Benchmarking the 3P performance of Dutch and Danish pork supply chains, a quantitative approach

By

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Summary

Measuring and benchmarking performance of supply chains in relation to people, planet and profit (3P) is becoming more important due to the growing concerns of stakeholders. Public concerns about modern pork production in Western Europe, are more towards sustainable production, and national and international governmental agencies are responding through establishment of regulations. On the other hand, the pork sector has to sustain its profitability. Therefore, the objectives of this study were to identify the 3P performance indicators of pork chain, and to benchmark the 3P performance of the Dutch and Danish conventional pork chains.

As a performance measurement tool benchmarking involves collection and comparison of indicators that measure results. Therefore, the 3P indicators were identified through literature review; were evaluated based on criteria of relevance, quantifiability, comprehensiveness, and data availability; and verified by expert. Eight indicators for each stage were identified and quantified. Dutch representative farrowing and finishing farms with 550 sows and 4000 fattening pigs, respectively; Danish representative farrowing and finishing farms with 500 sows and 3346 fattening pigs, respectively; and Van Rooi Meat B.V and Tican a.m.b.a. of Dutch and Danish slaughterhouses, respectively, were considered for quantification. Where data for farms and companies were not available the whole sector was considered. The overall result of quantification is summarized in the next table.

Our quantification of indicators from different data sources has forced us to compare performances of different chain levels. In addition, not all indicators for all chain stages were quantified due to lack of data. This has limited our conclusion about the overall performances and investigate possible tradeoffs among the 3Ps.

In the present study, although the mentioned limitations have impacted the quantification, it is shown pig farms, in general, had lower profit performance than the slaughterhouses. This is even worse in the Danish case, which rather had better performance in the people aspect. This gives a clue whether there is possibility to make trade-offs among the 3P indicators and undertake integrated assessment. Therefore, investigating possible trade-offs of the 3P indicators and undertaking an integrated assessment have to be considered as future research areas. Moreover, the relatively higher overall costs vs. relatively higher prevalence of pathogenic microbes in Dutch cases implies the need for further investigation.

A summary of the 3P performance indicators and overall quantification results.

Indicator	Farrowing farms		Finishing farms		Slaughterhouse		Sector	
	Dutch	**Danish**	**Dutch**	**Danish**	**Dutch**	**Danish**	**Dutch**	**Danish**
GVA/hr (€)	43.74	31.11	73.96	13.42	127.15	45.16	-	-
ROI (%)	0.97	-2.36	1.64	-5.95	13.51	11.01	-	-
Salmonella prevalence (infection of slaughter pigs in lymph node) (%)	-	-	-	-	8.50	7.70	-	-
Prevalence of MRSAST398 (in dust samples of farms) (%)	17.90	3.50	-	-	-	-	-	-
Energy use (MJ/sow or finished pig)	2323.33	1036.08	76.33	43.63	-	-	-	-
Water use (M^3/sow or finished pig	5.270	8.145	0.593	0.550	-	-	-	-
Global warming (kg of CO_2eq/kg of pork meat)	-	-	-	-	-	-	3.600	3.500
Eutrophication (kg of NO_3eq/kg of pork meat)	-	-	-	-	-	-	0.219	0.232
Acidification (kg of SO_2eq//kg of pork meat)	-	-	-	-	-	-	0.042	0.045

"-" indicates that no data was available.

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CHAPTER I

INTRODUCTION

1.1. General background and problem statement

Measuring and benchmarking performance of supply chains in relation to people, planet and profit is becoming an important issue due the growing concerns of stakeholders. Recent research shows that stakeholders in agri-food chains, especially in western countries, are placing strict requirements to food (Trienekens et al., 2008). Consumers' demands on quality, integrity, safety, diversity and information about the means of production, hygiene, genetic modification, application of pesticides and other environmental issues are increasing (Trienekens et al., 2008; Van der Vorst, 2006). This array of attributes is often referred to as sustainability. According to Nijhoff-Savvaki et al. (2008), the mentioned and other sustainability aspects that affect pork chains are categorized using the "People, Planet and Profit (3P) approach". Van der Vorst (2006) also suggested performance indicators in line with the 'Triple P' (people, Planet, Profit) have to be developed in addition to the traditional ones (such as costs, throughput time, or technical quality).

The pork chains in the Netherlands and Denmark are well organized in terms of resources and are export-oriented. As European leading pork producing countries, they have large share to the world pork market. Denmark is the world's largest pork meat exporter (Andersen, et al., 2007) and the Netherlands is the second largest pork exporting country with in Europe (Silvis and de Bont, 2005). However, currently both are facing many challenges. Production cost is getting higher as compared to USA and Brazil (Hoste and Puister, 2008) exposing them to stiffer competition. On the other hand, public concerns about modern pork production in Western Europe, as cited by Stern et al. (2005), for example, are more towards sustainable production. National and international governmental agencies like the European Union have established quality and safety regulations of agri-food products (Trienekens et al., 2008).

Quantitatively measuring performance with 3P indicators shows overall sustainability picture of the Dutch and Danish pork chains and their stages. Mainly, benchmarking analysis can help us to identify performance gaps thereby lead towards investigating improvements.

1.2. Objective of the study

The main objective of this study is developing the 3P performance indicators of pork supply chain and benchmarking the Dutch and Danish pork supply chain. The specific objectives are:

1. To identify the 3p performance indicators of pork chain; and
2. To benchmark performance of the Dutch and Danish pork chains with respect to people, planet and profit indicators.

The main focuses of this study were farrowing and finishing farms, and slaughterhouses of the Dutch and Danish farms. Representative farms of both countries, Van Rooi Meat of the Netherlands and Tican a.m.b.a of Denmark were considered to quantify the indicators. Where farm or company data were not available sector level data were used. The benchmarking was based on quantitative performance of conventional pork chains

1.3. Outline of thesis

The thesis is organized in six chapters. The first chapter is introduction containing general background and problem statement, and objective of the study. Chapter two is about overview of pork meat industry: general structure of Dutch and Danish pork chains and the existing key issues and concerns are assessed. Chapter three has included literature review about the 3P aspects and performance indicators. The 3P aspects are elaborated and long list of indicators for each aspect are identified. Moreover, practical performance measurement systems of the two countries' slaughterhouses are included. Chapter four deals with methodology: the type of benchmarking selected for this study; methodology used to come up with the final list of indicators; and source and methodology implemented to quantify each indicator for each aspect and research unit, are elaborated in detail. In chapter five, results of the quantification for each indicator are

summarized in tables and explained. Finally, chapter six has included conclusions and recommendations.

