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Impact of milk quota abolishment on Dutch dairy processing industry's profitability: nonparametric approach of Färe-Primont index decomposition

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Impact of milk quota abolishment on Dutch dairy processing industry's profitability: nonparametric approach of Färe-Primont index decomposition

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ABSTRACT

This thesis evaluates the impact of milk quota abolishment on Dutch dairy processing industry's profitability. Panel data from 8 dairy processors were analysed using a nonparametric approach, Data Envelopment Analysis (DEA) to decompose Färe-Primont profitability and productivity index. Components of indices were measured from 2009 to 2017. Overall results demonstrated a regress in profitability due to severe unfavourable terms of trade, although there was significant productivity growth. After milk quota had been abolished, the profitability index decreased below 1, indicating a profitability deterioration. Any gains in productivity change were lost to the highly negative terms of trade on profitability. Improved productivity was mainly attributed to gains in technical change, whereas efficiency changes remained constant, the exception being the period 2015-2016. Technical efficiency and residual mix efficiency changes were the primary sources of efficiency change over the study period.

Keywords: Dairy processing, Färe-Primont Index, Data Envelopment Analysis, profitability, productivity, technical change, efficiency change

SUMMARY

The Netherlands is a dairy country with a long tradition of milk, butter and cheese production and consumption, whose dairy sector contributes to 16% of agriculture and food economy. Plus, imports and exports of dairy products account for more than 7% of total trade in 2019. The introduction of a milk quota system in 1984 for the whole of Europe symbolised the beginning of limitations on dairy farmers who strove to increase farm scales in order to improve productivity. In response to the limits imposed on milk volumes, the Dutch dairy industry made more considerable efforts to become one of the most consolidated dairy industries in the world. Furthermore, the abolition of the milk quota system at the end of March 2015 marked the start of a new phase in the development of the dairy sector.

This thesis aims to evaluate the impact of milk quota abolishment on Dutch dairy processing industry's profitability change throughout 2009-2017. DEA was used as an empirical approach while Färe-Primont index was used as a theoretical framework to decompose profitability and productivity index and further analyse their exhaustive components. In order to achieve the objective of this research, financial data including operating revenue, fixed costs, material costs and employment costs were collected from both Orbis database and company websites, which were analysed using Productivity package in R.

The overall results indicated that the Dutch dairy processing industry suffered a profitability deterioration in 2017 (0.856) compared to 2009 due to the severe unfavourable terms of trade change (-51.5%) during the study period. In contrast, total factor productivity index held a constant larger than one value, which accounted for over 76.6% productivity growth in 2017. Notably, there was more than 8.387% productivity increase within one year after the abolished quota system. The main contributor to productivity growth was technological progress. Comparably, overall efficiency changes were stagnated over the whole period. The study observed that there was a growth in technical efficiency change (+6.4%) and regresses on scale efficiency (0.991) and residual mix efficiency (0.952) in 2017. It indicated that dairy processors in the sample could operate with improved efficiency but not on an optimal scale. Furthermore, they failed to change their inputs mix to become more efficient.

This study found that cooperatives in the sample were generally not profitable when compared with investor-owned firms. Considering the mission and objectives of dairy cooperatives, it is not surprising to see a profitability regress in cooperatives over the study period. It was also observed that investor-owned firms were overall more productive than cooperatives, which was due to their relatively substantial technical efficiency changes and residual mix efficiency changes under the same existing technology in the industry. Moreover, it is worth mentioning that cooperatives gained benefits of scale efficiency, indicating that they comparable worked at an efficient scale. To conclude and give recommendations, expanding capacities of dairy processors are required to handle extra delivered milk. More R&D funding is necessary to innovate technology in the dairy processing industry. In case of governmental support and policy applications, it is crucial to stay alert and take the company's situation into account.

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ABBREVIATIONS

CAP	Common Agricultural Policy
CMO	Common Market Organization
COOP	Cooperative
CPI	Consumer Price Index
CRS	Constant Return to Scale
DEA	Data Envelopment Analysis
EC	European Commission
EU	European Union
Eurostat	European Statistics
IOF	Investor-Owned Firm
ITQ	Individual Transferable Quota
LCI	Labour Cost Index
LP	Linear Programming
MP	Technical Change
OSE	Output-orientated Scale Efficiency
OTE	Output-orientated Technical Efficiency
PPRD	Phosphate Production Reduction Decree
PROF	Profitability
R&D	Research and Development
RME	Residual Mix Efficiency
SFA	Stochastic Frontier Approach
SMP	Skimmed Milk Powder
SPF	Stochastic Production Frontier
TAC	Total Allowable Catches
TFP	Total Factor Productivity
TFPE	Technical efficiency changes
TT	Terms of Trade
VRS	Variable Return to Scale
WMP	Whole Milk Powder

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1 INTRODUCTION

This chapter introduces the background and then presents the research problem, objective and questions. Research outlines are shown after that.

