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Farm Dimension and Efficiency in Italian Agriculture: A Quantitative Approach

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Abstract Technical efficiency and economic efficiency are useful research tools to analyse in a quantitative approach main relationships among inputs and output used in the productive process. The aim of this paper was to investigate if there is a connection between size of some Italian farms and efficiency using the FADN dataset. The latter is a sample of farms used by the European Union to assess some impacts of the Common Agricultural Policy on a sample of farms located in different European nations. In Italy, over the last 10 years, there has been a rise by 44.4% of the average farm surface, which has increased the usable Agricultural Surface from 5.5 hectares to 7.9. In this paper, large farms have had the best performances in terms of invested agrarian capital and land capital. Medium-small farms have however had the highest growth rates in terms of agrarian capital and also in terms of land capital. Nevertheless, large farms have been the most efficient Decision Making Units (DMUs) in absolute value of technical and economic efficiency compared to small farms, which have values of technical and economic efficiency lower than 1. Small farmers, that are fairly widespread in Italian rural areas and typical of Italian agricultural productive paradigm may improve their technical efficiency only by increasing their activities through diversification and by intensifying their agrarian and land invested capital. To sum up, small agrarian enterprises can take advantage based on technical efficiency of scale predominantly through a growth in size of surface and invested liquid asset, reducing the marginalization of agrarian territories and rural depopulation.

Keywords: *data envelopment analysis, farm size, technical efficiency, economic efficiency*

1. Introduction

In Italy there is a high diffusion of small farms, which are scattered largely in hilly and mountainous areas, with a surface that is below 5 hectares, which is by far less than the average size of Italian farms able both to guarantee business profitability and also to reduce the marginalization of rural areas due to a depopulation and migration towards urban areas. The latter areas, in fact, are considered appropriate to provide better socio-economic infrastructure, job opportunities, a good level of public amenities such as public transport, schools, education and social-health care and above all a satisfactory level of income.

Many actions financed by the European Union throughout the Common Agricultural Policy have tried to reduce rural depopulation and to get better the level of involvement of rural citizens and stakeholders in programming and planning [1] generating in the areas of study several Italian rural districts able to promote certified quality food, artisan activities and to valorise territories and their rural heritages [2,3], increasing the level of social capital and the sense of belonging to a rural community [4,5].

The multi-functionality has given to European farmers a new role in protecting rural space in less favoured rural areas. The European Union has focused its financial and economic efforts towards small farms because the latter are pivotal to guarantee, through the production of services and activities, a good level of positive externalities against marginalization of rural areas and rural depopulation. Moreover, the farmer is the first and foremost responsible entity able to protect the environment in the countryside; thus, the small farms are considered by the European Union as material public goods with polyvalent social goals and an ecological responsible nature [6]. As a result, agricultural activities have to involve, by an integrated and pluriactivity approach, many entrepreneurs, policy makers and stakeholders with the unique aim to protect rural space and to reduce the marginalization in rural territories [7].

In general, in Italy's less favoured rural areas such as mountainous and hilly territories, are located several multifunctional farms, managed by a farmer and his/her relatives, able to offer niche quality food and at the same time to promote multifunctionality utilizing both limited factors of production, such as land, labour force and cultivated surface and also under spending a workforce far below the average value compared to big conventional farms [8]. Conventional big farms as opposed small Italian agrarian enterprises are instead specialized in producing only commodities, such as cereals, other extensive crops and milk, without providing any action in protecting rural space or in producing certified quality food.

Between two variables such as farm size and output may be a relationship both in terms of income and also in

terms of economic and technical efficiency. In the literature, many studies have investigated if there are some relationships between the variable dimension of farms and technical and economic efficiency. Scholars have argued whether small farms can be considered efficient and able to produce some positive effects on the performances and productivity in the primary sector [9]. The size of farm affects economic decisions and management choices [10]. Furthermore, several authors have described different types of efficiency in the primary sector using a quantitative method to estimate them [11]; in this case authors have taken into account only land productivity ruling out other factors of production [9,10,11,12].