CHAPTER II

THE PORK MEAT INDUSTRY

2.1. The Dutch and Danish pork chains

The Dutch pork chain is well organized in terms of resources and is export-oriented sector (Hoste and Puister, 2008). Dutch primary pig production includes *farrowing* and *finishing* farms where the former produce and raise piglets to an approximately 25 kg while the latter fatten piglets received from the previous stage (Wognum et al., 2007). Although most of the farms are specialized in one stage, primary pig production can also be integrated in a single stage. The next stage is slaughterhouse, where in The Netherlands 95 % of slaughtering is controlled by four companies, the largest VION has 70 % of the slaughtering (Wognum et al., 2007).

The Danish pork industry is highly export-oriented sector, which amounts 85% of its production (Hamann, 2006; Karantininis, 2003) and 17% of world market (Hamann, 2006). In Denmark, 45% of the pig production is made in integrated systems which keeps herds producing pigs from birth to delivery for slaughter. The rest of the farms are specialized in either farrowing (produce and sell piglets at a weight of 25-30kg) or finishing farms (Danish Meat Association, 2007). The next stage, slaughterhouses, in Denmark is dominated by two cooperatives owned companies, Danish Crown (90%) and Tican a.m.b.a. (7%) (Hamann, 2006).

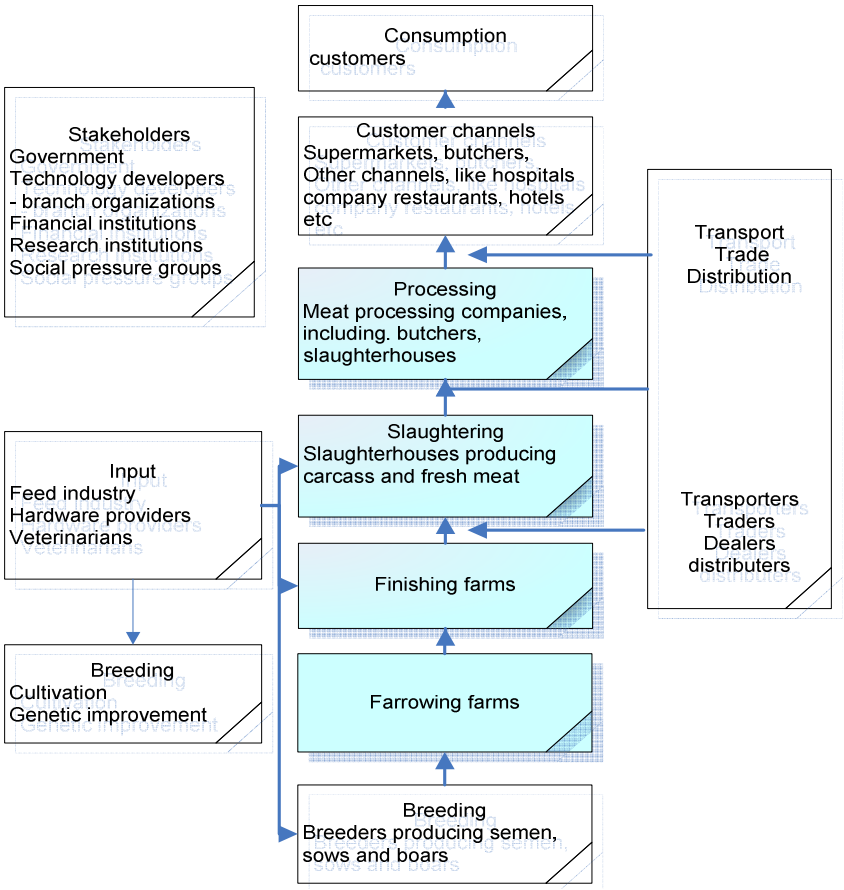

Fig: 1 Pork chain and its most important components (Wever and Wognum , 2008).

2.2. Key issues and concerns

Recent research indicate that there is a growing concern of stakeholders in agri-food chains, especially in western countries, with respect to *people* (societal concerns), *planet* (public concerns) and *profit* (commercial concerns) (Nijhoff-Savvaki et al., 2008). Consumers' demands on food quality, integrity, safety, diversity and information about the means of production, hygiene, genetic modification, application of pesticides and other environmental issues are increasing (Van der Vorst, 2006; Trienekens et al., 2008). Public concerns about modern pork production in Western Europe, for example, are towards sustainable production, mainly food safety and health for humans, animal welfare and animal health, environmental impact, sensory quality and the price of pork (Stern et al., 2005). In The Netherlands consumers have concerns about animal welfare and food safety (focusing on bone meal in pig feed, the use of genetic modification in pig

breeding and the chance of Salmonella) (Meuwissen and van der Lans, 2004). In response to *safety* concerns, for example, the European Union has issued regulation (EC) No. 2160/2003 on control of Salmonella and other zoonetic agents.

There is a growing concern of consumers on *environmental* impact of pork production (Meuwissen and van der Lans, 2004; Stern et al., 2005; Van der Vorst, 2006). According to Jongbloed (2008), environmental concerns can be divided into three categories: concerns related to soil (accumulation of nutrients), water (eutrophication) and air (global warming, ammonia, odours, dust). Petit and Van der Werf (2003) concluded stakeholders consider pig farms responsible for water quality, odor, soil quality and air quality. Large amounts of nutrients excreted in animal manures are lost to the environment resulting in accumulation (Jongbloed, 2008). In response to these environmental problems, the European Union and member countries have developed legislative frameworks like the 2006/1013/EC. In the Netherlands, for example, increasing complains from citizens and Friends of the Earth Netherlands due to fear of smell, noise, and soil and landscape pollution has limited farm sizes to 1000 pigs on average and very few with more than 10,000 pigs (Wognum et al., 2007).

Profit (*economic* sustainability) issue is also another concern of pork supply chain. According to Krystallis et al. (2009), economic issue is related to the ability to provide fair income and decent living for producers, as well as affordable prices to consumers. The pork sector is expected to sustain its profitability and at the same time fulfill all the above societal and public concerns.

CHAPTER III

THE 3P ASPECTS AND PERFORMANCE INDICATORS

3.1. The 3P aspects

The 3P (people, planet and profit) aspects are central dimensions that contribute to achievement of objectives of sustainable development, namely: social (people), environmental (planet), and economic (profit) objectives (UNCSD, 1998 as cited by Yakovleva, 2007). In this section literature focusing on the 3P aspects of sustainable agri-food supply chains, are included.