1.1 Background

The European dairy sector, as a net exporter of most dairy products, had suffered a decline in productivity because of the milk quota system (Jongeneel & from Berkum, 2015). The existence of quotas curbed the productivity improvement in dairy farming, which in return may lead to an extra accelerated boost to the development of efficiency (Madau, Furesi, & Pulina, 2017). However, on average, milk farms showed a small scope for improving efficiency with their technical input among 22 European countries (Madau, Furesi, & Pulina, 2017). In 2008 the European Union announced it would remove the milk quota system which was used to restrict the maximum amount of milk delivered to processors and the maximum amount of direct sales at the farm level. In order to allow for a "soft landing" of the dairy sector, the Commission proposed to increase quotas by 1 per cent annually between 2009 and 2013 in all Member States except Italy. Italy would get full 5 per cent immediately because of chronic overproduction (JRC, 2009).

After 30 years execution of milk quotas, this system had been officially ended in April 2015 because milk production surpluses were no longer a problem for EU by the 2000s when there was an increasing global consumption of dairy products (Commission, 2015). European dairy sector witnessed a rapid increase in milk production. Between April 2015 and March 2016, total EU milk deliveries were 4 per cent higher than the same period a year earlier. The top 4 fastest growth in milk deliver countries were Ireland (18%), Luxemburg (14%), Belgium (12%) and the Netherlands (12%) (Commission, 2016). In the Netherlands, more than 1 billion kg of extra milk was produced in 2016 compared to 2015, and an estimated 14 billion kg of milk were processed with an over 5% increase (ZuivelNL, 2016).

EU dairy sector is facing a policy and market change. Meanwhile, this change affects the Dutch dairy industry. This effect is twofold: on the one land, Dutch structural adjustment has been slowed down characterised by a decreasing number of farms with a continual increase in scale, and a long-term period of few cooperatives dominating the dairy processing sector. The number of dairy farms was reduced by 40% to a level of 17,500 in 2016 and 17,000 in 2017. Since 2000 an average of 97 dairy cows per dairy farm was observed (Jongeneel, Daatselaar, van Leeuwen, & Silvis, 2017). Dairy cooperatives have taken charge of processing milk for more than 130 years in the industry (Bijman, 2018). Five of the total 25 dairy processing companies are cooperatives occupying over 80% of the total market share since the 1950s (ZuivelNL, 2017). On the other hand, although abandoning milk quota system aligned the EU milk production more closely to the world market's demand, the occurred simultaneous low dairy prices with high volatility would put much pressure on dairy producers and processors (EU, 2018).

1.2 Research problem

It is essential to measure efficiency and productivity due to a few issues addressed by (Fried, Lovell, & Schmidt, 2008). First of all, efficiency and productivity scores can be used as indicators to evaluate the company's economic performance which is vital information for business managers and investors to know how companies perform in the market especially under the changing and volatile market condition. Considering market liberalisation, unstable product prices, changing customer preferences and increasing business internationalisation could all cause severe impacts on firms' profitability (Cummins & Weiss, 2013; Andries, 2011), it is necessary for no matter public institutions or private companies to identify the sources of efficiency or/and productivity to improve profitability with specific targets. The benefits of efficiency and productivity analysis are far-reaching. Firm managers can have a clear picture of how well production inputs are being transformed into outputs given the current production technology. It also allows researchers to give policymakers and firms appropriate and concrete advice considering policy implications and business improvements in the various business environment (Jaraitė & Di Maria, 2012).

However, although the expected and real impacts of milk quota abolishment on EU dairy sector were well addressed, there was no or limited research on Dutch dairy processing industry in case of profitability change and its exhaustive decomposition concerning productivity and efficiency change. Wageningen Economic Research had carried out some background analyses of sectoral and market structure and economic consequences after milk quota system (Jongeneel, Daatselaar, van Leeuwen, & Silvis, 2017; Jongeneel, Silvis, Daatselaar, & van Everdingen, 2017; Klootwijk, Van Middelaar, Berentsen, & De Boer, 2016). Besides, the research from (Soboh, Lansink, & Van Dijk, 2014) compared the technical efficiency and production frontier of dairy processing cooperatives with investor-owned firms in six major dairy producing European countries by using accountancy data from 1995 to 2005. It is evident to conclude the necessity of evaluating the impact of milk quota abolishment on Dutch dairy processing industry's profitability after 2015.

