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Analysis

Provision of environmental output within a multi-output distance function approach

Francisco J. Areal *, Richard Tiffin, Kelvin G. Balcombe

Agricultural and Food Economics Department, The University of Reading, PO Box, 237, Reading, RG6 6AR, UK

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ABSTRACT

This paper redefines technical efficiency by incorporating provision of environmental goods as one of the outputs of the farm. The proportion of permanent and rough grassland to total agricultural land area is used as a proxy for the provision of environmental goods. Stochastic frontier analysis was conducted using a Bayesian procedure. The methodology is applied to panel data on 215 dairy farms in England and Wales. Results show that farm efficiency rankings change when provision of environmental outputs by farms is incorporated in the efficiency analysis, which may have important political implications.

1. Introduction

The environmental goods (e.g. habitat for insects, bird species) and bads (e.g. pollution derived from the use of fertilisers) provided by farms create positive and negative externalities respectively in that the additional benefits and costs to society derived from the farmers' actions do not result in compensation to farmers for the benefits provided nor pay to society for the harm done. The non-existence of a market for the good and/or bad provided leads to a loss of economic efficiency giving governments an argument to intervene in order to internalise the externality.

Both positive and negative externalities have characterised the Common Agricultural Policy (CAP). Thus, the CAP in the last decades was based on price support which, as well as technological progress, has favoured intensification, specialisation and concentration of production. This has led to habitat loss and a decline in biodiversity, i.e. it has produced negative externalities (Potter and Goodwin, 1998). The introduction of set-aside in 1988 aimed to reduce overproduction of crops such as cereals and oilseed rape; and to deliver environmental benefits. Policy support to farmers for making environmental improvements to their land by changing farming practices has continued since then (e.g. payments for the provision of environmental goods through agri-environmental schemes (AES)).

This is in line with the idea of having a sustainable agricultural sector. According to this idea, the UK Government set up an independent Policy Commission on the future of farming and food. The Commission's report provided a vision of "a sustainable, competitive and diverse farming and food sector, playing a dynamic role in the rural economy and delivering effectively and efficiently the environmental goals we as a society set for ourselves" (Defra, 2002). The UK Government released in 2002 its vision on sustainability of the farming and food sectors which was in harmony with the independent Policy Commission report outcomes.

It seems clear that agricultural practices (i.e. land use) have an impact on the quality and availability of natural habitats which can have an effect on wildlife and biodiversity (Mattison and Norris, 2005; OECD, 1999). For instance, many bird species depending on permanent pasture land (OECD, 1999) can be affected in case this land use is changed.

Although accounting for multiple outputs has been treated to a large extent within the productivity and efficiency literature, few publications have incorporated externalities as an output of the farm (Dorfman and Koop, 2005), being negative externalities such as pollutants the core of research (Färe et al., 1989, 1996, 2001; Lansink and Reinhard, 2004; Murty et al., 2006; Reinhard and Thijssen, 2000; Reinhard et al., 1999, 2002). Yet few studies have included the provision of environmental goods (e.g. biodiversity) in production related analysis. An exception is the publication by Omer et al. (2007) who conducted a study in the productivity performance and biodiversity conservation in intensive agricultural systems using a stochastic production frontier approach. These authors included a biodiversity index (BI) based on measures of plant species richness to examine the relationship between the state of biodiversity and output in a specialised intensive farming system. A positive relationship between state of biodiversity and productivity was found, which suggests that implementing biodiversity conservation policies may be beneficial to productivity, rejecting the idea that environmental regulations have an adverse effect on productivity. The omission of environmental outputs provided by farms in production and efficiency analysis may lead to biased results, which if used for policy support, could mislead policy makers in their policy decisions. We take into account the environmental outputs by incorporating an indicator for environmental outputs as

* Corresponding author. Tel.: +44 118 378 8970; fax: +44 118 935 2421.
E-mail address: f.j.areal@reading.ac.uk (F.J. Areal).

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one of the outputs of the farms in the production function within a multi-output distance function approach. We use a proxy indicator for provision of environmental goods which measures the weight of both permanent and rough pasture on the total agricultural area.

Permanent and rough pasture is reported to be likely to contribute to positive environmental effects. Thus, the EC Regulation 1782/2003 considers that permanent pasture has a positive environmental effect and as a consequence it is appropriate to adopt measures to encourage the maintenance of existing permanent pasture to avoid a massive conversion into arable land. Article 5 of the regulation, which establishes the principles for keeping agricultural land in a good and environmental condition, states in its second paragraph that "Member States shall ensure that land that was under permanent pasture at the date provided by the area aid is maintained under permanent pasture". Grassland area has been previously used as an indicator to assess the effects of agri-environmental policy on landscape and nature (Oñate et al., 2000). Permanent and rough grassland in agricultural systems are close to natural ecosystems. Ecological services associated with the vegetative cover of grassland are the prevention of soil erosion, renewing ground water and flooding control by enhancing infiltration and reducing water runoff (Altieri, 1999: Menta et al., 2011). It is well known that grassland usually contains more earthworms than arable land (Edwards and Bohlen, 1996). Earthworms play a role in the supply of nutrients, soil structure improvement and water infiltration (Van Eekeren et al., 2008). The fact that permanent grassland and rough grassland are not disturbed by tillage favours the development microorganisms in the soil which do beneficial activities such as decomposition of plant residues, manures and organic wastes (Altieri, 1999). Permanent grasslands show both high soil fertility and rich soil fauna diversity (Menta et al., 2011). Soil organic carbon density, which plays a crucial role in the mitigation of the global greenhouse effect, was found to be high in permanent grassland compared to arable crop area (Leifeld et al., 2005). Soil organic matter content in permanent grasslands was found to be 3 times higher than in permanent arable areas (van Eekeren et al., 2008; Moscatelli et al., 2007). Gardner and Brown (1998) reviewed the publication findings on the effects of organic agriculture on micro and macro flora fauna. From this review positive impacts on soil organisms, invertebrates and possibly positive impacts on bird and mammal populations were found to be associated with permanent pasture. In addition many bird species are dependent on the presence of permanent pasture land (OECD, 1999). For example, Corn bunting density was found to be positively correlated with permanent grassland (Fox and Heldbjerg, 2008). Finally, there are some potential benefits that are derived from permanent and rough grassland landscapes such as aesthetic benefits.