According to Kramer and Meeusen (2003), the *people* aspect of agri-food chains focuses on working conditions (improving work location, and safety), food safety (reducing production borne illnesses), norm and values (stimulating integration of elderly, handicapped, immigrants, women, etc) and social responsibility related to social welfare (health, housing, safety, education, etc. of the community). Yakovleva (2007) argued that societal aspect aims for creating productive employment and achieving equality between people. Nijhoff-Savvaki et al. (2008) mentioned animal welfare and food safety as focus of pork supply chain. Animal welfare in this aspect relates to societal concern about the impact of agriculture on animal wellbeing (Van Calker et al., 2005).

The *planet* aspect of food supply chains aims in reduction of resource use and protection of natural environment (Yakovleva et al., 2004). Kramer and Meeusen (2003) mentioned transportation (reducing freight transport), energy (reducing energy use and promoting renewable energy use), materials (reuse of materials), water quality and air quality (reducing emission), and fauna (biodiversity i.e. preventing the reduction in diversity of sorts and types of animals) as focuses of this aspect. In the pork supply chain emissions and pollution are focuses of this aspect (Nijhoff-Savvaki et al., 2008).

According to Yakovleva (2007) *profit* aspect relates to promotion of economic growth, encouragement of open and competitive economy and changing consumption patterns. Kramer and Meeusen (2003) included cost and efficiency (price/quality ratio), and employment (quantity of employment, i.e. increasing number of jobs) as focuses of

profit (economic) aspect in agri-food chains. Nijhoff-Savvaki et al. (2008) identified chain efficiency as focus of this aspect in pork chain.

3.1. 3P performance indicators

Ness et al., (2007) define indicators as simple measures; most often quantitative that represent a state of economic, social and/or environmental development in a defined region. This section includes literature review which identifies the 3P performance indicators.

Literature adopted different criteria while developing and identifying relevant indicators. Kramer and Meeusen (2003) used criteria like scientific validity, communicability, data availability, representativeness, and reproducibility. Data availability, for example, was based on information contained in the Farm Accountancy Data Network (FADN) (Kramer and Meeusen, 2003). Heller and Keoleian (2003) identified many of the indicators in a stakeholders' workshop. Yakovleva et al. (2004) considered the objectives of sustainable development set by The United Nations Commission of Sustainable Development (1998); and criteria like the indicators' ability to capture all the chain stages, measurability in terms of calculation and availability of data. Yakovleva (2007) adopted the indicators developed by Yakovleva et al. (2004).

Most of the above literature used similar indicators for all stages of agri-food supply chains. Regarding pork chain, most of them have focused on environmental aspects (Zhu and Van Ierland, 2004; Hervani and Helms, 2005; Cederberg and Flysjö, 2004). Therefore, there is still greater possibility to use these indicators for pork supply chain. Specially, it is possible to suit the works of Yakovleva et al. (2004), Yakovleva (2007), Kramer and Meeusen (2003), and Heller and Keoleian (2003) to the different stages of pork supply chains because they are not focused on a specific food supply chain. Indicators identified from the assessed literature are included below and summarized in table 3.1.

Table 3.1. Long list of 3P performance indicators

3P Aspect	Chain stage	Authors and year	Indicator	Type of food chain
People	Primary production	Heller and Keoleian (2003)	- size of farms, number of animals/unit - time animals spend outdoors (animal welfare) - number of farms per capita - hours of labor/yield and/income - average farm wages vs. other professions	Agri-food chain
		Yakovleva et al. (2004)	- number of animals /m^2	Agri-food chain
	All stages	Kramer and Meeusen (2003)	- number of days of illness (%) - contribution to local economies - number of registered complaints (safety issues)	Agri-food chain
		Yakovleva et al. (2004)	- number of jobs, average wage - exposure to hazardous materials	Agri-food chain
		Yakovleva et al. (2007)	- gender balance: male vs. female full-time employment (%) - wages: average gross wages/employee - employment: employee/enterprise	Agri-food chain
Planet	Primary production	Heller and Keoleian (2003)	- energy input/ unit of production - quantity of chemical inputs/unit of production - air pollutants/unit of production - percentage of waste utilized as resource	Agri-food chain
		Zhu and Van Ierland (2004)	- eutrophication indicator N equivalents (Nitrogen (N) and phosphate (P))	Pork chain
	Processing	Heller and Keoleian (2003)	- energy requirement for processing, packaging and transportation - waste produced/unit of food - percentage of waste and byproducts utilized in food processing industry	Agri-food chain

			- percentage of food lost due to spoilage/mishandling	
	All stages	Kramer and Meeusen (2003)	- total energy use - mineral leaching, waste, toxic emissions and land use	Agri-food chain
		Zhu and Van Ierland (2004)	- water and energy use(MJ/pig for farming and MJ/kg for slaughterhouse and processing) - acidification indicator NH_3 equivalents (NH_3, NOx and SO_2) in kg/pig - global warming indicator CO_2 equivalents (CH_4, CO_2 and N_2O)	Pork chain
		Yakovleva et al. (2004)	- energy and water use, total waste	Agri-food chain
		Yakovleva et al. (2007)	- energy and water consumption (Euro) - waste arising: cost of disposal (Euro)	Agri-food chain
Profit	Primary production	Heller and Keoleian (2003)	- % return on investment, cost of entry to business - farmer savings and insurance plans	Agri-food chain
	Processing	Heller and Keoleian (2003)	- relative profits received by farmer vs. processor vs. retailer	Agri-food chain
	All stages	Kramer and Meeusen (2003)	- number of jobs, financial results, investments in capital - R&D, human capital, certification	Agri-food chain
		Yakovleva et al. (2004)	- share of GDP, labour productivity, firm profitability - distribution of enterprises by size - ratio of imported vs. locally produced products	Agri-food chain
		Yakovleva et al. (2004)	- labour productivity: gross value added per workforce (Euro) - market concentration: % of large enterprises trade importance: imported product vs. domestic (%)	Agri-food chain

3.1.1. Primary production

People aspect: According to Yakovleva et al. (2004) performance indicators of people (social) aspect at production stage of agri-food supply chains are number of jobs, average wage, exposure to hazardous materials, and number of animals per square metre. Yakovleva (2007) used number of employees per enterprise, average gross wages per employee and gender ratio as indicators of same aspect for all stages of agri-food chains. Kramer and Meeusen (2003) also identified indicators applicable to all stages of agri-food chains like number of registered complaints, number of days of illness (%), and contribution to local economies. Indicators identified by Heller and Keoleian (2003) included size of farms, number of farms per capita, hours of labour/yield and/income, average farm wages vs. other professions, number of animals/unit, and time animals spend outdoors (animal welfare).

