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M.SC. MAJOR THESIS

Comparing the Technical Efficiency of Organic and Conventional Dairy Farms in the Netherlands.

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I remember back in 2019 spending a lot of time working with small scale organic farmers in Kenya and because of their curiosity, they asked me a lot of questions about their enterprises and what they would do to improve them. The questions kept coming and I felt really challenged because I didn’t have answers to a lot of their questions. And so I decided to go to the internet to search for a place where I could improve my knowledge about organic farming and more importantly understand its economics to be better equipped to help them create wealth through organic farming.

And behold, Wageningen University and Research was among the best universities recommended and with the help of Anne van den Ban Fund, my studies here were made a reality. And since my goal was to better understand the economics of organic farming, doing a master thesis at the Business economics group was important to me. So I managed to get a topic within the BEC group which I had interest in, got an appointment with Prof Dr. Alfons Oude Lansink the chair of the Business Economics Group (BEC), who welcomed me and introduced me to Dr.ir. FKG (Frederic) Ang who became my supervisor.

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Disclaimer

This report is written by a student of Wageningen University as part of the master programme under the supervision of the chair group Business Economics.

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Abstract

This paper focuses on the dairy industry in the Netherlands, a country regarded as a dairy country because of its long tradition of milk, butter, cheese production and consumption. The sector is one of the largest and most vital agricultural sectors in the Netherlands which contributes significantly to the Dutch economy, contributing €7.6 billion to the economy while employing over 47,000 people (Zuivelnl, 2019). On the other hand, the dairy sector is under pressure because of its contribution to climate change as a sources of greenhouse gases (GHG) emissions, notably methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) (FAO and GDP, 2018).

Due to the adverse environmental impact of the intensive production systems there has been increased demand for more sustainable and efficient agricultural production systems (European Union, 2020). The European Union, of which the Netherlands is a member has laid forward a path for a sustainable food system where the European Green Deal is at the heart of it. Under the EU's Green Deal, the Farm to Fork strategy plays a critical role in this transformation and as such, the European Commission has set a target of getting the Union to at least 25% of its agricultural land to be under organic farming by 2030 (European Union, 2020).

In this research we compared organic and conventional dairy farms technical efficiency in the Netherlands using the European Union's FADN database with data from 2010 to 2019 using the non-parametric DEA method in measuring the technical efficiency. From the results, we could observe that the average total technical efficiency for organic dairy farms, with respect to their own technology (i.e. under VRS) is 0.82 indicating that organic dairy farms are only 82% efficient, for conventional dairy farms, with respect to their own technology the average total technical efficiency (i.e. under VRS) is 0.75 indicating that conventional dairy farms are only 75% efficient.

When a common frontier is used, the average total technical efficiency (i.e. under VRS) is 97% for conventional farms and 87% for organic farms. When it comes to scale efficiency, organic and conventional dairy farms have similar efficiencies (98% vs. 98%), suggesting that, if it is assumed that organic and conventional dairy farms have access to the same technology, conventional dairy farms would have better farming practices and better use of the technology but when it came to scale, they would both have similar operational size efficiency.

Apart from adding to the literature in this topic, this results can be a good guide for public policies in the Netherlands by supporting both organic and conventional dairy farmers to improve their respective technologies technical efficiencies. Supporting organic farming and farmers for example, through R&D could spur organic innovations that could eventually increase their efficiency of 82%. On the other hand, conventional dairy farms can also be supported through policy such as providing farmers with subsidies to invest in more efficient technologies such as Precision Livestock Farming (PLF) to help them improve their efficiency of 75%. Since most of the efficiency models comparing organic and conventional farming do not include environmental variable, Future studies could consider including this.

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1 Introduction

1.1 Background and research problem

The world dairy sector has gone through significant changes over the years perhaps not one greater than the financial crisis in the global economy that caused decline in dairy sector in late 2008 and had a dramatic impact on product prices during the first half year of 2009. The crisis impacted on every aspect of the dairy business from production, trade, consumption and prices (Blaskó, 2011). Growth of world milk production slowed down, Low milk prices and high input costs discouraged many farmers around the world. The second half year of 2009 and the year 2010 brought changes where world trade increased rather slowly but showed remarkable recovery which saw the first half year of 2010 prices recover and production improve.

Despite all the challenges, Milk remains as one of most produced and valuable agricultural commodities worldwide. In 2018, there was a total milk production of 843 billion liters valued at USD 307 billion and milk ranked third by production tonnage and was the second agricultural commodity in value terms worldwide. Milk also contributes to 27% of the global value added of livestock and 10% of that to agriculture (FAO Stat, 2016). The global demand for dairy is expected to increase by 2-3% each year in the next ten years where consumption per person will grow to 127 kg of dairy per annum (2.5 kg per week) in 2025, compared to the current 114 kg (OECD, 2018). A change that the dairy sector can benefit from coupled with worldwide population growth, urbanization, increasing prosperity and a change in dietary habits.

The dairy industry is also known for creating jobs as dairy producers are often organized in cooperatives or liaise with other value chain actors to process and sale milk and dairy products to consumers. At global level, skimmed milk (75%), cheese (12%) and butter (3%) represent over 90% of all processed milk. Evidence from Bangladesh, Kenya and Ghana suggests that for every 100 litres of milk traded between 1.2 and 5.7 full time jobs are created (Omore A. et al. 2011). Overall, about 240 million people are likely to be directly or indirectly employed in the dairy sector. With an estimated 150 million dairy farms worldwide, it is likely that the dairy sector supports the livelihoods of up to one billion people worldwide (FAO Stat, 2016). Dairy is also considered vital to a healthy diet, as it contains high-quality proteins, fats, vitamins and minerals and is even recommended by the Dutch government dietary recommendations. FAO (2012) also shows that dairy is part of a sustainable, healthy and affordable diet.

On the other hand, the dairy sector is under pressure because of its contribution to climate change as a sources of greenhouse gases (GHG) emissions, notably methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). Globally, the sector is estimated to have emitted 1,711.8 million tonnes of CO_2 equivalent where the total emissions increased by about 18 percent in 2015 relative to 2005 levels (FAO and GDP, 2018). Overall, emissions per unit of dairy product have decreased in the same period, because production has become more efficient from improved animal genetics, management, better grassland management and feeding practices a sign that farmers are adapting resources more efficiently to increase their outputs.

Due to the adverse environmental impact of the intensive production systems there has been increased demand for more sustainable and efficient agricultural production systems (European Union, 2020). Stolze et al., (2000) suggested that Organic farming does provide environmental services and reduces negative externalities and on average, organic farms tend to have slightly higher crop diversity than conventional farms (Sipilainen & Huhtala, 2013). IFOAM - Organics International defines Organic Agriculture as a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved (IFOAM, 2008)

Globally, there is 71.5 million hectares of organic agricultural land, including those in-conversion which represents 1.5 percent of the world's agricultural land. There are at least 2.8 million organic producers in across the world as Organic food and drink sales are valued to be more than 95 billion euros. In Europe, there is 15.6 million hectares of agricultural land representing 3.1 percent of the agricultural area managed organically by over 418'000 producers while Retail sales of organic products are estimated to be 40.7 billion euros (Willer et al., 2020). In the European Union, organic farming is legally distinguished from conventional farming by a set of principles. The European commission has a detailed regulation (EC) No 834/2007 and Commission regulation (EC) No 889/2008 to standardize the organic system which simplifies organic into detailed guidelines.

The European Union, of which the Netherlands is a member has laid forward a path for a sustainable food system where the European Green Deal is at the heart of it. Under the EU's Green Deal, the Farm to Fork strategy plays a critical role in this transformation and as such, the European Commission has set a target of getting the Union to at least 25% of its agricultural land to be under organic farming by 2030 (European Union, 2020). This follows the first European Action Plan for Organic Food and Farming which was published 10th of June 2004 which has significantly contributed to the growth of the European organic market (W. Sukkel et al., 2009).

Consumer demand for organic products in the Netherlands has risen steadily over the last 10 years. In 2008, consumer spending on organic produce amounted to €583 million, a market share of 2.1 per cent. The product group's fruit, potatoes and vegetables, and dairy and eggs enjoy the highest market shares of 3.8 and 4.3, per cent respectively. In 2000 the Dutch government set a target of getting five percent by 2005 and ten percent by 2010 of the total agricultural area to be organically managed (Acs, et al., 2005). In spite of the targets, the vast majority of farms in the Netherlands 98% of the dairy farms are still farming conventionally (LEI, 2012).

Distrifood, 2012 indicated that there has been a growing demand for organic milk. The greater disparity between organic and conventional dairy farms in the Netherlands is partly due to the general consensus of Greater efficiency on conventional dairy farms and that this is necessary in order for the sector to remain competitive especially to the export market (Zuivelnl, 2019).

This paper focuses on the dairy industry in the Netherlands which is known as a dairy country because of its long tradition of milk, butter and cheese production and consumption. The sector is one of the largest and most vital agricultural sectors in the Netherlands which contributes significantly to the Dutch economy (Zuivelnl, 2019). The Netherlands is home to 1.6 million dairy cows and calves with a yearly production of 14 billion kg of milk. The sector contributes €7.6 billion to the economy while employing over 47,000 people and has a share of almost 5% of global dairy trade and ranks as top-5 largest dairy exporters alongside New-Zealand, the US, Belarus, and Germany (Kwakman, 2021)

Mayen et al. (2010) showed that the technology of organic dairy farms in the USA were 13% less productive than the conventional farm. Kumbhakar et al. (2009) also found that organic dairy farms in

Finland were between 21% and 37% less productive than conventional farms. On the other hand, In a 40 years comparison between organic and conventional systems, organic is found to use 45% less energy (MJ/Ha/year), release 40% fewer carbon emissions (KgCO2/Ha/year), yields up to 40% higher in times of drought, leach no toxic chemicals into waterways and its yields are competitive with conventional after a 5-year transition period (Rodale Institute, 2018). Aldanondo-ochoa et al. (2014) who estimated the so-called environmental productivity by including environmental variables (nitrogen and pesticide use), found environmental productivity of organic farms to be 8.4% higher than for conventional farms.

