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ANALYSIS

Developing a social perspective to farm performance analysis

Mary Graham *

School of Accounting, Economics and Finance, Deakin University, Warrnambool, Victoria, 3280, Australia

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ABSTRACT

This paper examines how traditional farm productivity analysis can be extended to produce a performance measure from the perspective of society. A biophysical model is used to measure inputs from the environment which are combined with conventional marketed inputs to develop an environmentally sensitive Malmquist productivity index to determine social productivity growth. Data Envelopment Analysis (DEA) is used to analyze data collected from selected farms in South-East Australia and includes a measure of leaching and run-off as a proxy measure of the impact the application of fertilizers has on ground and surface water. The results show measured productivity growth increases for some farms and decreases for others when environmental factors are considered.

1. Introduction

Both productivity growth and efficiency measurement have a long history of being examined and are common measures of farm performance. Both measures underpin the long-run competitiveness and economic sustainability of a productive activity (Veeman, 2008). The estimates are predominantly developed using marketed output and purchased inputs. To remain profitable and competitive, farmers need to be able to apply marketable inputs efficiently. However, the nature of agriculture is such that the production process interacts with, and impacts on, the environment. To enable productivity growth to be related to the environment and natural capital resources, performance measures need to be widened to generate environmentally adjusted measures of productivity. This paper explores such an approach.

Agricultural output requires the use of both private and environmental or public inputs. In addition to private inputs such as fertilizer and fodder purchased in the market place, inputs from the environment include rainfall, sunlight, soil quality, birds to control pests, and the use of surface and ground water as a receptacle for waste. The production technology, S^t, that models the transformation of private inputs, $\boldsymbol{x}^t \in \Re_+^N$, and public inputs, $\boldsymbol{z}^t \in \Re_+^K$, into outputs, $\boldsymbol{y}^t \in \Re_+^M$, in each time period $t = 1,\ldots,$ T, can be represented as:

$$S^t = \left\{ \left(\boldsymbol{x}^t, \boldsymbol{z}^t, \boldsymbol{y}^t \right) : \boldsymbol{x}^t, \boldsymbol{z}^t \text{ can produce } \boldsymbol{y}^t \right\}.$$

The level of output, $\boldsymbol{y}^t$, is dependent upon both purchased or private inputs, $\boldsymbol{x}^t$, and environmental or public inputs, $\boldsymbol{z}^t$, (Carpenter et al., 1998; Jarvis, 1999; Pimentel, 1999; Powlson, 1999; Pretty, 1999; Tisdell, 1999; Fraser and Hone, 2001; Hodge, 2004; Parker, 2005; Williams, 2005). To cut back on using $\boldsymbol{z}^t$, for example using surface waterways to absorb excess nutrients, would result in a lower level of $\boldsymbol{y}^t$, and/or require a higher level of $\boldsymbol{x}^t$, such as a waste disposal system, to produce the same level of output. From a public policy perspective, performance measures need to capture the use of all resources. Traditional performance measures, using financial inputs and marketed output, need to be extended to include all inputs and generate a wider performance measure that reflects the perspective of society.

This paper develops a performance measure based on a 'whole farm systems' approach. The aim is to incorporate the services provided by the environment into productivity measurement and to see how their inclusion influences measured performance. This is analyzed in the context of the dairy industry.

Data on environmental inputs or outputs is required and this paper focuses on the use of a biophysical simulation model to capture the interrelationships that exist in resource use in a productive sector. The model, designed specifically for Australian dairy pastures, can also produce accurate and reliable environmental data and so overcomes the "serious data problems in isolating and measuring environmental resources" as Veeman (2008, pp.18–19) claims exist in some sectors, including the agricultural sector, making adjustments to productivity more problematic. The data produced by the biophysical simulation model is incorporated with data relating to marketed inputs and outputs to provide a social measure of farm productivity.

This paper is organized as follows. In recognition of production using both private and environmental inputs, the need to adopt a systems perspective to performance analysis is introduced in Section 2. Section 3 examines how a biophysical simulation model, DairyMod, can be used to provide data relating to the productive inputs provided

* Tel.: +61 3 55 633568; fax: +61 3 55633320.
E-mail address: grahamm@deakin.edu.au.

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by the environment. Data collected from 22 dairy farms in South-East Australia is used to demonstrate how such a model can be used to measure the level of environmental inputs used by each farm. The simulated data is combined with marketed data to develop a social production function. Different estimation procedures that are reported in the literature are examined before focusing on the Malmquist productivity index, the measure used in this study. The index can calculate changes in productivity without requiring market prices. The simulated and real data relating to the small group of non-randomly selected farms of varying size and structure[1] in South-East Australia is analyzed using DEA in Section 4 before general conclusions about the wider productivity measure are made in Section 5. Results confirm that when environmental impacts are considered, measured productivity differs.

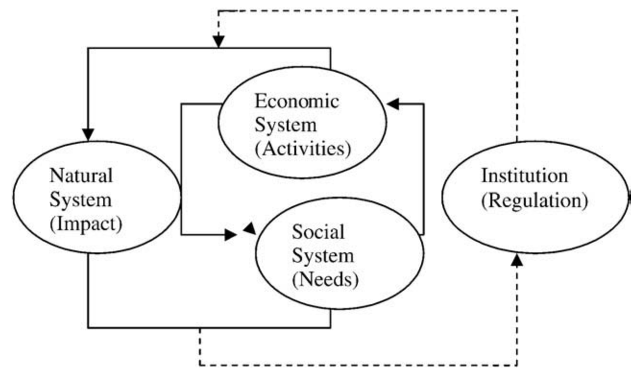

Fig. 1. Relationships within an integrated system.

