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Communicative farm-specific diagnosis of potential simultaneous savings in costs and natural resource demand of feed on dairy farms

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ABSTRACT

Feed plays a key role for dairy farmers to produce in an environmentally sustainable and competitive way. It determines both costs and natural resource demand. In this paper, we investigated whether and how dairy farms could simultaneously reduce feed costs and overall natural resource use in the feed supply chain without reducing farm revenues. We applied the frontier method Data Envelopment Analysis (DEA) on a data sample of specialized dairy farms in the region of Flanders (Belgium). Results showed potential simultaneous savings in costs and natural resources (up to 48%). This could mainly be achieved by increasing technical efficiency (proportionally minimizing the feed inputs, i.e. (i) on-farm produced roughage feed and (ii) purchased feed, consisting of concentrates and by-products) and to a lesser extent by increasing allocative efficiency (substituting these feed inputs up to a cost and/or natural resource use minimizing allocation). We offered farm advisors starting points to identify concrete improvement actions for individual farms, by graphically presenting improvement paths and by relating DEA's outcomes to Key Performance Indicators they are familiar with. High cost and natural resource efficiencies were related with (i) high milk production per cow obtained with as little as possible purchased feed, and (ii) low on-farm roughage production costs per ha associated with lower contract work costs and a lower proportion of grasslands in the available on-farm area. Finding a good equilibrium of purchased feed amounts and stocking density seemed to play a substantial role in optimizing allocative efficiency. Analysis with different frontier methods showed that the shape of the frontier influences the quantified improvement margins and the diagnosis of win-win and trade-off situations. Further research should focus on (i) the accuracy of the constructed frontier, (ii) relations with emission-related impacts and (iii) possible trade-offs between different resource types.

1. Introduction

Dairy farmers face a major challenge to keep their business profitable in harmony with the environment. Intensification has led to increased natural resource input and environmental burdens (e.g. greenhouse gas (GHG) emissions) (Arsenault et al., 2009; Meul et al., 2012). Feed plays a key role in improving the environmental and economic performance of dairy farms. It is the most important cost, mainly driven by purchased feed costs (Hemme et al., 2014). Feed is also the most resource-demanding input (Huysveld et al., 2015). Concentrates, as driver of increased milk yields on intensifying dairy farms (Alvarez et al., 2008), are more resource-intensive than roughages: 2.3 and 1.1 times per net energy for lactation and per true protein digested in the small intestine, respectively (based on Huysveld et al. (2015)). Life Cycle Assessment (LCA) studies of milk also show feed's important contribution in emission-related impacts (Cederberg and Mattsson, 2000; de Leis et al., 2015; Hospido et al., 2003; Thomassen et al., 2008). Animal emissions, such as methane, can be reduced by improving feed conversion (Waghorn and Hegarty, 2011). Increasing resource efficiency in feed production and consumption appears promising for simultaneously targeting economic and environmental wins on dairy farms.

Literature on exploring economic and environmental impacts of feeding strategies in dairy farming is broad. A normative and a descriptive branch can be distinguished. The normative branch aims to identify strategies for optimizing farm performance (Doole et al., 2013; Van Middelaar et al., 2014). Van Middelaar et al. (2014), for example, look to the impact of feeding strategies on GHG emissions and farm economic performance by optimizing an average farm. The descriptive branch

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starts from real farm observations (Basset-Mens et al., 2009; Thomassen et al., 2009). Links between economic and environmental indicators are analysed, often with regression techniques, and yield insight in win-wins and trade-offs between the indicators.

Above-cited approaches have some inconveniencies. Both branches generally assess an average impact, and thus fail to deliver farm-specific insights. Moreover, they mostly assume linear relationships and do not take into account the typically non-linear production function describing the transformation of inputs into outputs. These inconveniencies form a rationale to choose for productive efficiency models (Iribarren et al., 2011; Jan et al., 2012), which are used in a so-called frontier analysis (Coelli et al., 2005). These models consider the mostly non-linear production function. While linear regression techniques consider unique farm observations as deviations from an average regression line, frontier models see farm uniqueness as a deviation from the “frontier” production function, enabling identification of inefficient farms and quantification of their efficiency score. Frontier analysis also enables to decompose cost and environmental efficiencies in technical and allocative components, separating the mere technical production analysis from price and environmental impact information. By indicating farm-specific technical, economic and environmental performance benchmarks on the frontier, economic-environmental win-wins and trade-offs can be identified and improvement paths towards these benchmarks can be explored for specific farms (Coelli et al., 2007; Van Meensel et al., 2010a).