Planet aspect: Planet aspect indicators identified by Yakovleva et al. (2004) included energy consumption, water use, and total waste arising. Yakovleva (2007) adopted energy consumption, water consumption and waste arising. According to Kramer and Meeusen (2003) total use of energy, mineral leaching, toxic emissions, waste, and land use are planet aspect indicators for which information can be accessed from Farm Accountancy Data Network (FADN) in the Dutch agri-food system. Quantity of chemical inputs per unit of production, air pollutants per unit of production, percentage of waste utilized as resource, and energy input per unit of production were some of the indicators identified by Heller and Keoleian (2003).

Zhu and Van Ierland (2004) defined two types of environmental pressure indicators pork production: emission and resource (like feed, water and energy) use indicators. In their analysis indicators related to pork production were NH_3 emissions (from animal houses, manure storage and surface spreading), CH_4 emissions (from enteric fermentation in digestive processes and manure management systems), and Phosphorous (P) and Nitrogen (N) emission (from manure). They further categorized NH_3 equivalents as acidification indicator (NH_3, NO_x and SO_2), CO_2 equivalents as global warming indicator (CH_4, CO_2 and N_2O) and N equivalents as eutrophication indicator (N and P).

Profit aspect: According to Kramer and Meeusen (2003) profit aspect indicators included number of jobs, financial results and investments (in capital, R&D, and human capital). Indicators identified by Heller and Keoleian (2003), include percentage of return on investment, cost of entry to business, and farmer savings and insurance plans. Yakovleva et al. (2004) listed share of GDP, labour productivity, firm profitability, distribution of enterprises by size, and ratio of imported vs. locally produced products. Yakovleva (2007) used labour productivity, market concentration and trade importance as indicators of same aspect.

3.1.2. Slaughterhouse and processing

People aspect: In this stage, most of the authors have used similar indicators with primary production stage. In Yakovleva et al. (2004) number of animals per square metre was excluded from this stage. Zhu and Van Ierland (2004) also have similar indicators as the primary production except they left out eutrophication indicators.

Planet aspect: Heller and Keoleian (2003) identified energy requirement for processing, packaging and transportation, waste produced per unit of food, percentage of waste and byproducts utilized in food processing industry, and percentage of food lost due to spoilage or mishandling. Other authors used same indicators as the previous stage.

Profit aspect: According to Heller and Keoleian (2003) relative profits received by farmer vs. processor vs. retailer is mainly profit indicator of this stage.

3.2. 3P performance assessment systems

According to Albareda et al. (2009) companies contribute to sustainable development through Corporate Social Responsibility (CSR) and governments develop CSR policies to address these issues. In order to assess the CSR of Dutch and Danish pork producing firms, annual reports of VION (Dutch firm) and Danish Crown (Danish firm) were reviewed. Part of people and planet aspects included in their reports are given below and summarized in table 3.2.

VION has reported environmental (planet) aspects like production of environmental friendly alternative energy source from animal residual and by-products, purification of water used in production process, and reduction of energy and water

consumption. Furthermore, it has included the increased employment opportunities and upgrading employees' capacity through training.

Danish Crown, included issues like number of employees, social plan during layoff of employees, production of environment friendly energy source from animal by-products and reduction of water consumption. Moreover, it has included quantitative reports like energy and water consumption, CO_2 emissions, wastewater discharge, Nitrogen emissions, recycled for biogas production, and estimated biogas production as planet performances.

Table 3.2. People and planet aspects of VION and Danish Crown

Aspects	**Activities and Indicators**	
	VION	**Danish Crown**
People	- employees' training, number of employees - food security issues - food safety issues - animal welfare issues	- employees' training, - social plan to employees - average number of full-time employees
Planet	- production of energy and bio-fuels from animal residual and by-products - purification of waste water - reduction of energy and water consumption	- production of energy source (biodiesel) from animal by-products - reducing of water consumption - reducing discharge of waste water - costs wastewater treatment and discharge; disposal and management of waste; disposal of animal by-products; and noise and odour measurements - energy (MWh) and water (M^3) consumption, - CO_2, and Nitrogen emissions (kg) - wastewater discharge (in M^3), recycled for biogas production (kg), estimated biogas production (M^3)
*Profi*t	financial results and ratios	financial results and ratios

CHAPTER IV

MATERIALS AND METHODS

4.1. Benchmarking supply chains

Benchmarking is a performance measurement tool which measures comparative operating performance of companies and identifies the best practices (Lau et al., 2005). Benchmarking can be "indicator-benchmarking" and "ideas-benchmarking", where the former involves collection and comparison of indicators that measure results and the latter is about collecting ideas that inform improvement in organizational processes (Mayle et al., 2002 cited by Northcott and Llewellyn, 2005). According to Manning et al. (2008) a key requirement of benchmarking is to undertake formal measurement of measurable indicators and link the results to current practice and to identify mechanisms of improving performance. In this research indicator benchmarking was adopted where performance indicators were identified, performance of Dutch and Danish pork chains were measured and compared.

4.1. Selection of indicators

In order to carry out the benchmarking, first a long list of indicators (table 3.1) was identified through extensive literature review focusing in agri-food chains in general. Preliminary selection of indicators from the literature reviewed was based on their understandability (clarity). In order to come up with a short list of indicators the following criteria were used:

- *Relevance***:** indicators should be relevant in terms of their applicability to pork chain and contribution to the achievement of the respective aspect's objective**.** They should address the current focus of pork production. For this criterion the stakeholders' concerns (like welfare, safety and environmental issues discussed in section 2.2.) and the main focuses of annual reports of Danish Crown (2007/08) and VION (2008) were considered.
- *Quantifiability*: indicators have to be measurable quantitatively as our approach is quantitative.
- *Comprehensiveness***:** the set of indicators have to address all the 3P aspects.

- *Data availability:* data for the indicators have to be available in databases or be able estimated by experts.

Based the criteria outlined, eight indicators that can be applied for all stages of pork chain were identified. As a final step to the selection of indicators, an expert from LEI Wageningen UR was approached to evaluate and verify the identified ones. An alteration on the people aspect was made based on comment on the data availability criterion.

