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Assessing eco-efficiency of arable farms in rural areas

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ABSTRACT

Arable farming plays an important role in securing economic development in the rural region of Le Marche (Italy). However, this system could be unsustainable owing to the use of polluting inputs and the negative environmental effects induced by specialization. The objective of this paper is to analyze eco-efficiency of a sample of arable farms operating in the Le Marche region over the period 2011–2014 using the Farm Accountancy Data Network. For this aim, a two-stage analysis has been carried out. Firstly, eco-efficiency and pressure specific eco-efficiency scores are computed using Data Envelopment Analysis. Then, a robust regression analysis is carried out to identify the influence of a selection of economic, social and political factors on eco-efficiency. Results show that most arable farms exhibit a modest level of eco-efficiency and are characterized by specific eco-inefficiency in relation to the use of fertilizers and pesticides. Moreover, they indicate that farms are more eco-efficient if they are led by young farmers and participate to agri-environmental schemes. From these results, useful policy recommendations and conclusions can be drawn.

1. Introduction

Agriculture is defined as sustainable if "*conserves land, water, and plant and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable and socially acceptable*" (FAO, 1988). In Europe, since the 1960s, agriculture has been supported by the Common Agricultural Policy (CAP). Based on initial objectives of guaranteeing self-sufficiency and supporting farm income, the CAP stimulated the application of an intensification-based paradigm through protectionist mechanisms and aids for agricultural products, incorporated in prices and proportional to production. In the next decades, economic, environmental and social changes have pushed policy makers, through several reforms, to adopt a more sustainable approach. Nowadays, in spite of a stronger environmental awareness, purely productive aspects are coming back to be particularly important. The new European agricultural reform, i.e. the 2014–2020 CAP, establishes, among its objectives, that of guaranteeing long-term food security for European citizens and contributing to growing world food demand in the light of increased market instability, often exacerbated by climate change (European Commission, 2010).

There is therefore a new paradigm of agriculture, that of sustainable crop production intensification (FAO, 2011). Although there is some discussion about its exact definition, which can have different policy implications (Franks, 2014), sustainable intensification is a term which is commonly used to identify an agricultural model that is able to satisfy an increasing global demand for food while ensuring adequate ecosystem service provision.

The problem, however, is that promoting this production model raises doubts about compatibility between intensification-oriented farming systems and the objective of conserving natural resources and biodiversity, especially in the most sensitive areas. For this reason, there is a strong need for analytical instruments which are able to evaluate both the degree of environmental sustainability of farming systems, particularly of those which are oriented to a more intense use of technical inputs, and the effectiveness of environmental policies in improving the level of sustainability in agriculture.

At a territorial-level there is a quite standardized methodology to measure agri-environmental impacts (Commission of the European Communities 2000; OECD 2001; EEA 2005). Conversely, at a farm level, evaluating agricultural sustainability is still an open issue since there is no unanimous agreement about the environmental indicators to be used (Picazo-Tadeo et al., 2011). For instance, Firbank et al. (2013) measured sustainable intensification of a selection of British farms using indicators such as gross energy as a measure of food production; an index of biodiversity obtained by assigning different scores to different farm characteristics; total carbon footprint; nitrate and ammonia losses to water and air, respectively. Barnes and Thomson (2014) proposed 13 different indicators reflecting ecosystem, economic and social aspects of sustainable intensification.

A feasible approach to measure sustainability at an individual level, which is being increasingly adopted, is represented by the so-called economic-ecological efficiency or rather eco-efficiency, which appeared in the 1990s as a practical tool to measure sustainability. The term "eco-

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efficiency" was introduced by the World Business Council for Sustainable Development (WBCSD, 2000) to identify a management philosophy aimed at encouraging business to search for environmental improvements that yield parallel economic benefits. In other words, companies are asked to be more environmentally responsible and more profitable. The OECD (1998) refers eco-efficiency as to the efficiency with which ecological resources are used to meet human needs, which can be measured as a ratio of an output divided by an input, where the output is expressed by the value of products and services produced by a firm, sector or economy as a whole, while the input is the sum of environmental pressures generated by the firm, the sector or the economy. Therefore, an output increase, for a given level of inputs, or an input decrease, for a given level of outputs, leads to an improvement of eco-efficiency. However, a change in eco-efficiency does not necessarily reflect a corresponding change in terms of overall sustainability since what this ratio measures is only the relative level of environmental pressure in relation to the volume of economic activity, while sustainability is more related to absolute levels of environmental pressure. This means that increases in eco-efficiency at an individual level could be neutralized by macro dynamics (Huppes and Ishikawa, 2005). In spite of these possible drawbacks, measurement of eco-efficiency is still an important issue (Kuosmanen and Kortelainen, 2005).