Many studies have investigated, using a stochastic frontier approach, the main relationships between technical efficiency and typology of management, such as part-time versus full time farms, or crop specialization as mixed or not mixed farms in a defined geographical area [13]. Using the same approach (stochastic production function) in a small sample of American farms it has been possible to examine if there were some interactions between size and technical efficiency. Some studies have shown that many small enterprises are below the frontier of production; hence, they have not allocated efficiently different inputs. In fact, the first and foremost result was that 25% of the analysed farms, set up predominantly by the small enterprises, could get better their level of income by an improvement in used input, such as land, compared to the big size farms [14].

Earlier studies have investigated different kinds of farms, both in terms of size and also in terms of management and agrarian specialization, with the aim to find out which economic variables could be fundamental to improve the function of production in farm management in two European rural areas [15]. Other authors have focused their studies in several developing and developed countries to analyze the main relationships between farm size, and agrarian specialization in cereal crops in North American rural areas [16,17], using a balanced panel over 15 year time [18] and in a sub Saharan area specialized in rice production [19].

A recent study has investigated using a quantitative approach in some Italian dairy farms forming part of FADN dataset the relationships between efficiency and cost of production [20]; in other research, technical efficiency in dairy farms has been compared in three different European countries with the aim to estimate which variables such as dimension of farms and factors of production can im affect efficiency. The studies have shown that the dimension of analysed samples is tightly linked to technical efficiency [21,22]. Many authors using the Data Envelopment Analysis approach, have established some relationships between farm size and productive efficiency about specific and typical cultivations in developing countries [23,4] or in large farms located in south American countries [25].

2. Aim of the Research

Production is a result of an efficient combination of factors of production or inputs such as land, labour, capital and organization thus, a different quantity of land in terms of size, is an important input to get better the level of economic and technical efficiency with positive impacts on the level of final output.

The goal of this research has been to determine whether the dimension of farms is directly and tightly connected to the level of output, or rather whether the size is able to guarantee to farmers a significant level of income throughout an assessment of the technical and economic efficiency in some Italian farms classified in function of classes of income collected by the Farm Accountancy Data Network (FADN) dataset and published by National Institute of Agricultural Economics (INEA) over 3 years from 2008 to 2010.

The FADN is a sample of farms used by the European Union to analyze some impacts of the Common Agricultural Policy on a small group of farms representative of different European nations. This paper uses the DEA to estimate the technical, allocative and economic efficiency values.

3. Methodology

In microeconomic analysis efficiency is tightly connected to productivity. Efficiency is a ratio between obtained output and used inputs and is a pivotal tool to define the capability of each Decision Making Units (DMU) to produce a defined quantity of output using a specific quantity of input in different crosssectional data over time. In terms of productivity, if there are two DMUs such as A and B able to produce y_a or y_b using a specific quantity of input x_a and x_b the productivity is a simple ratio y_a/x_a and y_b/x_b. To estimate the efficiency considering the function of production

$$y = f(x) \tag{1}$$

it is easy to find the maximum level of output at a level of input.

A model of analysis and estimation of the efficiency at the level of a specific frontier of production has been implemented by the introduction of a non-parametric model called Data Envelopment Analysis (DEA) and specific statistical programs to assess the efficiency in the primary sector [11,26,27,28].

In this paper the DEA approach was used to estimate the economic efficiency in different kinds of farms or DMU, classified in function of their Standard Gross Margin (SGM) until the financial period 2009 and in terms of Standard Production (SP) since the financial year 2010 [29].