4.2. Data source and quantification of indicators

Theoretically, undertaking chain level benchmarking requires identification of specific route of each chain and collecting data, accordingly. In other words, in our case, the specific farrowing farms, finishing farms, and slaughterhouse have to be identified and data collected accordingly as our main objective was to measure performance of pig farms and slaughterhouses. However, this was not practically possible due to lack of data on which farms sell their products to specific customers. Furthermore, detailed data collection from farms and slaughterhouses was not practically possible. Therefore, based on sources of data, different approaches (sector level analysis and stage level analysis) were undertaken as presented below. An overview of the indicators, research units and data sources for respective indicator and country is also summarized in table 4.3.

This paper measures mainly the performance of conventional pork production. Therefore data related to planet and profit indicators were mainly collected from sources of conventional pork production.

4.2.1. Profit indicators

For profit indicators, pig farms and slaughterhouses were assessed. Therefore, the supply chains of Van Rooi meat B.V. from the Netherlands and Tican a.m.b.a. from Denmark were considered. Van Rooi Meat B.V. is an independent meat processor specialized in pork slaughtering, pork cutting and bacon production. Its production plants are all located in the Netherlands. Under the supply chain of this firm, Dutch representative open farrowing and finishing farms with only 550 sows and 4000 fattening pigs, respectively, were considered. Similarly, Tican a.m.b.a is a cooperative slaughterhouse and food company where its parent company, mainly responsible for the slaughtering activities (Tican a.m.b.a., 2007/08), is placed in

Denmark. Under the supply chain of Tican, Danish representative open farrowing and finishing farms with only 500 sows and 3,346 fattening pigs, respectively, were assumed.

i. Gross Value Added per hours worked

Labour productivity measured by Gross Value added (GVA) per number of hours worked shows economic performance of an industry/sector and its contribution to the country (Broersma and Van Dijk, 2005; yakovleva, 2007; Wosnitza and Walker, 2008). The higher the productivity is, the higher will be the economic performance of the sector and the higher level of welfare it can generate (CBS, 2009). Productivity is a concept that relates output to a given input like number of employees, hours worked or the value of labour cost (Kimbugwe et al., 2009). Therefore, labour productivity was calculated by the following formula.

Labour Productivity= GVA/hours worked.

Where:

1. *for primary farms, GVA (Gross value added) (*Chen et al., 2005)=*Turnover-direct costs (i.e. cost of fodder, animal health, insemination, cost of piglets, cost of breeding sows, transportation, delivery costs, cost of mortality, other costs), and*
2. *for slaughterhouses, GVA=Operating Profit for the period + (Cost of Employees + Depreciation).*

Primary farms

All the standard costs, hours worked and other cost related data used in the calculation of GVA and labour productivity of the Dutch representative pig farms (farrowing and finishing) were taken from KWIN-V (2009) and standard prices were taken from NVV (2009). Similar data for the Danish representative pig farms were collected through email communication(b). In addition, the following assumptions and technical data were considered based on standards set in the mentioned sources above:

1. All the standard costs, hours worked and other cost related data of both countries were assumed updated to September 30, 2009.
2. Exchange rate to convert from Danish kroner to Euro was taken from Pacific Exchange Rate Service as of September 30, 2009.

Table 4.1. Technical data of representative farms (September 30, 2009)

Technical data	Farrowing		Finishing	
	Dutch	**Danish**	**Dutch**	**Danish**
Housing construction cost €/animal place	2,602.00 /sow	3223.20/ sow	430.00/ fattening pig	439.83/ fattening pig
Number workers (incld. the entrepreneur)	2	2.99	1	1
Average labour hours/year	4136	5084	2349	1700
Gross hourly rate	€20.29	€21.49	€21.33	€21.49
Slaughtering weight	-	-	90.90kg	82.00kg
Piglets per sow per year (adjusted for mortality)	26.50	26.42	-	-
Rounds per year (adjusted for mortality),	-	-	3.07	4.00
Standard market price	€43.41/ piglet	€39.62/ piglet	€1.41/kg of meat	€1.11/kg of meat,

Slaughterhouses

Data related to revenue, costs and number of employees (excluding board and top management) of Van Rooi Meat for the year 2007 was taken from Amadeus data bank. Average number of hours worked per employee per week for manufacturing firms was taken from statistics Netherlands (2008).

For the Danish slaughterhouses, revenue, costs and number of employees (excluding board and top management) were taken from the 2006/07 and 2007/08 annual reports of Tican a.m.b.a. Only data belonging to the parent company were considered. Average number of hours worked per employee per week was taken from statistics Denmark (2008). The following assumptions were also considered:

1. Since the fiscal year of Tican a.m.b.a. ends on September 30, annual reports of 2006/07 and 2007/08 were considered. Accordingly, $3/4^{th}$ of the amounts from the fiscal year 2006/07 (January up to September 2007) and $1/4^{th}$ of the amounts from that of 2007/08 (October up to December 2007) were added to come up with a report of 2007. We assume all the revenues, incomes, costs and expenses were uniformly distributed throughout the months of the fiscal years.
2. Depreciation cost on the fixed assets of the parent company of Tican a.m.b.a was estimated indirectly from the total depreciation expense of the group based on proportional amount of fixed assets available. The detailed calculation is provided in table 4.2.

3. Average number of hours worked in the Dutch and Danish slaughterhouses were 35.2 and 37.2 per week, respectively. And the number of weeks per year was taken as 52.
4. Exchange rate to convert from Danish kroner to Euro was taken from Pacific Exchange Rate Service dated December 31, 2007.

Table 4.2 Estimation of depreciation expense (Tican a.m.b.a.) (in DKK, 1000)

	Group(2007/08)			Parent(2007/08)	
	Assets	**Depreciation**	**Dep/Asset**	**Assets**	**Depreciation**
Land & building	373,656	13,485	0.04	105,624	3,812
Plant & Machinery	222,812	29,508	0.13	85,738	11,355
Fixtures, fitting, tools and equipments	21,621	15,899	0.74	11,225	8,254
Total	618,089	58,892		202,587	23,421

ii. Return On Investment

Return on investment (ROI) can be used to evaluate an investment project or as a performance measure (McWatters et al., P.463). In this research ROI measures how effective net assets are being used to generate profits and is given by the following formula (Warren, p.246).

$$ROI = \frac{\text{Profit before tax and interest}}{\text{Net Assets}}$$

Where: Net assets= Total assets - Current liabilities

All the standard amounts of total investment, costs and expenses of the Dutch representative farms were taken from KWIN-V (2009). Standard amounts of same for Danish representative farms were collected through email communication (b).