Despite the above-mentioned advantages of frontier analysis, efficiency scores are rather abstract and difficult to communicate. They deliver little information on how farmers could act to improve their farm performance. This inconvenience can be solved by linking the outcomes of frontier analysis with traditional Key Performance Indicators (KPIs) farmers are familiar with (Van Meensel et al., 2010a). KPIs must then facilitate the work of farm advisors who search together with farmers for farm-specific improvement actions.

This paper's objectives are (i) to explore economic-environmental improvement paths of individual dairy farms, more specifically investigating whether and how dairy farms can simultaneously reduce feed costs and overall natural resource use in the feed supply chain without reducing farm revenues, and (ii) to offer farm advisors starting points to identify concrete improvement actions for individual farms. The efficiency decomposition in technical and allocative components allows us to distinguish between the effect of using less feed to obtain the same revenues and the effect of substituting two main feed types, i.e. (i) on-farm produced roughages and (ii) purchased feed (consisting of concentrates and by-products). We apply the frontier method Data Envelopment Analysis (DEA), following the Coelli et al. (2007) approach, on a set of dairy farms belonging to a farm accountancy network in the region of Flanders (Belgium). Feed costs are quantified using these farm accountancy data. To quantify overall natural resource use in the feed supply chain, we rely on Exergetic Life Cycle Assessment (ELCA), in particular the *Cumulative Exergy Extraction from the Natural Environment* (CEENE) method (Alvarenga et al., 2013; Dewulf et al., 2007). Finally, we consult advisors in the farmers' network after adding a translation step by using familiar KPIs.

Next section (Section 2) describes the dataset and the building blocks of our approach (CEENE, DEA and KPI analysis). The results section (Section 3) starts with the efficiency scores and then demonstrates the win-wins and trade-offs identified with DEA. Next, KPIs are analysed and feedback from farm advisors is reported. Section 4 discusses these results in both a methodological and thematic way. Section 5 presents the conclusions and perspectives.

2. Materials and methods

We used readily available farm accountancy data (2.1) as a common data source for quantifying overall natural resource use in the feed supply chain using the CEENE method (2.2), frontier analysis using DEA (2.3) and KPI analysis (2.4).

2.1. Farm accountancy data

Farm accountancy data of 103 specialized dairy farms in Flanders, affiliated with the same farm advisory company, were collected for a one-year period in 2010–2011. The initial sample contained 112 farms and did not include dairy farms with beef cattle and suckler cows to ensure sufficient homogeneity. We removed 9 farms from the initial sample because of off-farm rearing of young cattle or because of substantial structural changes during the studied period. Table 1 presents descriptive statistics of farm characteristics for the final data sample containing 103 farms.

We established inventories of technical, economic and natural resource use (CEENE) data. Here we describe the main data that could be retrieved from the farm accountancy files. Feed can be divided in purchased feed (concentrates and by-products) and on-farm produced roughage feed. With respect to purchased feed, used quantities and prices could be retrieved, separately for each type of concentrate (soybean meal, rapeseed meal, grains, etc.) and for each type of by-product (beet pressed pulp, brewers grains, etc.). Feed use data of both dairy cows and young cattle were included. With respect to on-farm produced roughages, production costs (rented and owned land, mineral fertilizers, pesticides, fuel, machinery and contract work) could be retrieved. These costs were adjusted for purchase and sale of roughage feeds in the accounting year and for roughage feed stock changes between the beginning and the end of the accounting year. Also physical data about on-farm roughage production (ha land, liters fuel, kg fertilizers and kg pesticides), necessary for CEENE calculations, were retrieved from the accountancy files. Annual farm revenues from milk and meat production (expressed in euro) were also retrieved, in addition to the produced amount of fat-and-protein-corrected milk (FPCM) (IDF, 2010).

Table 1
Descriptive statistics of farm characteristics for the 103 dairy farms in the data sample for a one-year period in 2010–2011.

Characteristic (unit)	Mean	Min.	Max.	Median	Interquartile range
Average number of dairy cows (−)	104	41	270	95	49
Average number of young cattle (−)	86	24	244	79	42
Milk sold (kg FPCM[a]/year)	912,978	263,156	2,439,105	855,406	436,936
Average milk yield (kg FPCM[a]/cow·year)	8988	6476	10,827	9015	1234
Total area for feed production (ha)	52	20	142	48	23
Area for grass production (ha)	28	9	81	25	12
Area for maize production (ha)	24	5	69	22	12
Use of concentrates and by-products[b] (kg/cow·year)	2668	1280	3932	2705	604

[a] FPCM: fat-and-protein-corrected milk (IDF, 2010).
[b] The quantity of by-products was recalculated to a dry matter content of 90%.