According to the description proposed in literature by Italian Institute of Agricultural Economics (INEA) and by the European Union, SGM is the difference between the value of standard production and the standard amount of some specific costs, correlated and related to a specific territorial area for each specific product within a given territorial level calculated by the National Institute of Agricultural Economics for 43 crops and 21 categories of livestock removing the depreciation and other costs of management, which are not linked to a single crop or type of livestock [29]. The Standard Production is the Gross Marketable Output of farm production in Euros for each type of crop or livestock multiplying these values of production for cultivated hectares and or number of animals raised.

Table 1. Classification of analysed farms in function of their productive dimension based on income and production (Source: www.rica.inea.it/public/it/area.php)

Farm Size	Standard Gross Margin (€)	Standard Production (€)
Small	2,400-9,600	4,000-25,000
Medium-small	9,601-19,200	25,001-50,000
Medium	19,201-48,000	50,001-100,000
Medium-big	48,001-120,000	100,001- 500,000
Big	>120,001	> 500,001

The quantitative model used in this paper has classified farms in 5 classes in terms of produced output using a specific quantity of input [10] in function of the economic and productive size given by FADN classification (Table 1).

The Italian sample of farms forming part of FADN is composed approximately of 12,000 farmers with different economic size and type of farming and animal breeding. It is a stratified random sample. The European Union Commission has stratified the FADN dataset using three criteria such as region, economic size and type of farming and or breeding.

This paper has used a Data Envelopment Analysis methodology because it is a non-parametric model and does not require a specification of the functional form. Hence, a DMU is able to be on the efficient front of a non parametric function of production or below this function if DMU is not efficient [10-30].

The non-parametric linear model throughout the Data Envelopment Analysis was introduced for the first time in 1978 [28] and it is useful in estimating the relative efficiency in each Decision Making Unit based on different inputs and outputs [31] with the aim of minimizing input used [32].

The goal of DEA linear programming is to minimize in a multiple-output model the multiple-input in each farm that is a ratio of efficiency which in a mathematical model is [10]:

$$\max h = \sum_r u_r y_{rjo} / \sum_i V_i X_{ijo} \quad (2)$$

subject to

$$\sum_r u_r y_{rj} / \sum_i V_i X_{ij} \leq 1 \quad (3)$$

$$J = 0,1,...,n \ (for\ all\ j)$$

$$u_r, V_i \geq 0$$

This model has many possible solutions and u_r* and v_i* are variables of the problem and they have to be greater or equal to a small and positive quantity with the consequence that a choice of an arbitrary weight given to a single unit of production not liked to any input and output could describe each unit efficiently [10-33]; hence, if h is equal to 1 there are no issues because this unit ($DMUh_1$) is efficient compared to others $DMUh_n$, but if h is above 1 there are many units more efficient than this unit ($DMUh_1$) and every unit can be tightly linked to input and output making each unit efficient [33]. To solve this negative aspect it is useful to transform the model in a linear paradigm by a linear programming proposed by Charnes, Cooper, and Rhodes and called CCR [28-34] written in this way [33]:

$$\max h = \Sigma_r u_r y_{rjo} \quad (4)$$

s.t. dual variable

$$\sum_i V_i X_{ijo} = 100\% \ Z_0$$

$$\sum_r u_r y_{rjo} - \sum_i V_i X_{ijo} \leq 0$$

with j = 0, 1, ...n (for all j) λ_j.

$-v_i \leq -\varepsilon i = 0,1,...,m$ and ε is a positive value s_i^+.

$u_r \leq -\varepsilon r = 0,1,...,t$ and ε is a positive value s_r^-.

In the dual problem proposed by Charnes, Cooper and Rhodes in 1978 [28] one has to give a dual variable in each constraint in the primary model; this paper has not taken into account in the dual model a constraint able to classify and to discriminate DMUs by the super efficiency proposed by Andersen and Petersen called A&P model [35]. In mathematical terms the solution of the dual model is:

$$\min 100Z_0 - \varepsilon \sum_i s_i^+ - \varepsilon \sum_r s_r^- \quad (5)$$

s.t.

$$\sum_i \lambda_i X_{ij} = X_{ijo} \ Z_0 - S_i^+ i = 0,1,...,m$$

$$\sum_i \lambda_i X_{rj} = y_{ijo} + S_r^- \quad r = 0,1,...,t$$

$$\lambda_i S_i^+, S_r^- \geq 0$$

λ_j are shadow prices able to reduce the efficiency in each unit lower than 1 and a positive value of λ_j is able to show the peer group in some inefficient unit. If j is a firm size inefficient, the value of technical efficiency is lower than 1 [28].