The objective of this paper is to evaluate eco-efficiency of arable farms in the period 2011–2014 and identify the possible influence of a selection of socio-economic and political factors. The territorial context considered is Le Marche, an Italian rural region. Eco-efficiency is measured as a ratio between economic value added and an aggregated indicator of environmental pressure. This ratio is used to derive eco-efficiency scores at farm level, which are computed using Data Envelopment Analysis (DEA) methods. DEA is non-parametric methodology introduced by Charnes et al. (1978) to measure the distance from the technology frontier identified by the best practices. Its main advantage is that no prior assumptions concerning the specific functional relationship linking inputs and outputs are imposed. Although it was conceived to assess performances of decision-making units on the basis of marketable inputs and outputs, its use has been successively extended to take account of bad or environmentally undesirable outputs and inputs (Zhou et al., 2008). This analysis also derives pressure-specific indicators of eco-efficiency to take account of inefficiencies related to specific environmental pressures deriving from inappropriate farming techniques. These pressures are measured in terms of degree of specialization, nitrogen and phosphorous balances, and pesticide risk. Moreover, it applies a double bootstrapped left-truncated regression. Regression is finalized to assess the contribution of some variables to explaining eco-efficiency while double bootstrapping is used to correct for bias and construct confidence intervals.

In literature, the use of DEA techniques to measure eco-efficiency in different sectors as well as for the assessment of environmental performance of farms and the agricultural sector is widely known (Gadanakis et al., 2015). Conversely, there are only a few studies which estimate eco-efficiency at a farm level using the DEA approach (Picazo-Tadeo et al. 2011; Gómez-Limón et al., 2012; Picazo-Tadeo et al. (2012); Berre et al. 2015; Gadanakis et al. 2015; Pérez Urdiales et al., 2016).

This paper adds into the literature about DEA-based eco-efficiency, allowing us to verify the applicability of some results and findings related to arable farms in different territorial contexts. In particular, it focuses on an Italian region that represents an interesting case study for its specific peculiarities. Indeed, Le Marche has been interested by radical changes that have brought the introduction of farming systems, which are typical of more flat areas and are hardly compatible with its natural characteristics of Mediterranean region. These systems, based in particular on arable crops, are economically very important for the region. They contribute to income and local development, so ensuring vitality of rural areas, but have also produced and can still produce several negative environmental effects that European and regional policies have been trying to mitigate through agri-environmental constraints and measures. See for instance Stoate et al. (2001) for an overview of ecological impacts generated by arable intensification. A further interest, therefore, is to verify if regional policy has been effective in reorienting arable production towards higher sustainability, while maintaining its economic contribution.

2. Materials and methods

2.1. The area under study

Le Marche is a region located in the Central-Eastern part of Italy and extends over an area of 9694 km^2, equivalent to 3.2% of the national territory. It is a predominantly rural and is characterized by the absence of large urban centres. The population density is 165 inhabitants per km^2, lower than the Italian average (201). According to the European territorial classification, there are not urban areas. There are only intermediate (43% of total surface) and rural areas (57%). In relation to the territorial classification adopted at a national level (Partnership Agreement), only 16% of population resides in urban centres while 84% of population is settled in rural areas.

From an environmental point of view, most of the area is mountainous or hilly. The annual average temperature is between 5 and 14 °C. In the coastal strip and middle hill the climate is Mediterranean. It gradually becomes sub-Mediterranean moving inward, while it is similar to the oceanic one in the mountains although there are still Mediterranean influences. Rainfall depends on climate zones: the average annual precipitation is 700 to 1400 mm as we move from the coast towards mountain areas. 16 and 3% of total surface is subject to risks of landslides and flood, respectively. Moreover, Le Marche is one of the few Italian regions where all municipal areas exhibit high likelihood of hydrogeological instability (ISPRA, 2015). Around 90% of agricultural areas, mostly located along hillslopes and where arable farming is predominant, are subject to erosion with annual values of eroded soil ranging between 5 and 20 tons/ha. This phenomenon is due to the natural morphology of the territory and is quite significant in terms of geographical coverage. The nitrate vulnerable zones cover an area which corresponds to 11% of territory, approximately 21% of total utilized agricultural area (UAA). These zones fall into major regional river basins and involve both areas around river courses and the regional coastal strip (Regione Marche, 2015).

Agriculture plays an important role in the region from a territorial standpoint. The share of total surface managed by farms amounts to 68%, against a national average of 57%. This is a clear signal of the importance of regional agriculture in managing natural resources and, thus, in affecting the overall quality of the environment. The widespread presence of agricultural activities ensures protection and maintenance of the rural landscape of the region. However, it has produced and can still produce several environmental and eco-system disservices which are mainly caused by the type of productive specialization of regional agriculture. Since the 1960s, agricultural policy, progressive depopulation in agricultural areas and other phenomena such as mechanization, ageing, deactivation and destructuration have radically changed the landscape and production systems of the region. Mediterranean crops such as vineyards, olive groves and orchards, which characterized regional agriculture, have been gradually replaced by high-capital-intensity crops such as cereals and industrial crops (in particular, soya, sunflowers and sugar beet), producing negative environmental effects, such as landslides, flood, water pollution, loss of biodiversity and landscape (Bonfiglio, 2000). For this reason, arable farms have been generally indicated as principal responsible for environmental deterioration (Bonfiglio and Sotte, 2000).

Based on agricultural census data, in 2010 regional arable farms were >39 thousand units, equivalent to 87.5% of total farms (against a national average of 51%), and cultivated almost 375 thousand hectares, which equal 60% of regional UAA. In comparison with the national