1.2 Objective and research questions

The objective of this research is to gain insights on the technical efficiency estimate of organic and conventional dairy farms in the Netherlands and how they compare to each other using Farm Accountancy Data Network (FADN) of the Agricultural Economics Research Institute (Wageningen, the Netherlands) containing organic and conventional farms between 2010 and 2019. The non-parametric method DEA will be used where Yearly efficiencies will be calculated, that is to say that a frontier will be constructed for each year.

To compare the performance between organic and conventional, first separate frontiers for each dairy system is used. This can show how farms in each system perform with respect to their own technology. Then both systems will be merged in a common sample supposing a hypothetical common technology and a common frontier (Meta frontier) is constructed. This allows to investigate which system has the more efficient technology, by calculating a technology ratio for each farm (Fogarasi and Latruffe 2020)

In literature, there hasn't been research that has focused on determining the technical efficiency of organic and conventional dairy farms focusing in the Netherlands. Kargiannis et al., (2012) compared the technical efficiency and scale efficiency of conventional and organic milk farms in Austria during the period 1997 – 2002 where they found both groups of farms having on average equal technical efficient (when compared to their production frontier).

Fogarasi and Latruffe (2020) conducted a Technical efficiency research in dairy farming but they compared France and Hungary and they showed that French farms had a more optimal scale of production than Hungarian farms, but Hungarian farms made better use of the technology. This research aims to provide technical efficiency estimate insights into the Dutch organic and conventional dairy farms and see how they compare, a research that will be helpful for dairy farmers and policy makers in making decisions towards ensuring 25% of land in the EU is Organic by 2030.

1.3 Outline of the research

The reminder of this thesis will be structured as follows: The just concluded first chapter aims to introduce the research topic by illustrating the background, the problem statement, research objective, questions and methodology, which will help clarify the context of this thesis. The second chapter will focus on the available literature on this topic. This will be divided into three major aspects: Overview of dairy in the European Union and the Netherlands, a look at the literatures on the differences between conventional and organic dairy and finally followed up by different literatures available on the efficiency of organic and conventional dairy.

The third chapter will present Data description to provide an overview of the data to be used. The fourth chapter will focus on the methodology where data analysis method of Data Envelopment Analysis will be elaborated. Chapter five will present the results and discussions while chapter six will include conclusions and recommendations. In there, it is aimed to answer the main question of how the technical efficiency of the organic and conventional dairy systems compare and put forth some recommendations to dairy farmers, educators and policy makers.

2. Literature Review

To establish a structured and coherent Literature Review, the discussed topic is divided into three major aspects: The definition of organic and conventional farming will be provided, followed by an overview of dairy in the European Union and the Netherlands and a look at the major literatures on the differences between conventional and organic dairy. Both scientific literature and grey literature will be included, for which corporate reports and market research will be included as well. The documents are analysed through quantitative content analysis. In this, a broad number of literature will be surveyed quickly, in order to gather as much as different perceptions on the same topic.

2.1 Defining Organic and Conventional Agriculture

The definition of organic farming is based on IFOAM's approved set of four principles which are intended to apply to agriculture in the broadest sense, including the way people tend soils, water, plants, and animals in order to produce, prepare, and distribute goods. The four principles include the health principle which emphasizes that organic agriculture should sustain and enhance the health of soil, plant, animal, and human as one and indivisible.

The principal of ecology stresses that organic should be based on the living ecological systems and cycles, work with them, emulate them, and help sustain them. The fairness principle is based on building relationships that ensure fairness with regard to the common environment and life opportunities while the principal of care emphasizes that organic agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment (IFOAM, 2008).

The Food and Agriculture Organization of the United Nations defines, in "Codex Alimentarius", organic agriculture as a "holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity" (FAO, 2018). The United States Department of Agriculture defines Organic agriculture as an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony. (Gold, 2021)

The Council Regulation (EC) No.834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No.2092/91 defines organic production as "an overall system of farm management and food production that combines best environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high animal welfare standards and a production method in line with the preference of certain consumers for products produced using natural substances and processes".

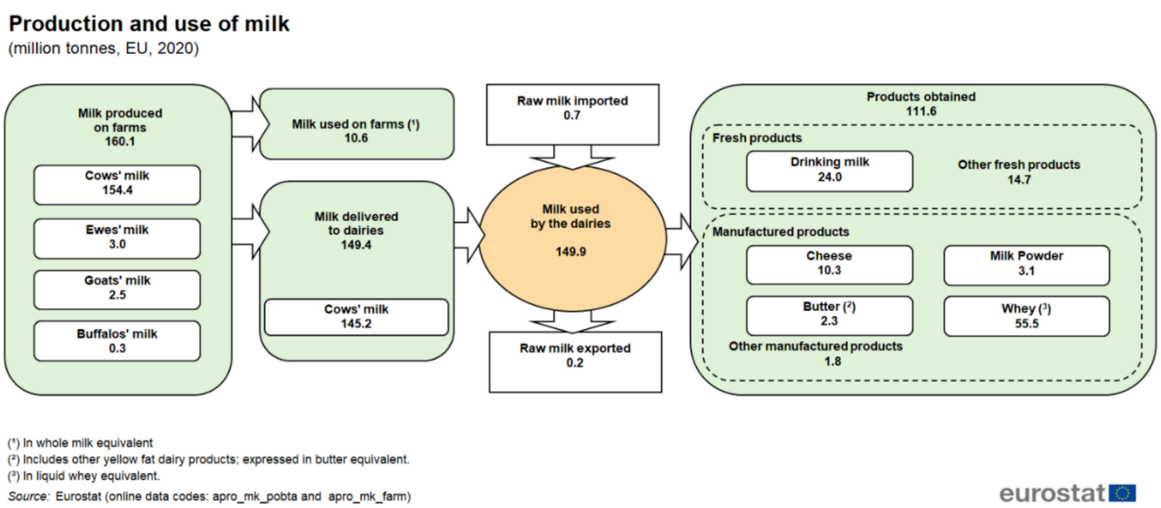
While organic is well defined and even anchored in law, Conventional farming definition is not. Conventional agriculture can be classified so if synthetic chemicals are used to maintain the plants. A significant amount of chemical and energy input is required in conventional agriculture to produce the highest possible yield of crops. It is a method that usually alters the natural environment, deteriorates soil quality, and eliminates biodiversity (USDA, 2015). The goal of conventional agriculture is to maximize the potential yield of crops. This is achieved through the application of synthetic chemicals, genetically modified organisms, and a number of other industrial products.

In maintaining a conventional system, biodiversity, soil fertility, and ecosystems health are compromised (Singh, 2017). Once established, a conventional farm requires constant maintenance but produces maximal yields. In general, conventional farming system is characterized by rapid technological innovation, large capital investments in equipment and technology, large-scale farms, single crops (monocultures); uniform high-yield hybrid crops, dependency on agribusiness, mechanization of farm work, and extensive use of pesticides, fertilizers, and herbicides. In the case of livestock, most production comes from systems where animals are highly concentrated and confined (Fisher, n.d.).

2.2 Overview of dairy in the European Union and the Netherlands

2.2.1 The Dairy sector in the European Union

The dairy sector is the second biggest agricultural sector in the EU, representing more than 12 % of total agricultural output. The Netherlands together with Germany, France, Poland, Italy and Ireland together account for almost 70% of EU milk production while organic milk production represents only a small share of the total production, around 3 per cent in 2016. In recent years, the EU dairy herd has been decreasing while the milk yield per cow has improved. In 2020, there were around 20 million cows in the EU, with an average of 7300 kg of milk produced per cow (European Commission, 2018).



Source: EUROSTAT 2020

Figure 2.2.1 Production and use of milk (million tonnes) In the EU

The EU has the common agricultural policy, which consists of a range of policy instruments designed to support farmers and address market imbalances. For instance, during the 2014 to 2016 crisis, which raw milk prices drop from around 40 to 25.7 cents per litre, the European Commission put forth a policy intervention which included public intervention-buying of excess milk, private storage and a range of exceptional measures which resulted to some recovery by 2017 (Augère-Granier, 2018). The European Union sees resilience and sustainability as key words for the future of the sector as they anticipate some challenges moving forward as articulated in the green deal.

The sector sees price volatility as a major challenge due to an end of milk quotas in 2015 which opened the sector up to global markets, making EU milk prices more susceptible to international price developments. Climate change perhaps poses a greater challenge and this was demonstrated during the 2018 'fodder crisis' as the hot and dry weather led to a lack of forage and grazing in several EU countries (Bas-defossez et al., 2019) where Bad grain harvests led to a rise in the price of the straw used to feed and bed the cattle which ultimately had an impact on farmers' incomes.

The dairy sector in the EU is highly specialised meaning that farm revenues are highly tied to a single output which increases farmers' vulnerability to income shocks. Mixed farms, with a more varied output, can be less vulnerable to such shocks and could help improve biodiversity in dairy farms which is part of EU's Biodiversity Strategy 2030 (European Union, 2020). Organic dairy production in the EU is largely concentrated in the EU-15. Between 2012 and 2017, the size of the organic dairy herd in the EU has increased annually by around 5.7% and the annual milk production by around 6.3 % with Austria, France and Germany, hold 51 % of the organic dairy cows in the EU (European Union, 2019).

All EU Member states show an increase in organic milk production, except for Poland and Estonia which show a decrease of production in 2017 of respectively 26 % and 41 % compared to 2012. Despite this increase, the share of organic milk in total milk production is still low, just below 3 % in the EU in 2017, but growing in most Member states.

2.2.2 The Dairy sector in the Netherlands

The Dutch dairy farmers have declined over the last 20 years, but the number of animals have increased during this period especially the category of smaller farmers with 50 cows or less, decreased with 75% between 2000 and 2017 (CBS, 2020). Due to continuous changes in regulation, and limited available land, Dutch dairy farmers are forced to invest in efficiency and intensity (Samson, et al, 2016). 64% of the dairy farms are located in Overijssel, Friesland, NoordBrabant and Gelderland. The Netherlands has 25 dairy processing companies, 86% of these regard cooperatives.

The largest cooperative being Friesland Campina, who holds 21 of the 53 processing plants (ZuivelNL, 2019). The raw milk is mostly processed into consumption milk, butter, cheese, or powdered products. About 65% of the dairy is exported, while 35% stays within the domestic market (NZO, 2018). The abolition of the milk quota system at the end of March 2015 gave a promising outlook for the Dutch dairy market which gave a boost to new investments aimed at capacity growth through modernization, expansion and new constructions (Zuivelnl, 2019). However, the strong growth in the sector resulted in the phosphate production ceiling to be set by the European Commission and on January 2018 the phosphate rights system went into effect.