Table 2. Main results over the time of invested capital in the sample of Italian farms in the dataset FADN (Source: www.rica.inea.it)

Farm size	Year	Land capital	Agrarian capital	Net worth
Big	2008	1,633,081	267,795	2,235,041
Big	2009	1,580,062	256,596	2,282,553
Big	2010	1,995,569	534,898	3,270,479
Medium	2008	290,853	38,812	365,545
Medium	2009	297,281	35,583	390,802
Medium	2010	354,231	41,479	489,299
Medium-big	2008	533,171	76,658	678,845
Medium-big	2009	540,179	71,687	730,168
Medium-big	2010	691,388	96,386	1,014,231
Medium-small	2008	151,528	20,329	190,608
Medium-small	2009	157,469	19,169	206,124
Medium-small	2010	248,986	21,495	323,526
Small	2008	128,702	16,490	156,848
Small	2009	138,947	16,410	174,439
Small	2010	144,057	9,600	178,069
Small	2010	144,057	9,600	178,069

The Data Envelopment Analysis is a powerful approach to evaluate in each farm the combination of several and different factors of production costs and to estimate the best level of efficiency among different groups of farms characterized by a dissimilar size, given a certain level of technology and with a cost of production of a specific amount of output, which is minimized at the point where the budget line is tangent to the isoquant or rather where it is possible to maximize technical efficiency and so that it

is the point of the best allocatively efficient technology [33].

4. Results and Discussion

The results showed that over three years there has been a sharp reduction in Italian farms. The number of farmers has decreased by 60% from 2.6 million farmers in 2000 (by the 5th National Agricultural Census) to 1.6 million farmers in 2010 (by the 6th National Agricultural Census), although there has been an increase in the average size of farms, which is above 7 hectares [36]. The analysis of data from the 6th General Census of Agriculture made by National Italian Statistical Institute (Istat) showed that a decline in active farms has been associated with a growth of farms managed by agricultural capital companies and co-ops, which increased from 1,742 units in 2000 to more than 3,000 in 2010.

These results have corroborated the need for Italian farmers to increase total cultivated surfaces in order to amortize their investments in farm machinery, to better agrarian incomes and to make technically and economically efficient both the agricultural production and also the use of family workforce and farm machinery, increasing the productivity in the primary sector. The average size of farm has grown in a decade from 5.5 hectares of Usable Agricultural Surface (UAS) per farm of 7.9 hectares (+44.4%). This is a consequence of a sharp decline in the number of farmers and agricultural income (-32.2%). Some explanations of this decrease in active farmers might be found in the Eurozone crises. The effect of economic crises has been on the one hand the closing of small size Italian farms and on the other hand stimulating a merger of agricultural and livestock activities in larger units of production more efficiently. However, Italian farms are less competitive and efficient than other European farms because Italian agricultural enterprises have small parcels of land and the average size of farms is well spaced out compared to the average dimension of farms located in other EU nations such as France, Ireland, Germany and the United Kingdom.