Data used in calculating return on investment of slaughterhouses and processing firms were taken from the annual reports of Van Rooi meat and Tican a.m.b.a. for the period ending December 31, 2007. Based on the mentioned standards the following additional assumptions were considered:

1. Housing construction costs used in cost price calculation of respective countries were taken as total cost of initial investments and include all costs of fixed assets related to animal housing.
2. Market price of piglets in the farrowing farm was taken as cost of piglets in finishing farm.

4.2.2. People indicators

Safety issues expressed in terms of number of events were identified as people aspect indicators. In the present research, safety issues related with prevalence of pathogenic microbes in pig farms and slaughterhouses were assessed. In order to focus on the most common pathogenic microbes in Europe, recent reports of European food safety authority (EFSA) were reviewed.

According to EFSA (2010), *Salmonella*, *Campylobacter*, *verotoxigenic E. coli* and *Listeria monocytogenes* are the most common and important zoonotic agents. Next to *Campylobacter*, *Salmonella* was the most frequently reported cause of food-borne outbreaks in 2008 EU member states (EFSA, 2010). In 2008 broiler meat and raw milk were reported as the most important sources of food-born *Campylobacter* outbreaks while pork was considered important source of human *Salmonellosis* next to eggs and fresh poultry meat (EFSA, 2010). Therefore, prevalence of *Salmonella spp*. in pig farms and slaughterhouses were considered for our analysis. According to Backus and King (2008) bacteriological testing of carcasses is the more accurate indicator for food safety. Due to lack of data on swab carcass tests, the prevalence of slaughter pigs infected with *Salmonella spp*. in lymph nodes was taken from EFSA (2008) report.

Another major public health concern is Methicillin-resistant *Staphylococcus aureus* (MRSA). Since recent years the MRSA lineage ST398 is recognized as an occupational hazard for people in contact with pigs (EFSA, 2010). Therefore, prevalence of MRSA ST398 in pig breeding farms of both countries for the year 2008 was taken from the 2009 report of EFSA. The EFSA report (2009) was based on environmental dust samples taken from the immediate environment of holdings including: breeding holdings which sell a proportion of gilts or boar for breeding purposes, while the remainder is sold for slaughter, and production holdings mainly sell growing pigs for fattening or provide slaughter pigs directly to slaughterhouses. Prevalence in production holdings (i.e., farrowing farms) was considered in the present study.

4.2.3. Planet indicators

Energy and water use of pig farms were analyzed. For emissions, acidification, global warming, and eutrophication indicators, the pork sector including production of input

for crop growing and feed processing, pig farms, manure application, slaughterhouses and all transportation activities between the stages in the sector were considered.

i. Energy use

Energy use (most of the time for heating and ventilation) of Dutch and Danish primary farms were taken from Kool et al. (2009). It includes total electricity (kwh), gas (m^3), oil (litre) and diesel (litre) consumed per average animal available. In the present research, all units were converted in to MJ per sow, or finished pig based on conversion factors from Queensland Government Environmental Agency (2006).

ii. Water use

In this research only mains water use for each farm were considered. Performances of the Dutch representative farms were collected through personal communication (a) and for the Danish ones, through personal communication (b). It is given in m^3 per sow per year and per finished pig for representative farrowing and finishing farms, respectively.

iii. Emission

Gases, which contribute to acidification, global warming, and eutrophication are NH_3 equivalents (NH_3, NOx, SO_2), CO_2 equivalents (CH_4, CO_2, N_2O), and N and P, respectively (Zhu and Van Ierland, 2004). The NH_3 emission is from animal houses, during manure storage and manure applied to soils while CO_2 emission is from energy use and transportation. CH_4 emissions are related mainly to enteric fermentation of pigs and manure management systems. N_2O emissions include emissions from manure management, direct N_2O emissions mainly from fertilizers and indirect N_2O emissions; CO_2, $SO_2$and NOx emissions are mainly due to the energy use; and Phosphorous (P) emission is related to manure and fertilizer use (Zhu and Van Ierland, 2004). Nitrates (NO_3-N) are also emitted to soil and leached to water due to manure and fertilizer use.

Performances regarding acidification and eutrophication indicators of Dutch and Danish pork chains were taken from Dalgaard et al. (2007) while for the global warming (green house gas emission) was taken from Kool et al. (2009). In this research, global warming, eutrophication and acidification performances are expressed in terms of CO_2, NO_3, and SO_2 equivalents per kg of pork produced

(Dalgaard et al., 2007). These performances cover all sources of emission starting from crop input production and crop growing at the source countries, feed processing, pig production (manure/slurry management and enteric fermentation), manure/slurry application, slaughterhouses, and all kinds of transportation with in the chain stages. For the eutrophication and acidification indicators of both chains, it includes transportation of pork from slaughterhouses 745 km and 354 km to destination, respectively (Dalgaard , 2007).

Table 4.3 Summary of indicators, research units and data sources

Indicator	**Unit of measurement**	**Research unit**	**Source of Data**	
			Dutch	**Danish**
Safety issues	*Salmonella* prevalence	slaughterhouses	EFSA, 2009	EFSA, 2009
	MRSA ST398 prevalence	farms	EFSA, 2010	EFSA, 2010
Energy use Water use	MJ/sow; MJ/finished pig m^3/sow; m^3/finished pig	farms representative farms[1]	Kool et al., 2009 personal communication(a)	Kool et al., 2009 personal communication(b)
Global warming	kg/kg of meat	sector level	Kool et al., 2009	Kool et al., 2009
Acidification	kg/kg of meat	sector level	Dalgaard et al., 2007	Dalgaard et al., 2007b
Eutrophication	kg/kg of meat	sector level	Dalgaard et al., 2007	Dalgaard et al., 2007b
GVA per hours worked	Euro	representative farms	KWIN-V, 2009	personal communication(b)
		company	Amadeus data bank, 2007	Tican a.m.b.a 2006/07, 2007/08)
Return on investment	%	representative farms company	KWIN-V, 2009 Amadeus data bank, 2007; Statistics Netherlands, 2008	personal communication(b) Tican a.m.b.a., 2006/07, 2007/08); Statistics Denmark, 2008

[1]550 and 500 sows for Dutch and Danish farrowing farms, respectively
4000 and 3346 fattening pigs for Dutch and Danish finishing farms, respectively.

CHAPTER V

RESULTS

5.1. Profit

In this section performance of Dutch and Danish pork chains with respect to 3P indicators are summarized in tables and explained in detail.