Addressing the farm-level efficiency and productivity, research from (Corbett, 1992; Alvarez, Arias, & Orea, 2006) showed farms were not productive and relatively less efficient under the milk quota policy. The market became liberalised after removing the milk quota system. Farmers tended to produce more to meet increasing global demand and boost profit. Therefore, the productivity on the farm level would be improved (Madau, Furesi, & Pulina, 2017). Considering this study focuses on dairy processors which are the next sector on the dairy supply chain, what I expect is that in the Dutch dairy processing industry, the productivity has increased after quota abolishment which contributed to the growth of profitability. Milk quotas limited the maximum amount of milk delivered from farms to processors. Dairy processing sector received more milk to produce dairy products when there was no limit on milk production. According to (O'Donnell C. , 2008), profitability change is the product of productivity change and terms of trade change. To tackle the low market price for dairy products, processors could increase their productivity to improve profitability. Therefore, the study aims to investigate whether there is increased productivity and profitability change after milk quota abolishment by applying Färe-Primont profitability and productivity index with the DEA approach.

1.3 Research objective and research questions

The objective of this research is to evaluate the impact of milk quota abolishment on the profitability change of Dutch dairy processing industry by determining productivity change and terms of trade change during 2009 and 2017. Total factor productivity index is decomposed further to investigate technical change and efficiency changes. The following main research question and sub-questions are answered to achieve the research objective:

Main research question:

What is the impact of milk quota abolishment on Dutch dairy processors' profitability?

Sub research questions:

1) What has changed after removing milk quotas in Dutch dairy processing industry?
2) What is the productivity change in Dutch dairy processing industry?
3) What are the terms of trade changes in Dutch dairy processing industry?
4) What are technical change and efficiency changes in Dutch dairy processing industry?

1.4 Research outlines

The remaining part of the report is structured as follows. Chapter 2 conducts a literature review to present a theoretical background on policy changes in the dairy industry and the impacts of milk quota abolishment on the Dutch dairy processing industry. Other forms of market liberalisation on the other industries are also reviewed to understand the effect of policy change on industry's profitability, productivity and efficiency change. The final section of Chapter 2 presents the expectations on Dutch dairy processing sector's profitability and productivity change. Chapter 3 describes the methods by firstly introducing the theoretical framework of Färe-Primont profitability and productivity index and then the empirical approach of DEA. This chapter also provides a description of sample size and data, including output and inputs that are selected in the dataset. Chapter 4 presents both overall results and exhaustive firm-based results of profitability index, total factor productivity index and their decompositions. The evolutions of annual indices are illustrated in figures. Chapter 5 discusses the main findings and methods used in the study. Finally, the report is concluded with Chapter 6 of conclusions and recommendations. Extra information relevant to this research is put into Appendices.

2 LITERATURE REVIEW

This chapter starts to introduce the history of CAP and its reform, milk quota system. New manure policy after the removal of the milk quotas is considered in section 2.2. Then section 2.3 illustrates the impacts on the Dutch processing industry and other industries due to trade liberalisation. Expectations of this study are shown in the last section.

2.1 The history of CAP and the milk quota system

The Common Agricultural Policy (CAP) represents the agricultural and rural policy of the EU. It was firstly introduced in 1962 after the Second World War with 5 objectives: to increase agricultural productivity, to achieve a fair standard of living for the agricultural population, to stabilize prices, to ensure self-sufficiency in food products and to offer reasonable prices to the consumers (Ackrill, Kay, & Morgan, 2008). For these purposes, the CAP built a price floor to ensure that farmers would get a minimum price for their products, which were between 50% and 100% higher than the world market prices. Due to the CAP, production among EU farmers increased dramatically in the 1960s and 70s. With the supply went up, the EU had to buy all the surplus products at the internal price accounting for approximately 40% of the EU budget. To tackle the oversupply, some food was sold in the world market at subsidised prices. This caused the supply of food on the world market went up, and prices went down, which put damage on the natural exporters of the subsided goods (Baldwin & Wyplosz, 2015). All in all, the reforms of the CAP were required to become more market-orientated and competitive. The EU in 2008 undergone a review as known by “Health Check” to push the market orientation of the CAP even further to focus on the dairy sector, which indeed brought the issue of milk quotas (Persson, 2017).