The average size of Italian farms in terms of Total Agricultural Surface (TAS), formed by Usable Agricultural Surface, woodland and unproductive tares, increased compared to the analyzed data of the 5th National Agrarian Census carried out in 2000, from 7.8 to 10.6 hectares. However, in absolute value, the TAS has decreased by 8%, which is more significant than the drop of the UAS equal to -2.3%. This data has pointed out that, in Italian primary sector, there has been in progress actions of rural depopulation because many old farmers have retired and also land consolidation and diversification due to a new generation of young agrarian entrepreneurs. The latter have decided to replace uncultivated lands and portion of cultivated areas with woodlands using funds allocated by the European Union with the aim to protect the environment against building in rural areas and to promote recreational activities in the rural spaces. In 2010 Italian farms with a Usable Agricultural Surface less than 1 hectare were found to be inefficent both economically and technically. in fact they decreased in efficiency, compared to the 5th Italian Agricultural Census in 2000, by 50.6% [36].

Table 3. Average value over analysed time of main economic and financial parameters in the dataset FADN (Source: our elaboration on data www.rica.inea.it)

Farm Size	Gross marketable output	Income from related activities	Net Income	Added value
Big	741,856	23,363	283,279	401,521
Medium	66,091	5,739	29,426	42,611
Medium-big	154,773	9,419	68,204	97,057
Medium-small	34,452	3,485	15,429	22,473
Small	20,041	2,613	8,626	13,092

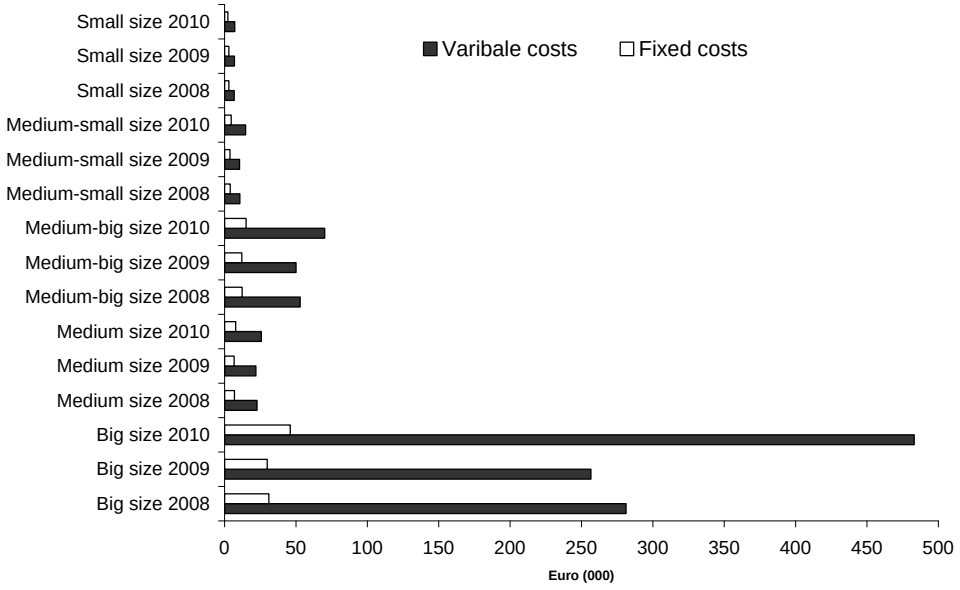

Figure 1. Fixed and variable costs in each group of farms over the time of observation *(Source: our elaboration on data www.rica.inea.it)*

The results of efficiency analysis using DEA have been estimated by the DEAOS software (Data Envelopment Analysis Online Software) able to investigate the technical and economic efficiency in every DMU based on the size of the Italian dataset FADN.

Large farms have had the best performance in terms of invested agrarian capital and land capital; Medium-small

farms have the highest growth rates over the three years of study both in terms of agrarian capital and also in terms of land capital. Unfortunately, farms classified as small enterprises have experienced during the three year time, a decrease in agricultural invested capital and a lower growth compared to the other (see Table 2). In terms of net worth the best performances have been found in large farms.

The three-year average of economic and financial parameters of the sample of farmers belonging to the Italian FADN dataset has shown that the medium-big farms and the big enterprises have had the best performances in terms of Gross Marketable Output, Added Value and Net Income (Table 3). Income from related activities such as sub contraction of tilling, agro-tourism, green tourism and educational farm have showed the best results in big enterprises and in medium-sized farms.