Under pressure from these measures, the dairy herd has now been brought back to the level of around the time the quota system was abolished perhaps an indication that dairy sector needs to move towards a sustainability path. The Dutch dairy sector has been proud in leading the way in efficient and sustainable use of technology. For example, between 2012 and 2015 the sector saw a huge decrease in primary fuel consumption per kg of milk produced (60 a.e. per 1,000 kg of milk in 2015 (9 for milk processing (30%) and dairy farming (9%). This decrease was mainly the result of the use of sustainable electricity (Samson, et al, 2016).

There has also been an improvement in animal health and welfare especially in reducing the use of antibiotics. Between 2009 and 2015, the use of antibiotics in dairy farming dropped by 47%. In 2015, this goal was achieved with a 99% success rate (NZO, 2019). A baseline scenario exploring the pathways scenario for the Dutch dairy sector towards 2030 Indicate that the number of dairy farms in the Netherlands is expected to decline by 33 per cent, from 16,000 in 2018 to approximately 10,600 in 2030 while the total amount of milk produced will remain the same until 2024 and then increase slightly until 2030 (Alfons, et al, 2020)

2.3 Organic and conventional Dairy systems

2.3.1 Conventional Dairy Systems

Conventional dairy farming is characterized as dairy farming system that focuses on intense production to gain maximum profits (Cederberg & Mattsson, 2000). Haas, Wetterich & Köpke (2001) defines Conventional dairy farming as a farming system that generally aims to obtain the highest yield per cow. The farmer relies on external inputs such as synthetic fertilizers, pesticides, herbicides and antibiotics in order to be able to focus on short-term profits and control of risks. Over the years, farms have scaled up and intensified to keep up with the cost of labour and to provide a reasonable financial income for a farmer.

Because of the up scaling, the production of dairy per cow doubled to about 8000 kg per year and the production per hectare tripled to about 15.000 kg per year over the last 50 years. Furthermore, the average number of dairy cows per farm increased tenfold, to about 85, while the number of farms was reduced tenfold to about 18.000 (ONVZ, 2016). The environmental performance of conventional dairy farming is considered to be poor due to its significant biodiversity loss (Elsaesser, 2015). What is more, dairy farming largely contributes to water pollution through erosion, runoff and leakage of nutrients like nitrogen (N) which end up in surface waters and can cause eutrophication which leads to dead waters as a result of oxygen depletion (Carpenter, 1998).

Animal welfare is an issue that has come to the forefront within conventional dairy farming systems (Groot & van't Hooft, 2016). Animals tend to have a lack of space, are crowded, open floors, muddy fields, tight passages and sometimes too little feeding and drinking opportunities as a result of too much many cows on a small surface area. On the other hand, Thomassen et al. (2008) results showed that conventional milk used lower land per kilogram of milk compared with organic milk. Wagenberg et al. (2017) provided a systematic overview of differences between conventional and organic livestock production systems on a broad range of sustainability aspects and animal species available in peer-reviewed literature.

Conventional systems had lower labour requirements per unit product, lower income risk per animal, higher production per animal per time unit, higher reproduction numbers, lower feed conversion ratio, lower land use, generally lower acidification and eutrophication potential per unit product, equal or better udder health for cows and equal or lower microbiological contamination, perhaps an indication of how the conventional system can be efficient. Ellis et al. (2007) found that conventionally produced milk fat had a higher mean content of vitamin A than organically produced milk fat, although there were no significant differences in the vitamin E or β-carotene contents between the two types of milk fat.

2.3.2 Organic Dairy Systems

Most of the consumed dairy products from the Netherlands come from dairy cattle where there are approximately 16,000 organic dairy cows on 305 farms, with an average cow density of 1.77 per hectare (Skal, 2013). All organic farmers must get certified and monitored with the SKAL Foundation which is responsible for this. In terms of animal and farm management, some specific guidelines are provided by SKAL. Organic dairy production is characterized by allowing cows to have enough pastures to graze, a maximum of 1.77 large cattle unit per hectare and as much of the raw feed of an organic dairy farm as possible (at least 60%) should come from the farmer's own land (Skal, 2013).

An acquisition to a maximum of 10% of the current adult livestock is allowed although animals acquired should be organic, when the availability of organic animals is insufficient, female calves could be acquired with exemption. In this case, those calves should pass a conversion period of 6 months before they may calf. The minimum of stall room for organic dairy cows is usually 6 m2 (Skal, 2013). In organic dairy farming, preventive antibiotics are not allowed and antibiotics may not be administered to cows not more than three times per year (Skal, 2013). Organic dairy farmers are advised to raise rather strong cow breeds in order to ensure their cow's health condition.

Conventional breeding is currently allowed in organic dairy farming (Skal, 2013). However, these cows are not adequate enough to resist and fight the diseases without conventional treating (medicines and antibiotics) and as a result, breeding programme for organic dairy farming was initiated (BioVee, 2015). Organic milk could be said to be healthier than conventional milk on some aspects. Research by the Louis Bulk Institute has shown that organic milk contains more healthy fatty acids such as omega-3 and CLA, which both have positive effects on developing cancer, cardiovascular diseases and reducing eczema (Burgt & Hospers-Brands, 2009).

The possible cause brought up for this is the healthy, fresh diet that organic cows receive in the form of grass. In terms of climate change and environment, organic dairy farming emission of greenhouse gasses per ton of product is less than in conventional dairy farming (Task Force Marktontwikkeling en Biologische Landbouw, 2007b). Organic soil has better capabilities of storing water, which makes the soil more resistant in times of drought. In terms of animal welfare, Wagner et al. (2021) showed that organic farms scored higher in all of their four Welfare Quality® principles: of "Good Feeding", "Good Housing", "Good Health" and "Appropriate Behavior" compared to conventional farms.

3. Materials and Methodology

This chapter begins by the description of the data that will be used for this study. The second section gives a brief introduction and definition of efficiency and there is a follow up with a deeper explanation about the data envelopment analysis (DEA) Method and constructing the Meta frontier.

3.1 Data Description

The dataset used for this study will be obtained from the database published annually by the European Farm Accountancy Data Network (FADN). FADN started in 1965 and it consists of an annual survey carried out by the Member States of the European Union (EU). FADN is an instrument for evaluating the income of agricultural holdings and the impacts of the Common Agricultural Policy in the EU region. The aim of the network is to gather accountancy data from farms for the determination of incomes and business analysis of agricultural holdings. FADN thereby provides representative data along three dimensions: region, economic size and type of farming.

The system supplies data with different levels of aggregation focusing on the biggest commercial farms, which jointly in the given region or member state generate at least 90% of the standard gross margin (SGM). The total value of the SGM for each farm makes it possible to determine its economical size, which is expressed in European size units (ESU). In the FADN system, each region is represented by a certain set of average farms determined on the basis of a set of farms classified to a specific combination of type and economic size.

FADN, at present has sample data that cover about 80,000 holdings which represent an aggregation of about 6,400,000 farms in the EU-27 Member States. The sample covers approximately 90% of the total utilized agricultural area (UAA) and accounts for about 90% of the total agricultural production of the EU (FADN, 2010).The database contains farm level data, where the input and output data express with monetary units (€). The dataset is organized by yearly for every farm, so this makes the panel dataset (FADN, 2010). In this research organic and conventional dairy farms from the Netherlands will be selected.

Two outputs will be used in this model:

1. The revenues from cow's milk production (€)
2. Revenues from other outputs (€)

And five inputs was used in the model:

1. Capital (K) Value of total assets (€)
2. Labour (L) is measured in working hours (AWU)
3. Land (A) Agricultural utilized area in hectares (ha)
4. Inputs (M) Total material inputs (€)
5. Livestock (S) is measured in standardized livestock unit (LSU)

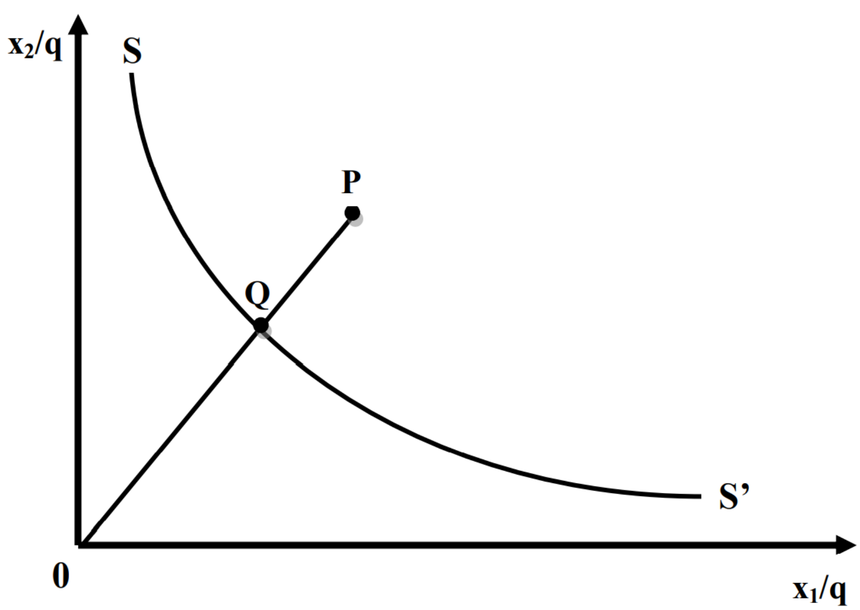
For the better estimation and to account for the dependence of revenues on inflation over time, the implicit quantities of the output revenues and the input costs in (€) are deflated with the Netherland's price indices for each category of variables, with prices obtained from EUROSTAT. Data analysis will be done using statistical analysis tool R.

3.2 Introduction to Efficiency

Efficiency in economics refers to as an outcome relative to a benchmark. For example, a farm producing 4.5 tons per hectare has an efficiency of 90% if the benchmark yield is 5.0 tons per hectare. Thus, an efficiency score of 90% means that the outcome is 10% points worse than the benchmark (Lakner et al 2017). The benchmark or the 'frontier' can be found by econometric estimation or mathematical programming based on all or a selection of sample farm.