Inferences about firm specific inefficiencies have been widely reported in the literature. It is also common to find in the literature a ranking of firms according to their mean efficiencies (Coelli and Perelman, 1999, 2000) or plots for mean, median and maximum efficiency levels (Koop, 2003). We investigate the consequences in efficiency rankings when provision of environmental outputs is incorporated into efficiency analysis. Accounting for environmental outputs when measuring efficiency is in concordance with policies aiming to achieve a sustainable agriculture such as the provision of both marketable goods (e.g. cereals, milk and oilseeds) and non-marketable goods (e.g. diversity of flora and fauna and landscape views) by farms. Information about farm efficiency levels is key for policy makers to identify which farms may be in need of support (i.e. those farms that are less efficient) and implement support policies (e.g. facilitation of credit to access to new machinery, training). If the information received by policy makers about farm efficiency levels is not harmonised with policy aims, policy measures may be ineffective at supporting the right farms. In other words, using a conventional efficiency measure (i.e. by not incorporating the provision of environmental goods by farms in efficiency analysis) may lead to policy makers, whose aim is to support those farms in line with sustainable agriculture, to target the wrong farms when designing an efficiency support policy. In addition, we examine how a measure that accounts for the provision of environmental outputs may affect the results associated with explaining technical efficiency. The following sections proceed by first discussing the methodology, then the sources and construction of the data. The empirical results are then presented and discussed, and the final section concludes.

2. Methodology

We study milk producer farms in England and Wales. Previous analysis of milk quota in England and Wales include work done by Dawson (1987) and Colman et al. (2002). Dawson (1987) concluded that the imposition of milk quotas helped to increase efficiency levels. The future of the dairy policy in the EU and its consequences has been always object of analysis since the introduction of quotas and specially during the changes in Agenda 2000 and the mid-term review of the CAP in 2003 (Benjamin et al., 1999; Mechemache and Requillart, 2000). Milk producers in England and Wales have an annual milk quota and a functioning quota leasing market in which producers can lease in and/or lease out milk during the production year. Therefore we include in the analysis the annual quota Q, leasing in quota qui as normal inputs and leasing out quota quo as a normal output.

Optimising behaviour is the assumption upon which conventional microeconomics is based. This means that producers optimise their production by not wasting resources and therefore operate near their production possibilities set. However there may be an array of motives for which not all producers are successful in optimising production. If this is the case technical efficiency is not achieved and measuring the distance between the production frontier and actual production is a crucial policy interest. From a policy and managerial perspective it is important to identify the determinants of inefficiencies and learn how inefficient producers are on average as well as individually (Färe et al., 1994; Farrell, 1957). The departure point of any technical efficiency analysis is the definition of the production technology of a firm. This can be characterised in terms of a technology set, the output set of production technology, and the production frontier.

Distance functions are useful since they describe technology in a way that efficiency can be measured for multi-input and multi-output enterprises (Coelli et al., 2005). An output distance function describes the degree to which a firm can expand its output given its input vector. We start from a producible output set, which is the set of all outputs that can be feasibly produced using the set of all inputs. The output set for production technology is defined as

$$\begin{aligned} P(x, Q) &= \left\{ y \in R_{+}^{M} : x \text{ can produce } y \text{ given } y_1 = Q + qui - quo \right\} \\ &= \{ y : (x, y) \in T \} \end{aligned} \tag{1}$$

where y refers to all outputs of the farm including milk (y_1), the leasing out quota (quo) and the environmental output and x refers to all inputs used in the farm including the leasing in quota (qui) annual allocation of quota Q (where $Q = Q_t = Q_{t-1} + \text{quota bought}_t - \text{quota sold}_t$).

The output distance function is defined on the output set $P(x,Q)$ as

$$D_O(x, y, Q) = \min\left\{ \theta : \left(\frac{y}{\theta}\right) \in P(x, Q) \right\} \text{for all } x \in R_{+}^{K} \tag{2}$$

which means that the initial allocation of quota Q, the leasing in qui and leasing out $quo$are treated in the same way as conventional inputs and outputs.

Assuming a translog functional form for the parametric distance function with M outputs and K inputs provides several attractive properties including flexibility, easy to derive and permit the