The analysis of fixed and variable costs over the three-year time of study has shown a growth of these especially in large farms that have doubled the percentage incidence of variable costs compared to fixed costs, while in the small farms both fixed and also variable costs did not increase significantly (Figure 1).

The three-year average of funds allocated by the European Union showed that large farms have received financial support above 50,000€ per year followed by those belonging to the medium-big size farms (Figure 2); small farmers have received less than 5,000€ per year.

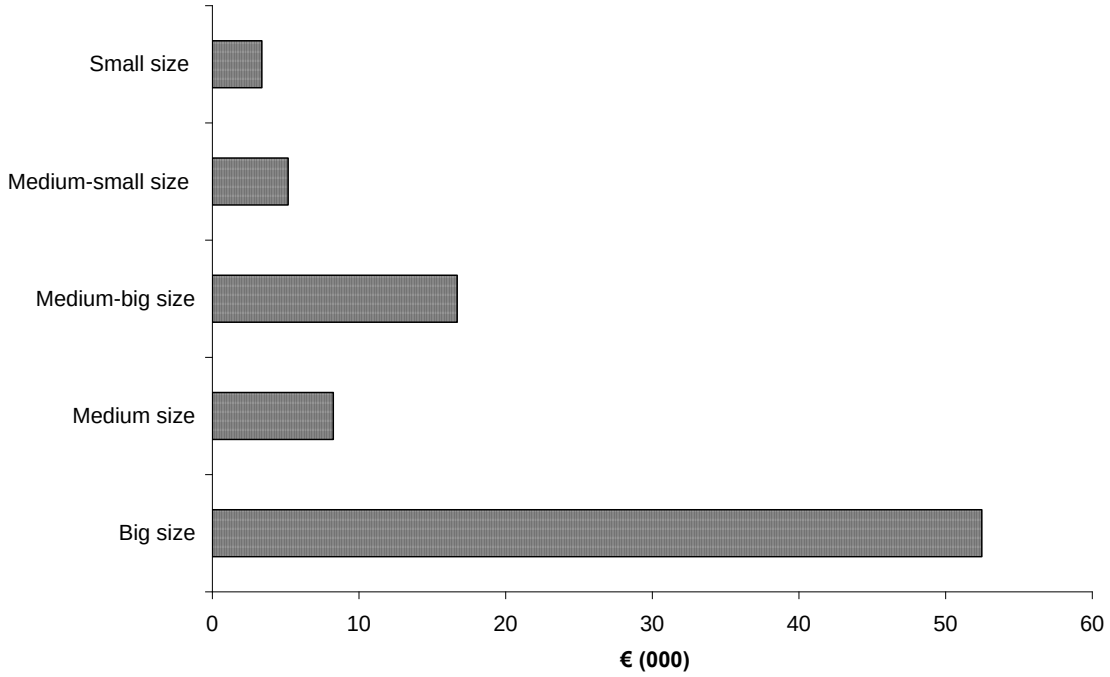

Figure 2. Average of funds allocated by the European Union in each group of farm *(Source: our elaboration on data www.rica.inea.it)*

Table 4. Average value over analysed time of main economic and financial parameters in the dataset FADN (Source: our elaboration on data www.rica.inea.it)

Size group	Percentage of farms in size group	Technical efficiency CRS	Technical efficiency VRS
Big	0.80	1.00	1.00
Medium-big	6.93	0.94	0.98
Medium	9.09	0.86	0.96
Medium-small	13.2	0.85	1.00
Small	69.9	0.73	1.00

Table 4 explains indices of technical efficiency and scale efficiency calculated with the DEA based on the FADN dataset and classified by economic size in 5 groups related to single frontier of dimension. Large farms have been the most efficient Decision Making Units in absolute value, while small enterprises have values of technical and economic efficiency lower than 1. Over three-year time of observation in average value both in terms of efficiency index calculated under constant returns to scale (CRS) and also calculated in terms of variable returns to scale (VRS), the analysis of efficiency has confirmed that the size of the company did not produce an efficient size of scale.

