returns to scale and the scale efficiency. Technical efficiency is just related to production function conceptualization. The scale efficiency derives from the previous ones The minimum level of technical efficiency in the case of constant return to scale is about the 30.5% of the maximum level, while the mean is about 68.8% of the maximum value. The variation of the efficiency degree is small moving from the second to the third quartile. The technical efficiency in the case of variable return of scale is quite similar. Conversely, here is a strong homogeneity level of scale efficiency.

We then run a truncated regression in which the dependent variable is the level of efficiency of the process and the covariate are the contextual variable: Altitude, Age of the entrepreneur, Importance of the crop and the amounts of the fertilizers used (N, P, K). We estimated one regression for each of the input considered in the analysis: *Land*, *Labour*, *Capital* and *Other costs*. The latter include also the total costs of the fertilization. The results are illustrated in the Table 3.

Altitude (*Alt*) and the importance of the crop (*UAL_soft wheat*) are both statistically significant in all the four models estimated. The picture concerning the fertilization strategies is more articulated. Only the amount of nitrogen is statistically significant in the model for *Land*. The variable *P* (Phosphorus) is significant in the model for *Labour* and *Capital*, while *P* (Potassium) has an influence on the *Labour*, *Capital* and *Other Costs model.*

In the model for *Land* the altitude increases the input slack by 0.1298 for each m.o.l.s. Our interpretation is that the orographic characteristics tend to make difficult to plan the productive operation determining the inefficient use of the input. This is confirmed also by the parameters of *Alt* in the other models. The largest effect of *Alt* is on the capital use, but also the slack of the *Other Costs* is significant.

Table2. Distribution of the technical efficiency level 1st stage (Obs. 212; n. output = 1; n. input = 4)

	Technical efficiency		
	Costant return of scale	Variable returns of scale	Scale efficiency
Min	0.305	0.312	0.443
1st quartile	0.578	0.588	0.994
2nd quartile	0.691	0.704	0.998
3rd quartile	0.764	0.801	0.999
Max	1	1	1
Mean	0.688	0.705	0.979
St. Dev.	0.157	0.161	0.065
C. V.	0.227	0.228	0.066
N. of DMU eff	16	20	48

Source: the authors

The importance of the percentage crop UAL has a positive impact on the slack for all the inputs considered. The crop quota can be considered a sort of index of specialization in the specific crop (Soft Wheat in this case). Therefore the evidence indicates that as the specialization increases, the inputs slacks increase too. The inefficiency is caused by the difficulties of managing the allocation of all the inputs in the farm production processes as the relative importance of a crop (soft wheat) increases.

The results concerning the age of the entrepreneur is also interesting. It shows that the young farmers increase the inefficiencies in the use of the *Land* and the *Labour*, but strongly reduce the inefficiencies in using the *Capital* and the *Other costs*.

The picture provided by the fertilization strategies is of particular importance in the context of this study. The evidence about the *Land* indicates that the strategy of fertilization for Nitrogen reflects a light trend to the reduction of inefficiency, also contrasting the effects of *Alt*, *UAL_Soft Wheat* and *Young*. This evidence suggests that: a) the farmer decisions tend to be efficient as for the level of the nitrogen used and this fact can be just explained in terms of the capability to apply the right technology (designed by the response function approach); b) the related management view tends to prevail over management of the other factors. However, the nitrogen fertilization approach appears to influence positively the inefficiency level in *Capital* and *Other costs*. We contend that this effect is due to the costly search to fit technological recipes. Both the potassium and phosphorus fertilization strategy appear to be positively influential on the inefficiency levels for *Labour*, *Capital* and *Other Costs*.