5.1.1. Gross Value Added per hours worked

The detailed GVA per hours worked (labour productivity) performance of farms is given in table 5.1. Dutch farrowing farms had labour productivity of €43.74 which was more than the Danish €31.11. This is expalined due to larger number of labour hours in Danish farms, i.e. on average 10.17hrs/sow while it was 7.52hrs/sow in the Dutch farms**.** Moreover, GVA of Dutch farms was €328.92/sow which was greater than the Danish €316.35/sow. On the other hand, feed cost of Dutch farrowing farms was €497.55/sow while for the Danish it was €512.05/sow. Costs like water, heating, electricity, telephone, insurance, housing maintenance and other miscellaneous costs were higher in Dutch than Danish farms.

Labour productivity of Dutch finishing farms was €73.96, which was greater than the Danish €13.42 as shown in table 5.6. GVA per kg of meat in Dutch finishing farms was €0.16 which was higher than the Danish €0.02. On the other hand, total cost per kg of pork was €1.25 in Dutch farms while in the Danish it was €1.09. This shows the greater GVA in Dutch farms was as a result of higher market price per kg of pork meat.

Labour productivities of Dutch and Danish slaughterhouses are given in table 5.2. The Dutch slaughterhouse had greater labour productivity, that is on average €127.15 than the Danish €45.16. Van Rooi meat B.V. is slaughterhouse and meat processor. Therefore, part of the higher labour productivity is explained by higher turnover due to value adding process. Moreover the average number of hours worked during the year, taken in the calculation was lower.

Table 5.1. Gross Value Added per hour worked of farrowing and finishing farms

Turnover	**Farrowing farm**		**Finishing farm**	
	Dutch	**Danish**	**Dutch**	**Danish**
Number of animal places	550 sows	500 sows	4,000pigs	3,346 pigs
Average number piglets or rounds/year	26.50	26.42	3.07	4
End weight animals	25	30	90.90	82
Market price (€)	43.41	39.62	1.41	1.11
Total Turnover (€/farm)	**632,701**	**523,410**	**1,573,915**	**1,223,359**
Costs (€) [1]				
Piglet	0	0	43.41	39.62
Feed	497.55	512.05	52.09	36.80
Insemination	52.92	13.12	0	0
Health care	28.95	55.07	1.19	2.69
Net cost to purchase/from sales of breed sows	38.29	42.24		0
Water, energy, telephone , ins. Maintenance manure and others	203.74	107.99	12.33	5.41
Transport and delivery	0	0	3.13	2.50
Average loss of mortality	0	0	1.87	2.69
Total cost (€)/farm	**451,798**	**365,233**	**1,400,176**	**1,200,539**
Gross Value Added (€/farm)	**180,904**	**158,177**	**173,739**	**22,820**
Number of hours worked/farm	4,136	5,084	2,349	1,700
GVA/hours worked (labour productivity)	**€43.74**	**€31.11**	**€73.96**	**€13.42**

[1]Detailed costs are per sow and per finished pig in the farrowing and finishing farm respectively.

Table 5.2 Gross Value Added per hours worked of slaughterhouses (2007)

	Dutch (Van Rooi meat B.V.)	**Danish (Tican a.m.b.a.)**
Operating profit for the period	5,640,000	11,884,482
Add:		
Cost of employees	5,236,000	44,750,742
Depreciation	1,692,000	3,140,271
Gross Value Added	**12,568,000**	**59,775,495**
Number of employees (excl. board and managers)	54	798
Average labour hours in manufacturing industry	1,830	1,659
Average labour hours worked	98,842	1,323,722
GVA/hours worked (labour productivity)	**€127.15**	**€45.16**

5.1.2. Return on investment

Return on investment (ROI) of Dutch and Danish farrowing farms is shown in table 5.3. ROI of Dutch farrowing farms was 0.97% which was higher than the Danish of -2.36%, indicating that the Danish were operating under loss. The overall cost of production was however, €1125.05/sow in Dutch farms which was slightly higher than the Danish €1123.02/sow. Therefore, the higher ROI of Dutch firms is due larger market price per kg of meat.

Dutch finishing farms had ROI of 1.64% which was larger than -5.95% of Danish. Here, it shows the Danish finishing farms were operating under loss. Cost of production however, was lower in Danish farms, amounting 1.19/kg of meat, than the Dutch of 1.38/kg of meat. Therefore, the difference in ROI is explained by the higher market value per kg of pork meat in case of Dutch farms.

Table 5.3 Return on investment of farrowing and finishing farms

Description	Farrowing Farm		Finishing Farm	
Turnover	**Dutch**	**Danish**	**Dutch**	**Danish**
Number of animal places	550 sows	500 sows	4000 pigs	3346 pigs
Average number of piglets per sow/year	26.50	26.42	3.07	4
End weight of piglet	25	30	90.90	82
Market price /25 kg of piglet	43.41	39.62	1.41	1.11
Total Turnover (€ /farm)	632,701	523,410	1,573,915	1,223,359
Costs and expenses[1] (€)				
Piglet (for finishing farm only)	0	0	43.41	39.62
Feed	497.55	512.05	52.09	36.80
Insemination	52.92	13.12	0	0
Health care	28.95	55.07	1.19	2.69
Net cost to purchase/from sales of breed sows	38.29	42.24	0	0
Labour	152.62	218.49	4.08	3.65
Depreciation	150.98	174.05	7.78	7.14
Water, energy., telephone., ins. Maintenance., manure and others	203.74	107.99	12.33	2.87
Transport and delivery	0	0	3.13	2.50
Average loss of mortality	0	0	1.87	2.69
Total cost and expenses (€/farm)	**618,778**	**561,508**	**1,545,788**	**1,210,874**
Profit/loss (€/farm)	13,923	-38,098	28,127	-87,515
Cost of net assets(€/farm)	1,431,100	1,611,600	1,720,000	1,471,680
Return On Investment (%)	**0.97%**	**-2.36%**	**1.64%**	**-5.95%**

[1]Detail costs are per sow and per finished pig in the farrowing and finishing farm respectively.

Table 5.4 shows return on investment of slaughterhouses. The Dutch slaughterhouse had ROI of 13.51%, which is greater than the Danish 11.01%. As explained in the previous section, part of the difference is explained by the increased turnover due meat processing activity of Van Rooi meat B.V.

