Explaining relations between economic and life cycle assessment indicators for Dutch pig fattening farms

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ABSTRACT

Economic and environmental indicators were quantified for 29 specialized fattening pig farms in 2007, based on data from the Dutch FADN (Farm Accountancy Data Network). Economic indicators used were: gross value added (GVA) expressed per 100 kg slaughter weight (SW) or per annual working unit. Environmental indicators used were deduced from a "cradle-to-farm-gate" life cycle assessment, and were: land occupation, non-renewable energy use, global warming potential, eutrophication potential and acidification potential, each expressed per 100 kg SW. Results on economic and environmental indicators are within the range of results in literature. Variation among farms was larger for economic than for environmental indicators. A high GVA on a pig fattening farm was associated with a low acidification and eutrophication potential. From partial least squares regression analysis, it was concluded that this relation was affected by farm characteristics related to scale or to type of feed used.

Keywords: pig fattening, explanatory variables, FADN, economic performance, environmental performance

1. Introduction

Pork production is an important sector in the Netherlands. Over the last decades, sustainable production of food is becoming increasingly important (Anonymous, 2009a). Sustainable production of pork requires farms that are economically viable, ecologically sound and socially acceptable, both now and in the future. Important sustainability issues with respect to Dutch pork production are animal welfare, ammonia emission and farm income (Boone and Dolman, 2010). To improve sustainability of pig farms, variation in, for example, their environmental performance can be used to identify promising mitigation options (Thomassen *et al.*, 2009). Deduction of mitigation options from variation in performances among farms, however, requires a relatively large number of farms and insight in multiple environmental issues. To quantify the environmental performance of a farm, a life cycle assessment (LCA) can be used. In the recent past, multiple LCA studies are performed to quantify environmental performance of pork production. These studies, however, often focused on input-output figures only, used one or a small number of farms, or were based on scenarios (Cederberg and Darelius, 2002; Zhu and Van Ierland, 2004; Basset-Mens and Van der Werf, 2005; Williams *et al.*, 2006; Blonk *et al.*, 2008). The impact per kg of meat widely differed among studies (De Vries and De Boer, 2010), which implies, next to differences is modelling, variation in performance among farms or scenarios. To our knowledge, no scientific publication exists that analysed LCA results on a large number of fattening pigs farms. Moreover, when LCA results were computed at farm level, their relation with the economic performance was not investigated. Therefore, the main objective of this study is to quantify the economic and environmental performance on a large number of specialized fattening pig

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farms and to identify and explain relations among economic and environmental performance indicators. Data of the Farm Accountancy Data Network (FADN) were used to meet above mentioned objectives (Vrolijk *et al.*, 2009).

2. Materials and methods

2.1. Data

The economic and environmental performance of specialized national FADN fattening pig farms were analyzed for 2007. The Agricultural Economics Research Institute continuously collects technical and environmental data for an randomly selected stratified sample of fattening pig farms. These data include information on quantity and type of feed used, quantity of energy and water used, and detailed information on housing facilities. Because this study focused on specialized fattening pig farms, farms were selected from this stratified sample only when at least 67% of the gross margin originated from fattening pigs (Poppe, 2003), and no other animals were present. In total 29 farms were analyzed. On each farm, all feed required for pork production was purchased. Possible on-farm activities related to crop production, such as purchase of fuel, artificial fertilizers and crop revenues were therefore excluded from the analysis.

2.2. Economic performance

The economic performance of 29 farms was assessed by computing the gross value added (GVA). GVA is an economic measure for reimbursement of labour, capital and land, and is computed by subtracting the non-factor cost from farm revenues, whereby depreciation is excluded (Barry *et al.*, 2000). Non-factor costs include all costs except costs related to land-lease, labour and interest. To correct for differences in farm size, GVA was expressed in euro per annual working unit[1], or per 100 kg of SW.