The index of technical scale efficiency in the period of study (Table 5) showed a significant finding in big enterprises highlighting how other sizes of farms operate on a level of technical and economic efficiency lower than the optimal one, hence small farmers could improve their technical efficiency only by increasing their activities and their agrarian and land invested capital or rather increasing their level of productivity and technology. Big, medium small and small farms have been more sensitive to an increase of scale of production due to a more efficient use of inputs, such as arable land and invested agrarian capital and new technologies, with a value of technical efficiency increasing return to scale equal to 1.

Allocative efficiency is the ability in a technical sense of each DMU to produce the given output at minimum cost; this implies an optimal combination of inputs in function of their prices and their marginal productivities with the aim to obtain the specific and definite level of output. The best result, equal to 1, in terms of allocative efficiency in the three year time of observation, has been found in small size farms whilst the worst value, equal to 0.97 and 0.98, which implies a combination of factors of production far from the point of tangency between

isoquant and isocost, has been found in medium enterprises and in medium-big size farms.

Table 5. Average value of technical efficiency in analyzed size of farms in the dataset FADN (Source: our elaboration on data www.rica.inea.it)

Size group	Technical efficiency increasing return to scale	Technical efficiency decreasing return to scale	Scale efficiency
Big	1.00	1.00	1.00
Medium-big	0.98	0.94	0.96
Medium	0.96	0.86	0.89
Medium-small	1.00	0.85	0.85
Small	1.00	0.73	0.73

5. Conclusion

The study has investigated how the size of farms is a very important parameter to improve the performance of enterprises especially in those of small dimensions that characterize the 70% of Italian agricultural sector and are located mainly in areas at risk of marginalization and in which the productive diversification is the most and foremost incentive to get better economic and technical efficiency and profitability in small farms able to use less than 7 hectares of Usable Agricultural Surface compared to the big ones capable of having on average 78 hectares. The small farms, in fact, can take advantage according to the indices of technical efficiency of scale only through a growth in size of surface and investments in agrarian capital or rather invested liquid asset.

Technical efficiency is a useful in valuing which inputs are fundamental to improve it even if small agrarian enterprises can use more efficiently the workforce than big farms. Small agrarian enterprises have several issues to use in an efficient way the land capital and agrarian capital because they have difficulties in accessing credit due to their dimension. Small farms have less opportunities than big ones to improve their technical efficiency and their scale of production by enlarging cultivated surface, by investing money in new technologies labor saving and in lessening not efficient management linked to their small dimension. In fact, credit institutions do not consider small enterprises able neither to use efficiently nor to pay back loans. For the future European Rural Development Program, it would be pivotal that the European Commission decides to help small farms by providing specific funds and other subsides with the aim to stimulate investments in technology. Throughout the analysis of technical and economic efficiency using the FADN database the European Commission can investigate and decide how to support small farms reducing rural marginalization. In fact, small size enterprises, by the multi-functionality and pluriactivity such as agro-tourism and other rural activities, are able to lessen depopulation and marginalization in rural territories. Furthermore, the rural entrepreneur has a key role in environmental protection and also it is pivotal to increase the sense of belonging in rural communities and in the process of rural planning and development. This aspect is particularly true in less-favored rural areas in which are predominantly located small farms.

For the future, in particular for the next Rural Development Plan 2014-2020, it is pivotal that Italian government intervenes by supporting the opportunity of using public lands throughout lease contracts for fifteen years, renewable 2 times only, to improve the scale of land capital with the consequence of increasing levels of working capital and investment with a positive impact on the socio-economic development of rural areas solving the rural emigration from rural territories.

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