Table 3. Truncated regressions for inputs (p<0.1 = *: p<0.05 **: p<0.001 = ***)

Covariates	Land	Labour	Capital	Other Costs
Alt	0.1298 ***	63.125 **	211.105 ***	165.7138
UAL_Soft wheat	0.0699 *	1344.191 ***	1183.568 *	1117.4520
Young	0.9803 **	175.340 *	-119.375 **	-364.7839
N	-0.0035 *	0.003	0.482 ***	7.0495
P	-0.0019	9.665 ***	17.275 ***	4.5592
K	0.0175	9.899 *	83.426 ***	52.6102
Const	0.1761 ***	77.588 **	-287.560 ***	-951.5819
Sigma	1.8006 ***	981.341 ***	2541.670 ***	1832.1900
logLH	-1425.49	-1761.2663	-1963.0174	-1893.6278
Obs.	212.00	212.00	212.00	212.00
Wald chi2(6)	21.35	65.2	38.86	25.82

Source: the authors

We corrected the level of the input assuming the worse input conditions for each farm.

The new levels of efficiency are reported in the Table 4. The Tau Kendal correlation between the original and the corrected level of efficiency is 0.42 indicating that the correction caused an intensive change in efficiency ordering. The results show a reduction of the level of efficiency, of its variance and of the number of the efficient farm. This results indicates that penalization of the farms active under the worse conditions is larger that the advantages of the farms active in better conditions. The heterogeneity of the farms is confirmed by the variance of the performance.

Table 4: Technical Efficiency (soft wheat) - 2nd stage

	TE CRS	TE VRS	Scale Eff.
Min	0.053	0.417	0.053
1st quartile	0.399	0.751	0.485
2nd quartile	0.508	0.826	0.655
3rd quartile	0.609	0.900	0.824
Max	1	1	1
Mean	0.510	0.816	0.641
St. Dev.	0.183	0.126	0.229
C. V.	0.359	0.155	0.358
N. DMU eff	4	20	5

Source: the authors

Finally we investigated the potential effects of modification of the fertilization strategy. We used the truncated regression to simulate levels of efficiency corresponding to hypothetical level of nitrogen use. We supposed to change the nitrogen use according to the following alternative patterns:
- Optimal range: 100-150 $KgHa^{-1}$
- Reduced use: actual (if smaller than 125 $KgHa^{-1}$)-125 $KgHa^{-1}$

The results are shown in the table 5.

Table 5: Levels of efficiency in alternative fertilization strategies

Statistics	Normal level	Optimal range	Stewardhip principles
Mean	2.457	2.738	0.298
Standard deviation	0.949	0.697	0.328
Percentile 10	1.328	2.187	0.01
Percentile 25	1.907	2.311	0.13
Percentile 50	2.347	2.444	0.22
Percentile 75	2.948	3.005	0.33
Percentile 95	4.294	4.294	1.16

Source: the uthors

The results show that the optimal range strategy is characterized by a higher inefficiency (input slacks) in average, but the increase has lower rate than the normal case. The strategy based on the reduction of nitrogens characterized by the lower level of inefficiency in average. This would indicate that the reduction 0 the amount of nitrogen used, would give raise to an increase of the efficiency of the process.

5. Conclusions

A first point to be underlined is that the specialization of the crop (in terms of percentage of UAL) tends to decrease the levels of efficiency. Except than for the case of a light influence of nitrogen (see Table 4), the fertilization strategy as a whole have a similar impact. The specialization of an activity is normally expected to provide efficiency gains. The specialization of an activity is normally expected to provide efficiency advantages. Our interpretation of the evidence is that as the size of the crop increases relatively to the farm, managerial diseconomies arise at level of the implementing of the productive operations. The point is relevant in vegetable crop because while the farm may gain advantages from specialization in terms of equipment investments and also competencies creation, the management of the productive operation may suffer of the possibility of allocating the resources (e.g. labour) in the right space-time coordinates. The results about the fertilization are coherent with this view. Also the role of the experience – accounted by the variable *Young* in our analysis – is coherent with this picture: a small experience reduce the efficiency in using two major factors, the land and the labour in the case of soft wheat and labour in the case of sunflower - directly positing the problem of space-time allocation of the resources. The importance of the organizational variable is also confirmed by the absence of any influence of altitude, soil types and latitude (see note 2, p. 23). The fertilization programs exhibit an articulated picture, but in general their effects appear to smaller that those of the organizational variables.

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