2.3. Environmental performance

The environmental performance of 29 farms was quantified using a life cycle assessment (LCA). LCA is a method that evaluates the environmental impact of all stages in the life cycle of an activity, in this case pork production. The stages of the pork production cycle included up to the moment that fattening pigs leave the farm (i.e. “cradle-farm-gate” LCA) were: production of feed (including production and use of fertilizer, pesticides and energy required for cultivation, processing and transport), production of piglets and fattening of pigs. The functional unit was 100 kg of slaughter weight (SW) leaving the farm gate. We performed an attributional LCA. Whenever a multifunctional process occurred, economic allocation was used. Impact categories (and corresponding indicators) included were: land occupation (m^2 per year/kg SW, non-renewable energy use (MJ/kg SW), global warming potential (GWP in kg CO_2-eq/kg SW), eutrophication potential (EP in kg NO_3^--eq/kg SW) and acidification potential (AP in kg SO_2-eq/kg SW). Characterization factors for EP and AP were based on Heijungs *et al.* (1992), whereas for GWP they were based on IPCC (2006).

[1] Regularly employed labour is converted into Annual Work Units (AWU). One AWU is equivalent to one person working full-time on the holding. A single person cannot exceed 1 AWU equivalent, even if his actual working time exceeds the norm for the region and type of holding (EC, 2005).

Production of feed and piglets

For each farm, detailed information on the type of feed was known, i.e. exact quantity used, and dry matter (DM), N and P content. Three feed types were distinguished: two dry feed groups (compound and singular concentrates), and one group with other feed products (mainly wet by-products from the food processing industry). The average composition of compound concentrates (i.e. main feed type) was based on monthly publications of Nevedi (2008). Main ingredients were tapioca (30%), wheat expeller (11%), soy cake (8%), wheat (8%), maize (6%) and rapeseed cake (5%). For each feed ingredient used, the environmental impact of crop cultivation, processing and transport were based on Thomassen *et al.* (2009) and additional empirical data, literature or expertise from feed processing companies. Moreover, impact of production of compound concentrates was included. On 10 farms, pigs were fed other feed products (i.e., whey, potato steam rinds) in addition to concentrates. Similar to compound concentrates, impact related to crop cultivation, processing and transport were included.

Production of piglets

The environmental impact of the production of piglets included the impact from housing and feeding of farrowing sows, and the impact from feed used to rear piglets up to 25 kg. The environmental impact from housing and feeding of sows was expressed per piglet, based on average figures of specialized pig rearing farms in FADN. The impact from use of feed for piglet rearing was computed based on data of an average pig rearing farm in FADN, and expressed per kg live weight, since the live weight of purchased piglets was known for each fattening pig farm analyzed (Deusings, 2008).

Stable balance and gaseous losses

For each farm, excretion of N and P in manure was computed specifically. Since 2006, Dutch pig farms are obliged to verify their NP excretion in manure using a stable balance (Anonymous, 2008). In such a balance, gross NP excretion is computed by subtracting the amount of N and P in meat sold, from the total amount of N and P in purchased inputs, such as feed and piglets. NP inputs or outputs resulting from stock changes are included (Groenesteijn *et al.*, 2008). Subsequently, for each farm gaseous N losses were computed. Emission of NO_x and N_2O was computed as 0.01 kg and 0.001 kg per kg of N excreted in manure (Oenema, 2000). Emission of NH_3 was assumed to depend on stable type and floor area per animal place. We distinguished traditional housing and low-emission housing, either with an air-brusher or with an adapted floor system. For farms with < 0.8 m^2 per animal place, NH_3 emission was assumed at 2.5 kg/place/yr for traditional housing and 0.8 and 1.2 kg/place/yr for low-emission housing, either with an air-brusher or with an adapted floor system. In case of > 0.8 m^2 per animal place, these values were 3.5, 1.1 and 1.5 kg/place/yr NH_3 respectively (Anonymous, 2009).

2.4. Relating economic and environmental performance

Relations between economic and environmental indicators were quantified by a correlation analysis. Pearson's rank correlation was used in case of normality, whereas Spearman's rho correlation was used in case of non-normality. To further explain relations, partial least squares (PLS) regression was performed. PLS regression yielded the main orthogonal factors underlying a relation, and quantified the loading value (-1 until 1) of 16 farm characteristics on each orthogonal factor. A farm characteristic with a loading value above 0.3 was considered important for the relation found.

3. Results

3.1. Descriptive

On average, 1,927 fattening pigs were present per farm (table 1). Piglets were purchased with an average live weight of 25.2 kg. Fattening pigs were sold with an average SW of 90.9 kg. Fattening pigs were fed 285 kg DM per 100 kg SW, of which 75% originated from dry concentrates. Expressed per 100 kg SW, gross nutrient excretion in manure was on average 4.7 kg N and 1.8 kg P in 2007.