Farell (1957) distinguishes output and input orientated measures depending on which factor we assume altering. In the output orientated measure, the measuring question is: By how much can output quantities be proportionally expanded without altering the input quantities used? (Coelli et. al. 2005). While in the input orientated measure which will be used in this research, we try to find out by how much the input quantities changes without changing the output quantities.

The assumed objective here is to reduce the input quantities as much as possible, without changing the output quantities. If the technology is characterized by constant returns to scale the two orientations produce the same technical efficiency score. Differences, however, appear under variable returns to scale.



Source: (Kovács, 2010)

Figure 3.1: Technical efficiency from an input orientation

To illustrate the input-orientated measure according to Farell (1957) and Coelli et. al. (2005) consider a firm with a single output (Y), under the assumption of constant returns to scale (which allows the technology to be represented using the unit isoquant) and using two inputs (x1 and x2) in Figure 3.1 above. The fully efficient (which is a theoretical frontier) firm represented by SS'. The firm defined by point P is inefficient. The technical efficiency of the firm is the ratio of 0Q and 0P. The efficiency score will lie between zero and one, and indicate the degree of technical inefficiency of the actual (P) firm.

Firm Q is technically efficient, because it is on the SS' isoquant: there is no reduction of inputs possible without reduction in output (Figure 3.1). For instance, if a firm's technical efficiency is 80% (the technical efficiency score is 0.8), that means 0Q line is 80 percent of the whole 0P line, thus the QP line is 20 percent of the whole 0P line, so firm P is 20 percent inefficient in that case comparing with firm Q (which is a fully efficient firm). Thus if we assume input-orientated technical efficiency of 80 percent for a farm, that means the farm can reduce inputs by 20 percent without changing output.

3.3 Data Envelopment Analysis (DEA)

In most cases, Non-parametric Method Data Envelopment Analysis (DEA) or Parametric Method Stochastic Frontier Analysis (SFA) are used. Both model approaches of Data Envelopment Analysis (DEA) or Parametric Method Stochastic Frontier Analysis (SFA), allow for the application of so-called 'metafrontier models' that formulate a frontier for a subgroup (e.g. organic dairy farms or conventional dairy farms) where a common frontier for both groups shall be used in this research.

The Data Envelopment Analysis (DEA) measures the relative efficiency of a farm in the presence of multiple inputs and outputs. It compares efficiency without knowing the production function, namely, without needing to know a functional relationship between inputs and outputs (Hormazábal and Wyngard 2007). The challenge with DEA is that it is deterministic (Begum et al. 2009) and its frontier does not account for measurement errors and other sources of statistical noise. Thus all deviations from the frontier are assumed to be the result of technical inefficiency (Coelli et. al. 2005).

The stochastic production frontier approach proposed by Aigner et al. (1977) assumes that total production deviates from the optimal production by a random noise and an inefficiency component. The stochastic frontier analysis (SFA) objective is the same as the DEA: to measure efficiency. Referring to Coelli et. al. 2005, the main advantages of this analysis over the DEA is that it accounts for the noise which provides DEA with one of its strengths in that it does not require any assumptions about the functional form.

Finding and comparing the technical efficiency of organic and conventional farms will be achieved by using Data Envelopment Analysis (DEA). This is due to DEA's advantages such as it does not require a prior specification of the functional form of the production function and distributional assumption of the inefficiency term. Furthermore, it can handle multiple outputs and inputs with each being stated in different units of measurement, and it generates a set of "peer" units with which a unit can be compared (Coelli et al., 2015). Also, the SFA models is usually more complicated than DEA.

DEA is a quantitative and analytical technique involving measuring and evaluating performance. This technique was first developed by Charnes et al. (1978) and it allows a researcher to evaluate the performance of individual DMUs taking only into account observed quantities of marketable inputs and outputs and does not require an assumption of a functional form relating inputs to outputs (Reig-Martínez et al., 2011). The framework for the Data Envelopment Analysis (DEA) approach was introduced by Farrell (1957) at first and popularized by Charnes, Cooper & Rhodes (1978).

In this research, the focus will be on the input oriented measures which also happened to be Farrell's original idea, which had an input-reducing focus. The first and widely applied model of the input orientated CRS models, solves the following linear programming problem for each firm to obtain the efficiency score:

$$\text{Max}_{u,v} \ (u'y_i / v'x_i),$$

$$\text{Constrains:} \quad u'y_j / v'x_j \leq 1, \qquad j=1, 2,..., N, \quad (1)$$

$$u,v \geq 0$$

Where regarding to Coelli et. al. (2005), assuming K inputs and M outputs for each N firms. For the i-th firms the column vectors are represented by x_i and y_i respectively. X indicate the K*M input matrix and Y shows the M*N output matrix for all N firms. To measure efficiency we want to obtain the measure of the ratio of all outputs over all inputs, like $u'y_i / v'x_i$ where u represents the M*1 vector of output weights and v represents the K*1 vector of input weights.

The obtained efficiency score will be less than or equal to one. There is one problem with this formulation, because it has an infinite number of solutions. Charnes, Cooper & Rhodes (1978) solved it by adding one constrain $v'x_i$ =1 and reformulate the objective function a bit, this form we known as the multiplier form of the DEA. Using the duality linear programming method from the multiplier formula the envelopment form can get, which is the following:

$$\text{Min}_{\theta\lambda} \ \theta,$$

$$\text{Constrains:} \quad -y_j + Y\lambda \geq 0, \qquad (2)$$

$$\theta x_i - X\lambda \geq$$

$$0, \lambda \geq 0,$$

Where λ represents the vector of peer weights. θ is a scalar and the value of it will be the efficiency score for the i-th firm, the value of 1 indicate the frontier and hence a technically efficient firm (but in practice it is not exist). This linear programming problem must be solved N times, once for each firm in the sample. Hence, each firm has its own θ efficiency score (Coelli et. al. 2005).The points of the fully efficient firms determine the fully efficient frontier line.

Regarding to the Eq. (2), takes the i-th firm and then seeks to radially contract the input vector, xi, as much as possible, while still remaining within the feasible input set. The inner boundary of this set is a piece-wise linear isoquant (refer Eq. (1)), determined by the observed data points which are the firms in the sample. The radial contraction of the input vector, xi, produces a projected point, (Yλ, Xλ), on the surface of this method. This projected point is a linear combination of these observed data points. The constraints in Eq. (2) ensure that this projected point cannot lie outside the feasible set (Coelli et. al. 2005).

The constant returns to scale assumption is acceptable if the firms in the sample are operating at an optimal scale, but in practice the firms with imperfect competition do not behave like that. Banker, Charnes and Cooper (1984) suggested a model which can deal with variable returns to scale (VRS) situation. This model is quite similar to the CRS model except by adding a convexity constraint ($N1'\lambda = 1$) to the model, which accounts for the variable returns to scale.

The model regarding to Banker, Charnes and Cooper (1984) and Coelli and Perelman (1996) presents an output oriented model, when the firms have fixed quantity of resources (capital, labour, livestock, land) and want to produce output (milk) as much as possible. This model is very similar to the input orientated model. So the formula of an output orientated VRS model is the following:

$$\text{Max } \phi\lambda\ \phi,$$

Constrains: $- \varphi\ y_j + Y\lambda \geq 0,$

$$x_i - X\lambda \geq 0, \qquad (3)$$

$$N1'\lambda = 1$$

$$\lambda \geq 0,$$

Where the N1 is an N*1 vector of ones moreover $1 \leq \varphi < \infty$ and φ-1 is the proportional increase in output that could be achieved by the i-th firm, with input quantities held constant. 1/ φ determine the technical efficiency score, which lies between zero and one. The DEA VRS formula envelopes the data points more tightly and provides higher or equal efficiency scores than the CRS model. The difference between the VRS and CRS technical efficiency scores is the scale inefficiency.

3.4 DEA Approach to Metafrontier

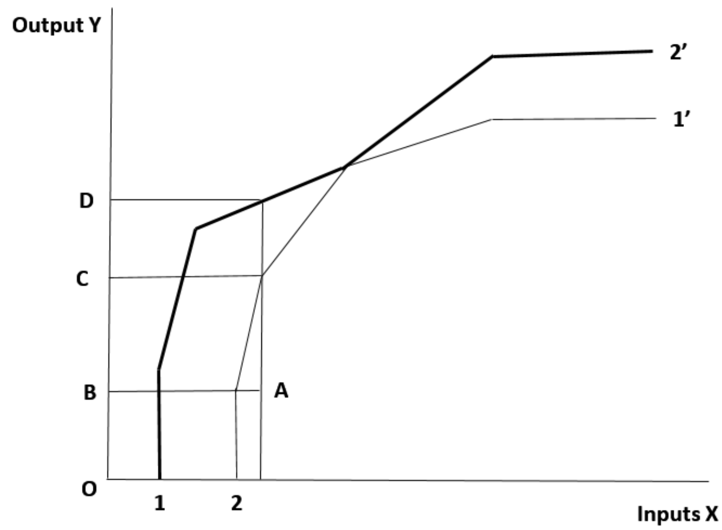
To assess the technology gap between organic and conventional technologies, the method originally proposed by Charnes et al. (1981) is used. The method relies on constructing a DEA metafrontier, that is to say a frontier enveloping the groups of observations whose technology differs, and comparing it with the respective frontier of each group, in order to identify technology gaps between each group's frontier and the enveloping metafrontier.

Since DEA allows to estimate the production frontier for a group of farms with similar production technology sets. O'Donnell et al. (2007) argued that the DEA method might sometimes lead to inaccurate results if the sample under consideration includes firms which belong to different environmental characteristics. This is because the efficiency frontiers for these firms might not be identical to provide an unbiased comparison. Hence, these firms should not be treated as one homogenous group.