Table 5.4 Return on investment of slaughterhouses (2007)

	Dutch (Van Rooi Meat B.V.)	**Danish (Tican a.m.b.a.)**
Operating profit for the period (thousands €)	5,640	11,885
Total assets (thousands €)	89,304	135,462
Current liabilities (thousands €)	47,572	27,521
Net assets (thousands €)	41,732	107,940
Return on investment	**13.51%**	**11.01%**

5.2. People

Prevalence of *Salmonella* in the Dutch and Danish slaughter pigs and MRSA ST398 in pig farms is given in table 5.5. The prevalence of Dutch slaughter pigs infected with salmonella in lymph in was 8.5% while the Danish was 7.7%. This result reflects infection on the farms of origin, or during transport or lairage (EFSA, 2007).

Prevalence of MRSA ST398 in the Dutch and Danish breeding farms is given in table 5.2. It shows that the prevalence MRSTA ST398 in the Dutch farrowing farms was 17.9% while it was 3.5% in case of Denmark.

Table 5.5. Prevalence of salmonella in slaughter pigs and MRSA ST398 in pig farms

Sample taken from	**Dutch**		**Danish**	
	% prevalence	**95% CI**	**% prevalence**	**95% CI**
Salmonella Slaughterhouses (Lymph nods)	8.5	7.3-9.8	7.7	5.5-10.7
MRSA ST 398 Farrowing farms	17.9	13.6-23.6	3.5	1.8-7.1

5.3. Planet

5.3.1. Energy consumption

Energy consumption of the Dutch and Danish pork chains is presented in table 5.6. The overall energy consumption was higher at the Dutch farms than the Danish ones. This is mainly due to less energy usage for heating at the Danish farms (Kool et al., 2009).

Table 5.6 Energy and water consumption of farrowing and finishing farms

	Farrowing farm (per sow per year		Finishing Farm (per finished pig)	
	Dutch	**Danish**	**Dutch**	Danish
Energy consumption (MJ)	2323.33	1036.08	76.33	43.63
Water consumption (m^3)	5.270	8.145	0.593	0.550

5.3.2. Water consumption

Water consumption of primary farms is given in table 5.6. It indicates the Dutch had lower consumption. In the finishing farms, the Dutch had 0.593 m3/finished pig which was higher than the Danish 0.55 m3/finished pig. The difference can be explained by higher consumption for same animal weight and/or difference in consumption as a result of difference in delivery weight.

5.3.3. Emission

Emission performances of Dutch and Danish pork chains are given in table 5.7. The Dutch pork chain emits 3.6 kg of CO_2eq per kg of pork which is slightly higher than the Danish 3.5 kg of CO_2eq. This was explained due to relatively higher contribution from share of transport in feed processing and due to the relatively higher delivery weight of fattened pigs (kool et al., 2009). The Dutch chain shows slightly better performance with regard to eutrophication and acidification potentials.

Table 5.7 Emissions of Dutch and Danish pork chains per kg of pork produced

	Dutch	**Danish**
Global warming (kg of CO_2eq)	3.600	3.500
Eutrophication potential (kg of NO_3 eq.)	0.219	0.232
Acidification potential (kg of SO_2 eq.)	0.042	0.045

CHAPTER VI

DISCUSSIONS AND CONCLUSIONS

6.1. Conclusions

The objective of this study was to develop the 3p performance indicators of pork supply chain and benchmarking the performance of Dutch and Danish pork supply chain. As a performance measurement tool benchmarking involves collection and comparison of indicators that measure results. Therefore, the 3P indicators were identified through review of literature; they were evaluated based on criteria of relevance, quantifiability, comprehensiveness, and data availability and verified by expert to come up with a final list of indicators. To quantify the indicators, representative farms and companies (slaughterhouses) were considered. When data for farms and companies were not available we used the whole sector. The overall findings are summarized below:

1. A total of eight indicators, applicable for all stages, namely: safety issues, energy and water use, emissions (global warming, acidification and eutrophication indicators), GVA per hours worked and return on investment were identified.
2. *Profit:* both GVA per hours worked (labour productivity) and Return On Investment (ROI) were higher in Dutch finishing farms, farrowing farms and slaughterhouse. In the primary farms, this was explained due to higher market price per piglets and kg of meat. Moreover, number of labour hours in Danish farrowing farms was also higher.
3. *People:* prevalence of infection with *Salmonella* in lymph nodes of Dutch slaughter pigs was higher than the Danish. Similarly, the prevalence of MRSA ST398 was higher in Dutch farrowing farms than the Danish.
4. *Planet:* generally Danish farms had lower energy and water consumption, except in farrowing farms, where they had higher water consumption. The higher energy consumption in the Dutch farms was due to higher heating required in pig houses. Green house gas emission (global warming indicators) was slightly higher in Dutch pork chain than the Danish where as acidification and eutrophication potentials were higher in the Danish pork chain.

5. Generally, Dutch farms had better profit performance (GVA and ROI). This was mainly due to higher market price of piglets and kg of meat. Cost of production was also higher in Dutch primary farms. Danish farms on the other hand, had better people (lower prevalence of pathogenic microbes) performance and lower energy consumption and lower production cost. Moreover, slaughterhouse had better profit performance as compared to farms in both countries.

6.2. Discussion and future research out look

The following points had major impact in our benchmarking analysis:

1. The main focuses of the present study were pig farms and slaughterhouses of the two countries. However, due to lack of data, energy and water consumptions in slaughterhouses were not measured. This has limited our conclusion about the overall performances and possibility of making trade-offs among the 3P indicators.
2. Our quantification of indicators was based on data from different sources. This has obliged us to compare performances of different levels. For example, profit indicators, energy and water consumptions were measured per representative farms, whereas the emissions performance covered for the whole sector. Same level comparison could provide clear indication whether performance of people and planet affect the profit performance and vice versa.
3. In addition, the difference in delivery weight of piglets has made our profit performance analysis complicated. Difference in efficiency of costs and consumptions of the respective representative farms could have been identified and explained more.
4. We were not able to separate slaughtering and meat processing activities of the Dutch slaughterhouse due to lack of data. Therefore, it makes difficult to draw strong conclusion that the higher GVA and ROI of the Dutch slaughterhouse is due to higher turnover or cost efficiency.

Achieving sustainability objective requires considering all the 3P aspects as overemphasizing on one aspect affects the others. In the present study, although the mentioned limitations have impacted the quantification, it has shown pig farms in general had lower return on investment than the slaughterhouses. This is even worse in the

Danish case, which rather had better performance in the people aspect. This gives a clue whether there is possibility to make trade-offs among the 3P indicators and undertake integrated assessment.

Therefore, investigating possible trade-offs among the 3P indicators and undertaking an integrated assessment have to be considered as future research areas. Moreover, the relatively higher overall costs vs. relatively higher prevalence of pathogenic microbes in Dutch farms imply the need for further investigation.

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