2. Developing a systems approach

A producer aims to maximize or at least manage the flow of utility to his or her family. Modern agriculture has been successful in increasing output over many decades. Within the agricultural sector, including the dairy sector, changes in technology have been biased towards using more purchased inputs such as fodder and fertilizer, and while these have been important in raising individual farmer's profits, they have also been responsible for environmental damage. Nitrogen fertilizers, for example, are used extensively in the dairy industry to increase pasture growth and hence animal milk production. However, nitrogen as a pollutant can cause water quality problems, and while such costs are not borne fully by the individual farmer, society or the ecosystem, and in particular soil and water, will bear the loss (see, among others, Carpenter et al., 1998; Jarvis, 1999; Pimentel, 1999; Powlson, 1999; Pretty, 1999; Parker, 2005; Tisdell, 1999; Williams, 2005).

In essence, agricultural products and environmental services are produced jointly and reflect the input and output decisions of farmers (Fraser and Hone, 2001). In situations where different types of capital, particularly natural capital, are being used in the production process, conflicts are likely to arise between the maximization of a farmer's utility and that of society. Natural capital, due to its public good characteristics, tends to be undervalued by an individual and hence overused in the production process. Private or marketed inputs are said to be freely or strongly disposable and will have a positive price. Any change in the use of a purchased input will be reflected in the value of output produced. By contrast, environmental inputs are likely to be weakly disposable, in that any reduction in input usage will only be feasible if marketed inputs are increased and/or output falls. The 'free' environmental input will need to be replaced with a purchased input if output is to be maintained. There is then a private cost associated with any attempt to decrease the use of an environmental input. An individual private producer is unlikely to willingly change the use of the environmental input. However from society's perspective the efficient use of such inputs are important. Consideration needs to be given not just to the level of private productivity, but also to the wider social impact of the productive activity.

Being highly dependent on the biosphere and living resources, the wider social impact of agricultural production calls for a holistic approach, where natural or biophysical impacts, social needs, economic activities, and institutional regulations, (i.e. the dimensions of sustainability), as illustrated in Fig. 1 below, are considered (Tisdell, 1999; Ewert et al., 2006). Farming practices need to be economically viable, socially acceptable, and biophysically sustainable.

Adopting a 'whole farm systems' approach, whereby biophysical processes are integrated into performance measurement with the economic principles of agricultural production, allows for the interaction and interdependence that exists between agricultural activities and the environment. Private and economic choices relating to inputs and outputs, as well as the effect of these private choices on the biophysical processes, can be considered. The focus of this paper is on capturing the interdependence between the economic system and the natural system in a performance measure.

Agricultural production takes place over time and with many interacting sub-systems adding to the complexity of the production process. Each component of the system may be dynamic but if the properties are not integrated dynamically, the relationship could be described as 'loose coupling' (Antle et al., 2005). Productivity is then determined by exogenous biophysical conditions and economic decisions, such as land use and management. Economic decisions affect environmental outcomes, but environmental changes do not feed back to the economic outcomes. If however, close coupling characterises the system, the biophysical and economic components of the model interact dynamically. Hence, management decisions impact on soil productivity and soil productivity in turn affects management decisions. The use of a biophysical model developed specifically for dairy farm production is one attempt to capture these dynamics and judge the system in terms of economic and environmental performance.

An evaluation of the sector's performance requires the production of private goods output, with environmental, private, public or semi-public goods as inputs (Weaver et al., 1996). When applying general systems modelling principles to dairy farms, the level of the private output (milk and stock sales in the case of dairy farming), will be partly dependent on a vector of traditional inputs, such as labour, feed, fertilizer, public or quasi-public unpaid environmental inputs, such as nutrient flows in surface and ground water, as well as other environmental inputs such as rainfall and the slope of the land. An integrated model, composed of an economic model involving the private good production process and a biophysical model describing the biophysical processes, can be developed. Using the notation of Weaver et al. (1996) the integrated private good/biophysical technology ($G\cdot$) can be expressed as:

$$G(\boldsymbol{Y}_i, \boldsymbol{Q}_i, \boldsymbol{X}_i, \boldsymbol{E}_i, \boldsymbol{Z}, \theta_i) = 0$$

where the subscript i, indicates the variable is associated with the ith producer, the farmer. The output ($\boldsymbol{Y}_i$) refers to the private goods produced and inputs, $\boldsymbol{Q}_i$, $\boldsymbol{X}_i$, $\boldsymbol{E}_i$, $\boldsymbol{Z}$, $\boldsymbol{\theta}_i$, include environmental, private, and public, or semi-public good inputs.

In particular,

- $\boldsymbol{Y}_i$ is a $M\times 1$ vector of private good outputs, (e.g. milk, animal and forage sales);
- $\boldsymbol{Q}_i$ is a $J\times 1$ vector of environmental inputs, (e.g. leaching, run-off, soil quality);
- $\boldsymbol{X}_i$ is a $N\times 1$ vector of private good variable inputs, (e.g. labour, fertilizer, feed);

[1] Table 1 in Appendix A outlines the characteristics of each farm.