To address this heterogeneity problem, and obtain comparable technical efficiencies for the two technologies in our sample, I will follow the meta-frontier approach (Hayani & Ruttan, 1971; Lansink et al., 2002; Battese et al., 2004; O'Donnell et al., 2008). In which figure 3.2 below shows the relationship among technology frontiers (11' and 22') curves representing the two technologies and the formed metafrontier. To find the efficiency score of all individual farm A, the linear programming problem of Equation (4) must be solved.

$$\begin{aligned}
&\underset{\emptyset,\lambda}{\text{Max}}\ \emptyset \\
&s.t \sum_{i=1} \lambda_j x_{mj} \leq x_m(A) \qquad m = 1, 2, \cdots, M \\
&\sum_{J=1} \lambda_j y_{nj} \leq \varphi\ y_n(A) \qquad n = 1, 2, \cdots, N \qquad (4) \\
&\sum_{j=1} \lambda_j = 1 \\
&\lambda_j \geq 0 \quad j = 1, 2, \cdots, J
\end{aligned}$$

Where the variables xmj and ynj indicate the amount of input (m = 1, 2, · · ·, M) and output (n = 1, 2, · · ·, N) for each farm (j = 1, 2, · · ·, J; A ∈ {1, 2, · · ·, J}), respectively. N, M, and J M, and J are the number of output variables, the number of input variables, and the number of farms used in the analysis, respectively.



Source: Adapted from Jin et al. (2020)

Figure 3.2 Illustration of Metafrontier

Figure 3.2 shows the relationship among technological frontiers (11', 22'), which form the metafrontier and the technological gap ratios. As a result, the technical efficiencies regarding to the Metafrontier are the creation of the technical efficiency in respect to the group frontier and the technological ratio for that technology (Rao, et al., 2003). The DEA metafrontier works to assess efficiencies of different firms that operate under different technologies.

To apply the metafrontier approach with DEA, it is necessary to solve separate models (Equation 3) for each firm in order to specify the technology-specific frontiers and one for the joint data set for solving the metafrontier. When the metafrontier envelops all group production frontiers, the efficiency can be decomposed into two components (Metafrontier efficiency TE* and technological frontier efficiency TE) and the ratio of these two can be called as meta-technology ratio or technological gap ratios (TGR).

$$\mathrm{TGR} = \frac{TE^*}{TE}$$

The TGR can be defined as: TGR=TE*/TE. The TGR measures the ratio of the output for the frontier production function for the k th group relative to the potential output that is defined by the metafrontier function, given the observed inputs (Battese & Rao, 2002; Battese et al., 2004). In the figure above, the technical efficiency of the observation A (inefficient farm because it is below the curve 22') with respect to the technology of 2 is equal to the ratio OB/OC and with respect to the Metatechnology is OC/OD.

Then the TGR for this observation is measured by OC/OD. The TGR has values between zero and one. The average technology ratios, in our case organic and conventional technologies are then compared; if they are different, it indicates a gap between both technologies, with the higher average revealing the more technical efficiency.

4. Results and Discussions

4.1 Basic statistics

Table 4.1: Averages for respective organic and conventional variables

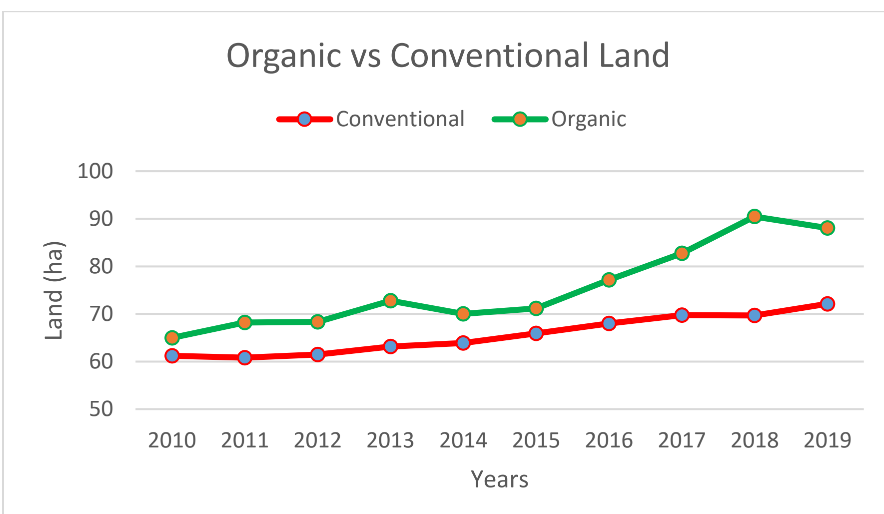
Variables	Observations (n)		Mean	
	Organic (323)	Conventional (3,372)	Organic	Conventional
Labor (AWU)			4,051	4,888
Land (ha)			75.53	65.58
Animal (LSU)			112.42	159.64
Capital (€)			41,230	54,883.1
Inputs (€)			132,475	220,484
Milk (€)			245,379	360,729
Other Output (€)			567.6	1,584

Source: Own calculation based of the FADN database 2010-2019

Table 4.1 above presents the average outputs and inputs for both organic and conventional dairy systems over the period studied of 2010 - 2019. When it comes to land usage, Organic dairy farms use more land compared to their conventional counterparts. On average, organic dairy uses about 76 ha compared to conventional 66 ha, with the largest organic dairy farm having 320 ha compared to conventional which had 284 ha.

The more usage of land by organic dairy can be attributed to the requirements by organic certification that animals must have enough pastures to graze, requiring a maximum of 1.77 large cattle unit per hectare (Skal, 2013) while with conventional, there is no such requirements and thus farmers can have as many animals as possible. This trend is also confirmed by Thomassen et al. (2008) who showed that conventional milk used lower land per kilogram of milk compared with organic milk.

Figure 4.1: An evolution of organic and conventional dairy farms land usage over the studied period

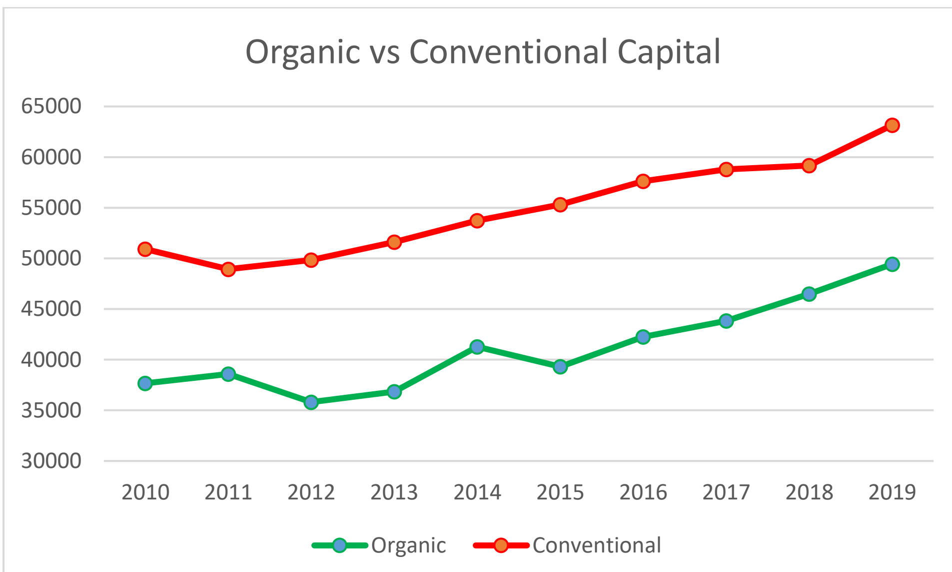


Source: own calculation based of the FADN database 2010-2019

On the other hand, conventional dairy system has more livestock, with an average of 160 (LSU) with the largest farm having up to 1,008 (LSU) compared to organic dairy systems which on average has 112 (LSU) with the largest farm having only 346 (LSU). The lower number of livestock's in organic dairy perhaps confirming Wagner at al. (2021) findings that showed organic dairy farms scoring higher in four Welfare Quality principles of ''Good Feeding", ''Good Housing", ''Good Health" and ''Appropriate Behavior" compared to conventional farms. This trend is also reflected on their labor usage where conventional dairy farms on average require more labor compared to organic farms.

For example, conventional farms on average use 4,888 (AWU) with the largest farm using up to 37,451 (AWU), organic on the other hand on average uses 4,051 (AWU) with the maximum labor usage being 14,190 (AWU). Looking at labor usage trends over the period studied, there is a slight increase in 2015 for both organic and conventional dairy systems which coincided with the end of the milk quota system in the European Union, perhaps signifying increased labor investments after the end of the milk quota system for an anticipation for increased milk production in the future.

Figure 4.2: An evolution of organic and conventional dairy farms capital usage over the studied period

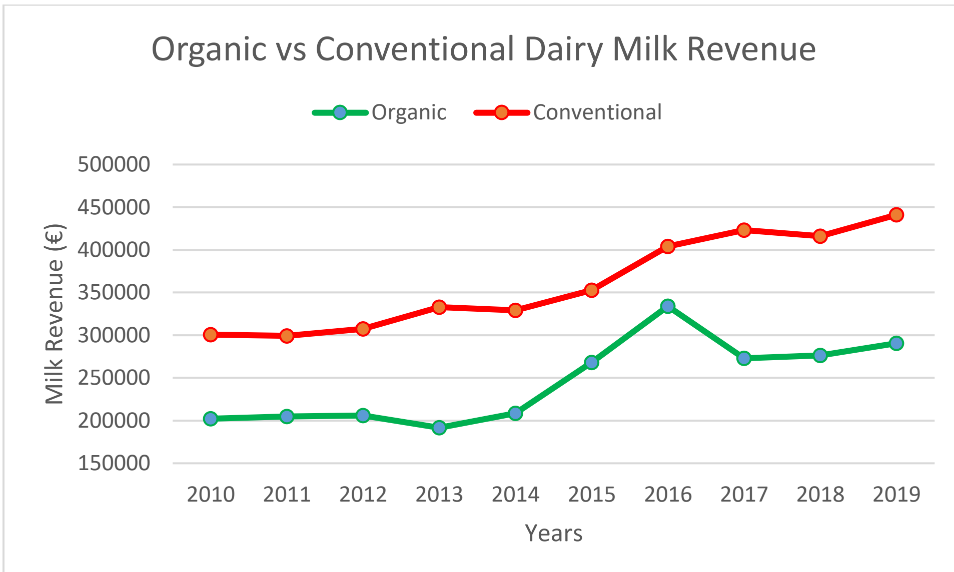


Source: own calculation based of the FADN database 2010-2019

Conventional dairy systems also on average require larger amount of capital investments compared to that of organic. On average, conventional dairy uses about 54,883 € compared to 41,230 € for organic dairy farms. This is also the case for inputs where conventional farms on average use about 220,484 € with the largest dairy farm using up to 2,217,549 € while organic on average uses 132,475 € with the largest organic farm using only 185,498 €. The maximum figures for conventional dairy systems demonstrating how intensive they can be. The capital investments over the years also demonstrates increased investments for both organic and conventional dairy systems after the milk quota was lifted in the European Union in 2015.