Table 1: Weighted mean and standard deviation (st.dev) of farm characteristics for 29 specialized pig fattening farms (FADN 2007).

Farm characteristic	Unit	mean	st.dev
Average no. fattening pigs	Number	1,927	1,481
Traditional animal places	number	1,088	829
Low-emission animal places	number	1,028	1,370
Labour	AWU	1.0	0.5
Average piglet weight	kg per piglet	25.2	1.3
Average slaughter weight (SW)	kg per fattening pig	90.9	2.2
Slaughter weight delivered	kg per year	505,426	365,244
Dry feed intake	kg DM per 100 kg SW	188.7	68.5
Other feed intake	kg DM per 100 kg SW	66.1	72.1
Gross N excretion	kg N per 100 SW	4.7	0.5
P excretion	kg P per 100 SW	1.8	0.3

3.2. Economic and environmental performance

The average GVA per 100 kg SW was €5.1 per 100 kg SW, and €26,150 per AWU. Coefficient of variation was 151% for GVA per 100 kg SW and 173% for GVA per AWU (table 2).

Table 2: Mean and standard deviation (st.dev) of the economic and life cycle assessment indicators for 29 specialized pig fattening farms in 2007.

Indicator	unit	Total mean	Total st.dev	On-farm (mean)	Off-farm (mean)
Land occupation	m^2 per 100 kg SW	937	105	2	935
Non-renewable energy use	MJ per 100 kg SW	1,995	227	169	1,826
Global warming potential	kg CO_2 eq per 100 kg SW	530	56	38	492
Acidification potential	kg SO_2 eq per 100 kg SW	9.3	1.9	1.9	7.4
Eutrophication potential	kg NO_3^- eq per 100 kg SW	85.9	8.7	3.7	82.2
Gross value added	€ per 100 kg SW	5.1	7.7		
Labour productivity	€ per AWU	26,150	45,140		

Total AP was 9.3 kg SO_2-eq per 100 kg SW, of which 45% was from emission of NH_3, 40% from emission of NO_x and 9% from SO_2. Total climate change was 530 kg CO_2-eq per 100 kg SW, of which 24% was from emission of CO_2, 9% from CH_4, and 68% from N_2O. Total EP was 85.9 kg NO_3^--eq per 100 kg SW, of which 49% was from leaching of nitrate and 34% from phosphate. Total land occupation was 937 m^2 per year, where total energy use was 1,995 MJ per 100 kg SW. For each impact category, the majority (ranging from 79-99%) of the environmental impact occurred off-farm, i.e. during production and transport of required farm inputs. The major part of this off-farm impact resulted from cultivation and transport of dry feed (components). This stage of dry feed production contributed 41% to the total non-renewable energy use, 55% to total AP. The coefficient of variation was smaller for environmental indicators (i.e. 10-20%) than for economic indicators.

3.3. Relations among economic and environmental performance

A correlation was found between GVA and total AP and EP. For GVA per 100 kg SW, as well as for labour productivity this relation was similar. The relation between labour productivity and AP per 100 kg SW of -0.53 was strongest. Such a negative relation implies that farms with a better economic performance produce pork with a relative low AP. With PLS regression, one orthogonal factor was found which explained 54% of the variation of both dependent variables. Farm characteristics that loaded high one this factor (value between brackets) were related to scale (i.e., the average number of fattening pigs (0.4), the total amount of labour (0.4) or the number of low-emission animal places (0.4)), or to the type of feed used (i.e., dry feed intake per 100 kg SW (-0.3) and other feed intake per 100 kg SW (0.3)).

4. Discussion and conclusion

Results on economic and environmental indicators are within the range of results in literature (De Vries and De Boer, 2010; Hoste and Puister, 2009). Variation among farms was larger for economic than for environmental indicators. This was because the environmental performance was determined mainly by cultivation and transport of one average compound feed. Economic performance, however, was highly affected by variation in production cost (Hoste and Puister, 2009). Furthermore, a high GVA on a pig fattening farm was associated with a low AP or EP. Farm characteristics that influence this relation were related to scale or type of feed used. Increasing the amount of “other feed” in the diet, for example, reduced feed costs and AP or EP per kg SW, because “other feed products” were cheaper than the dry feed, and had a lower EP and AP from cultivation and transport.

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