When it comes to milk revenues, conventional dairy farms have higher milk revenues compared to organic dairy farms producing up to 360,729 € while organic produces 245,379 €. Of interest is that milk revenues for conventional farms increased while that of organic reduced when the milk quota was removed. Perhaps indicating organic dairy farmers were not eager with the increased milk production that would follow in the market. The higher revenues is also the case for revenues from other outputs where on average conventional farms produces 1,548 € and organic produces 568 €. When you look at the minimum for both organic and conventional, they both loose some money with conventional losing the most with -17,804 € while organic loses -3,402 € perhaps indicating continued investments towards other outputs through the years.

Figure 4.3: An evolution of organic and conventional dairy farms milk revenue over the studied period



Source: own calculation based of the FADN database 2010-2019

4.2 Data Envelopment Analysis results.

4.2.1Technical and scale efficiency calculated under organic dairy farms

Table 4.2: Yearly technical and scale efficiency as averages for the studied period of 2010-2019; under organic dairy frontier.

Organic Dairy Farming Technical Efficiency Summary				
Year	**Observations**	**Crste**	**Vrste**	**Scale**
2010	33	0.71	0.80	0.90
2011	32	0.72	0.81	0.89
2012	31	0.68	0.78	0.88
2013	31	0.68	0.78	0.88
2014	30	0.76	0.83	0.92
2015	30	0.80	0.87	0.91
2016	29	0.84	0.89	0.95
2017	32	0.77	0.83	0.93
2018	32	0.76	0.83	0.92
2019	34	0.76	0.82	0.93

Average	**31**	**0.75**	**0.82**	**0.91**

Source: own calculation based of the FADN database 2010-2019

Note: crste = technical efficiency from CRS DEA; vrste = technical efficiency from VRS DEA;

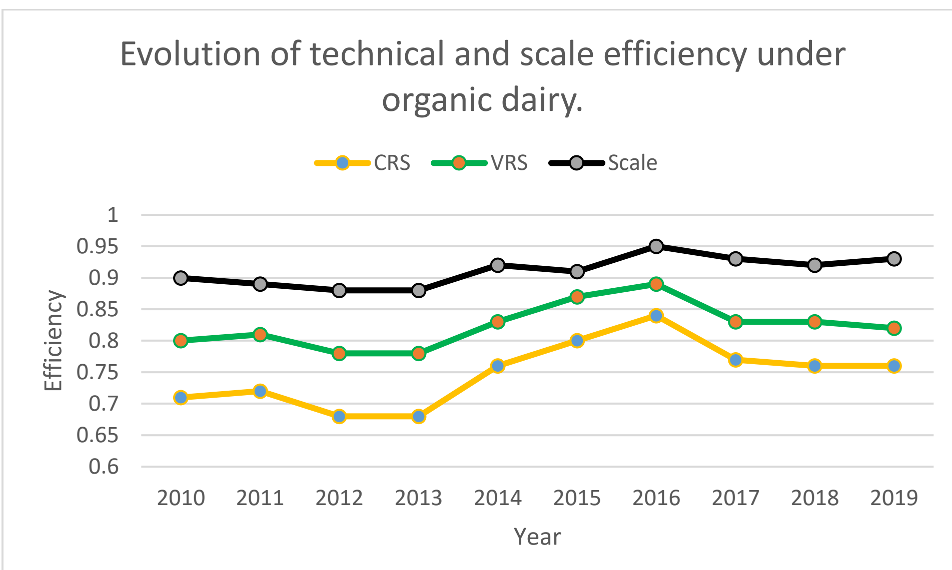
Scale = scale efficiency = crste/vrste

Table 4.2 above presents the technical efficiencies calculated for each year for organic dairy systems for the whole period of 2010-2019. The average total technical efficiency (i.e. under Crste) is 0.75 indicating that organic dairy farms are only 75% efficient in their own technology. In this case, they can reduce their inputs by 25% and still produce the same outputs. 2016 was the most efficient year with 84% while 2012 and 2013 were the least efficient years with 68% right at the height of the dairy crisis in Europe where prices fall below the cost of production and saw subsequent protests across Europe.

The average total technical efficiency (i.e. under Vrste) is 0.82 indicating that organic dairy farms are only 82% efficient on their own technology, where these farms can reduce their inputs by 18% and still produce the same. 2016 was the most efficient year at 89% while 2012 and 2 013 were the least efficient with 78%. The scale efficiency for organic dairy stood at 0.91. For the evolution of efficiency averages over the studied period, there was a steady increase in organic's efficiency from 2013 since the end of Europe's dairy crisis to the end of the milk quota in 2016 where there is visible decline in efficiency. Perhaps indicating the effect that policy change can have on efficiency of organic dairy farms.

According to Lakner, Sebastian & Breustedt, Gunnar. (2017) they found that on average, organic farms to be about 4% less efficient. However, in some single cases, organic farms can achieve the same level of efficiency (as in Breustedt et al., 2011) and in two studies that included environmental variables (Sipilainen and Huhtala 2013; Aldanondo-ochoa et al., 2014), organic farms achieve even a higher level of efficiency.

Figure 4.4: An evolution of Crste, Vrste and Scale efficiency for the studied period of 2010-2019 under organic dairy frontier.



Source: own calculation based of the FADN database 2010-2019

Since each year consumers are becoming more aware of the environmental challenges, the importance of healthy food and the fact that the standards and regulations in the environment, product quality, and social pressure on environmental performance in the European union are increasing, a favorable policy towards organic milk production which is strongly linked to permanent pastures, which deliver fodder, preserve soils, and do not destroy organic matter and organisms could be of great importance moving forward towards achieving those objectives. At 82% efficiency, organic can still improve its efficiency especially through policies than can support it in areas of R&D to increase the productivity of dairy technology given the organic standards.

4.2.2 Technical and scale efficiency calculated under conventional dairy farms

Table 3 below presents the technical efficiencies calculated for each year for conventional dairy systems for the whole period of 2010-2019. The average total technical efficiency (i.e. under CRS) is 0.68 indicating that conventional dairy farms are only 68% efficient. In this case, they can reduce their inputs by 32% and still produce the same. 2017 was the most efficient years with 73% while 2015 was the least efficient years with 61%.

Table 4.3: Yearly technical and scale efficiency as averages for the whole period 2010-2019; under conventional dairy frontier.

Conventional Dairy Farming Technical Efficiency Summary				
Year	**Observations**	**Crste**	**Vrste**	**Scale**
2010	338	0.70	0.77	0.91
2011	345	0.69	0.76	0.91
2012	337	0.63	0.71	0.89
2013	330	0.69	0.76	0.91
2014	319	0.69	0.76	0.91
2015	334	0.61	0.69	0.89
2016	346	0.62	0.69	0.89
2017	338	0.73	0.79	0.93
2018	344	0.69	0.76	0.91
2019	330	0.70	0.76	0.92
Average	**336**	**0.68**	**0.75**	**0.91**

Source: own calculation based of the FADN database 2010-2019

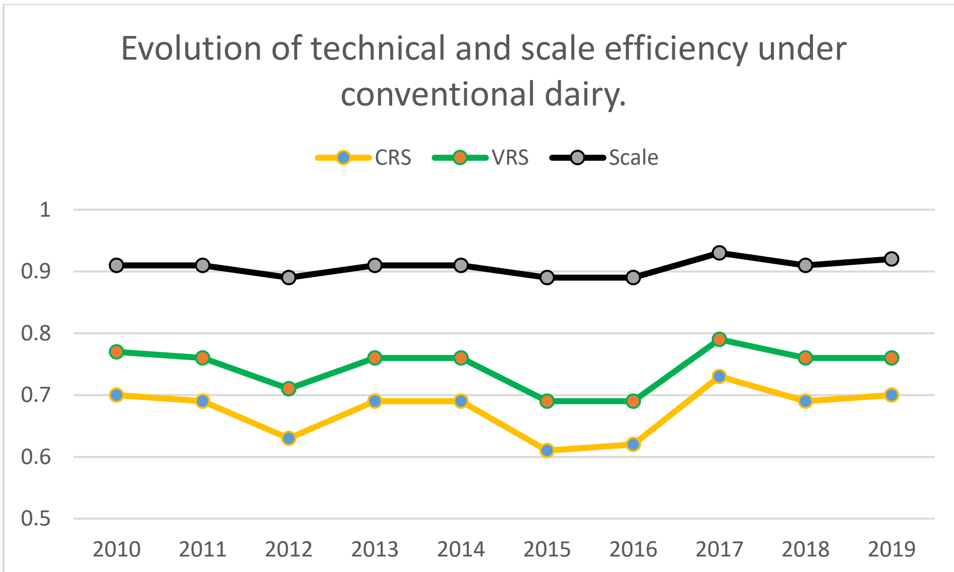
Note: crste = technical efficiency from CRS DEA; vrste = technical efficiency from VRS DEA;

Scale = scale efficiency = crste/vrste

The average total technical efficiency (i.e. under VRS) is 0.75 indicating that conventional dairy farms are only 75% efficient, where these farms can reduce their inputs by 25% and still produce the same. 2017 was the most efficient year at 79% while 2015 and 2016 were the least efficient with 69%. The scale efficiency for conventional dairy stood at 0.91 indicating that under conventional, the dairy farms will have an operational size efficiency of 91%.

For efficiency evolution over the period studied, there is visible decline in efficiency since the end of Europe's milk quota system in 2016. Perhaps due to large investments that were made in anticipation for increased production in the future, because for the following year we see efficiency significantly improved again. While the abolition of the quota system in 2015 that allowed an increase of milk production and efficiency, it also led to some environmental problems which lead to an increase of nitrogen and phosphate which saw the Dutch government introduce the so-called phosphate rights for dairy farms.

Figure 4.5: An evolution of Crste, Vrste and Scale efficiency under conventional dairy farms for the whole studied period of 2010-2019



Source: own calculation based of the FADN database 2010-2019

Regarding the performance related to each systems frontier, Organic dairy farms showed a better use of its technology than conventional farms with the total technical efficiency (i.e. under Vrste) of 0.82 while that of conventional dairy system total technical efficiency (i.e. under VRS) being 0.75. Representing a 7% difference in efficiency in respect to their own technologies. When it comes to scale efficiency, both systems have a similar scale efficiency of 0.91 indicating they would both have similar operational size efficiency.

Oude Lansink, and Pietola (2002) showed that, using data envelopment analysis (DEA) to compute overall technical and input specific technical efficiency measures, that organic crop and livestock farms in Finland did operate closer to their respective benchmark, but organic fall behind conventional farms regarding overall productivity. A result that seems to correspond to these result as well. They also suggest that the conventional technology has more potential regarding resource utilization, which could possibly be attributed to stricter regulation of organic farming.

4.3 Comparing the technical efficiency of organic and conventional dairy farms.

Comparing the technology for both organic and conventional dairy systems is done by merging both samples and calculating efficiency with this merged sample, i.e. under a common frontier. This allows for investigating which Dairy system has better efficiency, by calculating the efficiency ratio for each farming system. This measure is calculated as the ratio between the efficiency score calculated under the common frontier and the efficiency score calculated under the respective farming system's efficiency frontier (Charnes et al., 1981).

The average technology ratios for organic dairy farms and conventional dairy farms are then compared, the higher average indicating the dairy system with the better efficiency. Table 4.4 shows the averages of the technical and scale efficiency under the common frontier. The summary of the ratio is provided on table 4.5 but the full results for the ratio of each dairy system efficiencies are given in Appendix.

Table 4.4 Yearly technical and scale efficiency as averages for the whole period 2010-2019; under the common frontier.

Technical and scale efficiencies under the common frontier				
Year	**Observations**	**CRS**	**VRS**	**Scale**
2010	371	0.63	0.71	0.89
2011	377	0.63	0.71	0.89
2012	368	0.63	0.71	0.89
2013	361	0.63	0.71	0.89
2014	349	0.60	0.68	0.88
2015	364	0.61	0.69	0.88
2016	375	0.67	0.75	0.90
2017	370	0.68	0.75	0.91
2018	376	0.67	0.74	0.91
2019	364	0.68	0.74	0.91
Average	**368**	**0.64**	**0.72**	**0.89**

Source: own calculation based of the FADN database 2010-2019

Under the common frontier, the average total technical efficiency (i.e. under CRS) is 0.64 indicating that common frontier, the dairy farms are only 64% efficient. In this case, they can reduce their inputs by 36% and still produce the same. 2017 and 2018 was the most efficient years with 68% while 2014 was the least efficient years with 60%.

The average total technical efficiency (i.e. under VRS) is 0.72 indicating that common frontier, the dairy farms are only 72% efficient where these farms can reduce their inputs by 28% and still produce the same. 2016 and 2017 was the most efficient year at 75% while 2014 was the least efficient with 68%. The scale efficiency stood at 0.89 91 indicating that under the common frontier, the dairy farms will have an operational size efficiency of 91%.

Table 4.5: Crste, Vrste and Scale Efficiency Averages for respective efficiencies, common frontier and compared efficiencies for both organic and conventional dairy.

Common Frontier Efficiencies		**Respective Efficiencies for;**		**Ratio of Compared Efficiencies**	
		Organic	**Conventional**	**Organic**	**Conventional**
CRS	0.64	0.75	0.68	0.85	0.95
VRS	0.72	0.82	0.75	0.87	0.97
SE	0.89	0.91	0.91	0.98	0.98

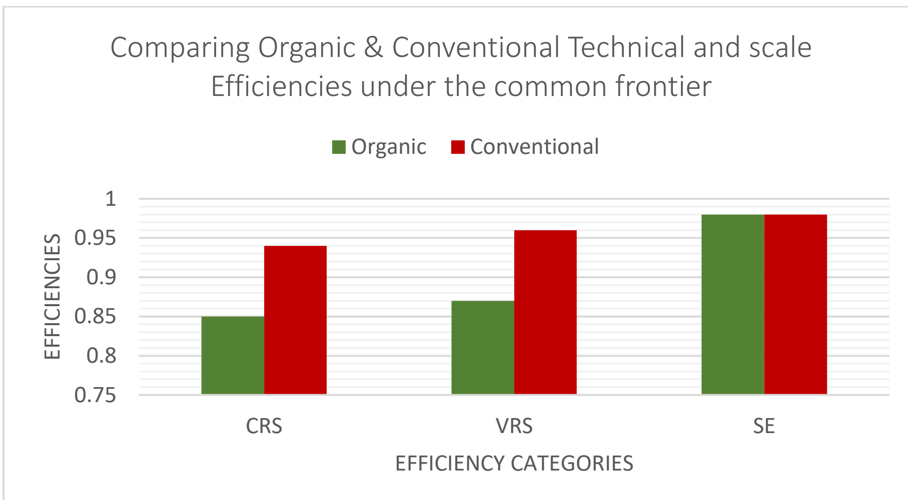
Source: own calculation based of the FADN database

Conventional dairy farms display a much higher average total and pure technical efficiency than organic dairy farms over the period studied; the average total technical efficiency (i.e. under CRS) is 0.95 for conventional farms and 0.85 for organic farms, which is a 10% range between the two dairy systems, suggesting that more conventional farms are on or closer to the efficient common frontier than organic farms.

For the average total technical efficiency (i.e. under VRS), Conventional stood at 0.97 compared to organic's 0.87, representing a 10% range between the two dairy systems as well. This result seems to be demonstrated by Mayen et al. (2010) as well where the results showed that the technology of organic dairy farms in the USA is 13% less productive than that of conventional technology. Guesmi et al. (2012) also found organic grape farms to be 12% less productive than conventional farms

When it comes to scale efficiency, organic and conventional dairy farms have similar efficiencies (0.98 vs. 0.98), suggesting that, if it is assumed that organic and conventional dairy farms have access to the same technology, conventional dairy farms would have better farming practices and better use of the technology while when it came to scale, they would both have similar operational size efficiency.

Figure 4.6: Comparison of organic and conventional technical and scale efficiencies calculated under a common frontier



Source: own calculation based of the FADN database 2010-2019

5. Conclusions and Recommendations

In this research we compared organic and conventional dairy farms technical efficiency in the Netherlands using the European Union's FADN database with data from 2010 to 2019. The number of dairy farms in the sample was a total of 3,395 observations with organic containing 323 observations while conventional contained 3,372 observations. The first step was to go through basic statistics to understand their usage of available inputs and outputs. The next step was measuring the efficiency with respect to all inputs and all outputs. The non-parametric DEA method was used in this research in measuring technical efficiency.

The DEA method measures the relative efficiency of a farm in the presence of multiple inputs and outputs Two outputs were used in this models, the revenues from cow's milk, revenues from other outputs and five inputs of land, livestock, labor, capital and inputs. For the better estimation to account for the dependence of revenues on inflation, the output revenues and the inputs were deflated with country-wide price indices for each category of products. To aggregate various variables, the Tornqvist price index was used.

From the results, we could observe that on average, conventional dairy farming system uses more labor, requires more capital, inputs, keeps more livestock, and produces more milk revenue and other outputs than the organic dairy system. Organic on the other hand does require more land, this is so because the conventional dairy farming practices can involve very large numbers of animals raised on limited land while in organic technology, this is not allowed.

In terms of efficiency, The average total technical efficiency for organic dairy farms (i.e. under VRS) is 0.82 indicating that organic dairy farms are only 82% efficient, where these farms can reduce their inputs by 18% and still produce the same. The end of the milk quota in 2016 saw a decline in efficiency, perhaps indicating the effect that policy change can have on efficiency. For conventional dairy farms, the average total technical efficiency (i.e. under VRS) is 0.75 indicating that conventional dairy farms are only 75% efficient, thus these farms can reduce their inputs by 25% and still produce the same.

The end of Europe's milk quota in 2016 also saw a visible decline in efficiency for conventional dairy systems as well Perhaps due to large investments that were made in anticipation for increased production in the future, the difference with organic being that the following year efficiency improved again. From the respective dairy system technology efficiencies, we can observe that organic dairy farms are more efficient on their own frontier with 82% efficiency compared to conventional dairies of 75% which implies that organic farms operate closer to their specific frontier than conventional farms. When it comes to scale efficiency, they both have a similar efficiency of 91% indicating the similarity of their operational size efficiency.

When a common frontier is used, The conventional dairy farms display a higher average total and pure technical efficiency than organic dairy farms over the period studied; the average total technical efficiency (i.e. under VRS) is 0.97 for conventional farms and 0.87 for organic farms, which is a 10% technical efficiency between the two dairy systems, suggesting that more conventional farms are on or closer to the efficient common frontier than organic farms.

When it comes to scale efficiency, organic and conventional dairy farms have similar efficiencies (0.98 vs. 0.98), suggesting that, if it is assumed that organic and conventional dairy farms have access to the same technology, conventional dairy farms would have better farming practices and better use of the technology but when it came to scale, they would both have similar operational size efficiency.

Apart from adding to the literature in this topic, this results can be a good guide for public policies in the Netherlands especially as they work towards achieving the target of getting to 25% organic land by 2030. Since scaling up organic farming is often considered as a promising option for a more sustainable food system (Reganold and Wachter 2016) and since organic also contains among other benefits increased biodiversity and improved animal welfare, supporting organic dairy farmers through friendly policies could contribute to achieving the 25% organic land target set by the European union to its member states, in this case the Netherlands.

Both organic and conventional dairy farmers should be supported to improve their respective technologies technical efficiencies. Supporting organic farming and farmers for example, through R&D could spur organic innovations that could eventually increase their efficiency of 82% given the organic technology through increasing the productivity of organic dairy technology using organic standards. On the other hand, conventional dairy farms can also be supported through policy such as providing farmers with subsidies to invest in more efficient technologies such as Precision Livestock Farming (PLF) to help them improve their efficiency of 75%.

Since most of the efficiency models comparing organic and conventional farming do not include environmental variable, Future studies could consider including this. As part of their study, Kantelhardt et al. (2009) investigated the technical and environmental efficiency of 102 farms participating in different agri-environmental programs (AEP) and found that organic farms seem to be quite successful in combining environmental and economic efficiency.

Aldanondo-ochoa et al. (2014) also investigated the environmental efficiency of eighty-three organic and conventional vineyards where they included environmental variables of nitrogen surplus and potential toxicity of pesticides. The results showed a significantly higher environmental efficiency of organic vineyards with respect to their own frontier and also to the joint metafrontier (0.784 vs. 0.559). While environmental efficiency is interesting it's also data-demanding method. That's why there are only a few studies using this methodology.

In some of the studies, the number of observations is too low to draw general conclusions for e.g. the organic sector as a whole. The evidence is often restricted to a specific farm-type, to a specific region or to a specific research question (participants of environmental schemes). There is a slight trend that organic farms perform better than conventional farms, if environmental variables are included in the model. Thus more research is necessary to verify or falsify this trend. Technical Efficiency in the Conversion Period could also be interesting to study. Lohr and Park (2006) found that organic farms with more than five years' experience in organic farming to be more technically efficient than those who have just converted. A study by Nastis et al. (2012) also found that experienced organic alfalfa producers in Greece (with more than two years' experience) to be more technically efficient.

It would also be worthwhile to extend the analysis in order to be able to formulate precise and informed policies. By incorporating quantity and price data, we could decompose the changes in efficiency into price changes and technical efficiency changes. This would enable us to identify underlying changes in the technologies which could yield additional insights. Unfortunately these analyses needs more time and also requires complicated model to estimate the frontiers. The use of other methods to measure efficiencies like the total factor productivity (TFP) indexes could also provide better insights.

As with most numerical methods generally, the main limitations of DEA arise from failure of the assumptions. Random noise, measurement error, or outliers are normal in data. It is not simply appropriate to assume that an outlier is also a best practice. In DEA, the random impacts on the observations are treated as real and deterministic where few observations may heavily influence the level of the frontier.

One of the ways that this limitations can be dealt with is to compare the consequences deduced from a model with phenomena in reality. Any judgment on the quality of a DEA model must be made in the light of the purposes for which the results are used. While in DEA You can impose assumptions, the DEA method does not have to specify a relationship between the inputs and the outputs of the decision-making units. It only requires that input and output combinations are known for each unit.

The DEA method assumes that there is no random noise, measurement error, or outlier cases in the data and that the data used to represent inputs and outputs are correctly known, and it does not matter how many variables are needed. In DEA, there are no unique outputs or inputs. Correspondingly, if an output or input is zero, it has no significant effect on the measurement of the efficiency of a unit.

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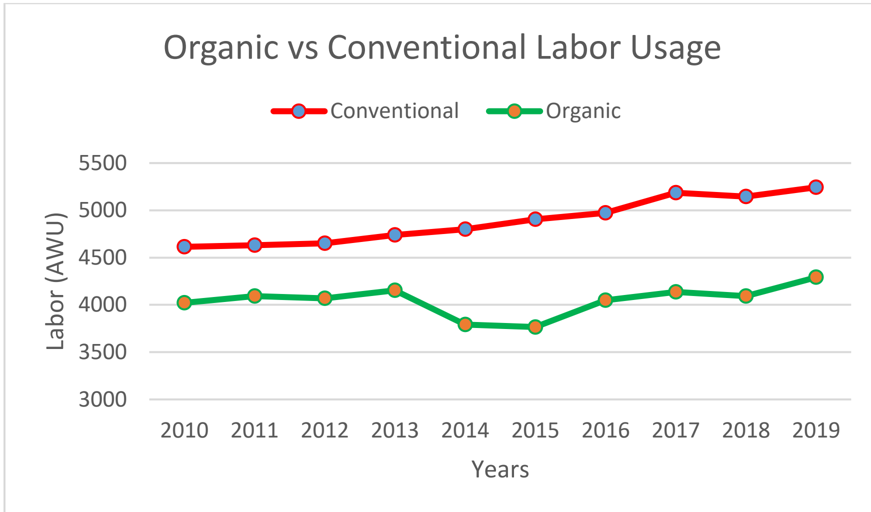
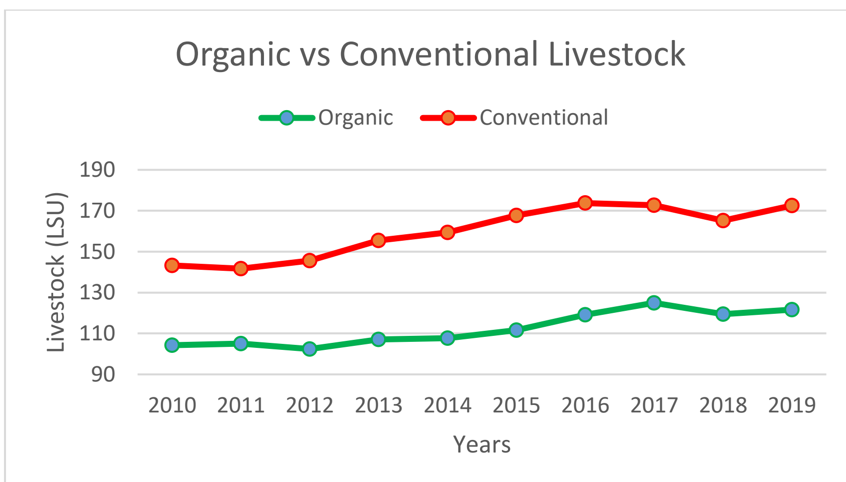
7. Appendix

Figure 4.7: An evolution of organic and conventional dairy farms labor usage over the studied period



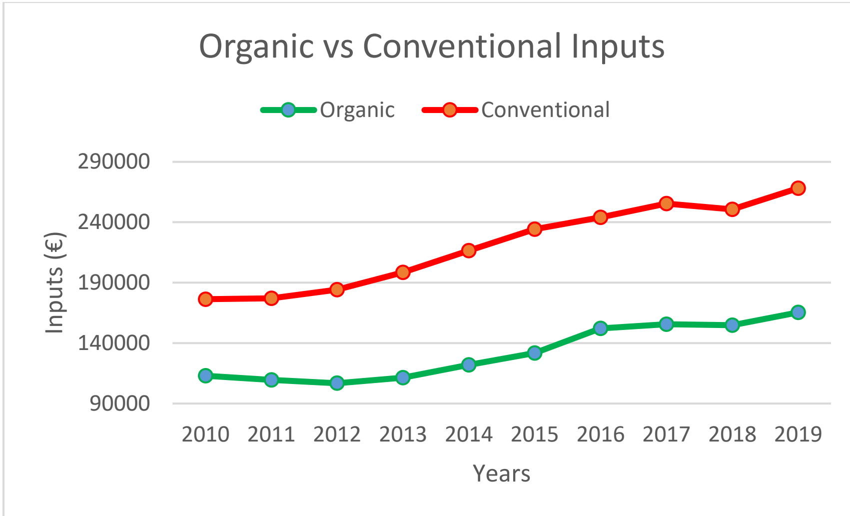
Source: own calculation based of the FADN database 2010-2019

Figure 4.8: An evolution of organic and conventional dairy farms Livestock kept over the studied period



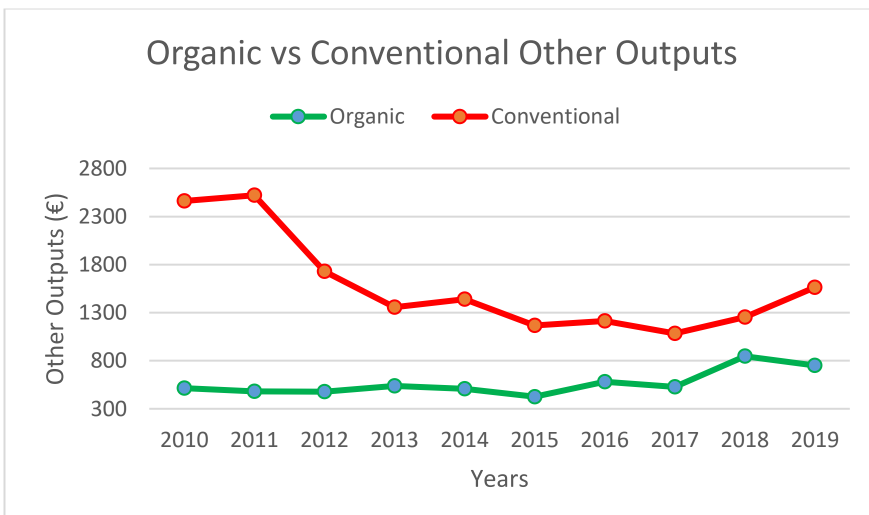
Source: own calculation based of the FADN database 2010-2019

Figure 4.9: An evolution of organic and conventional dairy farms Inputs usage over the studied period



Source: own calculation based of the FADN database 2010-2019

Figure 4.10: An evolution of organic and conventional dairy farms other output revenues over the studied period



Source: own calculation based of the FADN database 2010-2019

Table 4.5: The ration of Organic dairy farms with common frontier representing yearly technical and scale efficiency as averages for the whole period 2010-2019.

Ratio of Organic dairy farms with common frontier Technical and scale Efficiency				
Year	**Observations**	**CRS**	**VRS**	**Scale**
2010	371	0.88	0.89	0.98
2011	377	0.87	0.88	0.98
2012	368	0.91	0.90	0.99
2013	361	0.92	0.91	0.99
2014	349	0.78	0.82	0.95
2015	364	0.76	0.79	0.96
2016	375	0.79	0.83	0.95
2017	370	0.87	0.89	0.98
2018	376	0.88	0.89	0.98
2019	364	0.88	0.90	0.99
Average	**368**	**0.85**	**0.87**	**0.98**

Source: own calculation based of the FADN database 2010-2019

Table 4.6: The ration of conventional dairy farms with common frontier representing yearly technical and scale efficiency as averages for the whole period 2010-2019.

Ratio of Conventional dairy farms with common frontier Technical & Scale Efficiency				
Year	**Observations**	**CRS**	**VRS**	**Scale**
2010	371	0.89	0.92	0.97
2011	377	0.91	0.93	0.98
2012	368	0.99	0.99	0.99
2013	361	0.90	0.93	0.97
2014	349	0.85	0.89	0.96
2015	364	0.99	0.98	0.98
2016	375	0.98	0.99	0.99
2017	370	0.93	0.94	0.98
2018	376	0.97	0.98	0.99
2019	364	0.96	0.97	0.98
Average	**368**	**0.95**	**0.97**	**0.98**

Source: own calculation based of the FADN database 2010-2019