In the EU dairy sector, the price paid to the dairy farmers was significantly higher than the price on the world market as many other products. With a higher income guaranteed, farmers were capable of upgrading the production techniques to increase further the output volume, which triggered the milk oversupply problem. As a way of limiting milk production and stabilising the milk prices, the EU milk quota system was initially introduced in 1984. The Member States had two limits to deal with: the maximum amount of milk delivered to dairies and the maximum amount sold at farm level. For example, if the amount of delivered milk exceeded the quota levels, farmers were obliged to pay a hefty levy (Marquer, 2015). Initially, the quota was intended to only implement for five years. Under the condition that it was not restrictive enough to reduce the oversupply, the further tightening was required during the 1980s and 90s. The quotas were successful in solving the oversupply problem. The production of milk among the EU Member States never reached the 1980s level again (Binfield, 2009). As decided by the Commission, milk quotas were officially abolished on April 1, 2015. The main reason to abolish the quotas is to make the EU dairy policy more market-orientated in response to the increasing global demand for milk and agreements on trade liberalisation in global dairy markets (EU, 2015).

Most importantly, it had become clear that, over the years, the milk quota system had been distorted the market and maintained the milk production in less competitive regions. Before the abolishment milk quota, there were gradual quota increases in some regions because of lower productivity among dairy farmers. To prepare a "soft landing" for the milk sector, the Commission in the Health Check agreement proposed to increase the quotas by 1% annually among the Member States except for Italy between 2009 and 2013. Because of the chronic overproduction, Italy got their full 5% immediately. Therefore, from 1 April 2013, the quota levels were held constant until the expiration date of the system (JRC, 2009).

2.2 New manure policy after milk quota abolition in the Netherlands

The abolished milk quota system allows farmers to increase milk production. In most EU countries, milk production increases variably. In the Netherlands, a growth of more than 7% was observed in 2016 compared with 2015 (ZuivelNL, 2016). Due to the proximity to the harbour of Rotterdam to import the feed and the central location of the Netherlands in western Europe whose demand for livestock products is high, livestock density in the Netherlands is the highest in Europe. The high livestock density results in high manure excretion of nitrogen and phosphate per hectare, causing severe environmental problems like eutrophication of ground and surface water (Oenema & Berentsen, 2004). The Netherlands has a phosphate production ceiling of 172.9 million kg/yr for the entire Dutch livestock sector. Of this total amount, 84.9 million kg/yr is allocated to the dairy sector based on production level in 2002. However, this limit was overstepped by 0.7 million kg of phosphates. To restrict the further growth because of abolished milk quota, the Dutch government introduced a new manure policy, "Dairy Act" and implemented in 2014 to support the growth of the Dutch dairy sector and restrain the increases in phosphate production at the same time (Klootwijk, Van Middelaar, Berentsen, & De Boer, 2016).

In 2015, phosphate production from the dairy sector was 92.9 million kg. The national phosphate production increased to 180.1 million kg, which was more than 4 per cent over the national phosphate ceiling. To make the Netherlands conform to the national phosphate ceiling by 2017, the Dutch government and the dairy sector have developed a package of measures which contains the Phosphate Production Reduction Decree (PPRD). The PPR plan of ZuivelNL was initially a plan for the private sector based on agreements between milk processors and farmers. The decree aims to achieve an agreed protocol between all involved farmers and processors (Jongeneel, Daatselaar, van Leeuwen, & Silvis, 2017).

2.3 Impacts of abolishing milk quotas in the Dutch dairy processing industry

On behalf of responding to the limits imposed on milk volumes, the Dutch dairy industry makes a greater effort to create itself one of the most consolidated dairy industries in the world. Since the abolition of the milk quota system, promising developments on the global dairy markets have been boosted new growth in the industry (ZuivelNL, 2016). This chapter aims to present four specific impacts mainly include the production volume and prices changes of dairy products, export and import, and also structural change on the Dutch dairy processing sector specifically.

2.3.1 Milk deliveries and processed amount of dairy products

There was 7.5% more milk delivered to the Dutch dairy factories in 2016 compared to 2015 (ZuivelNL, 2016). This amount slightly decreased (-0.2%) in 2017 (ZuivelNL, 2017). The dairy industry had processed an estimated over 14 billion kg of milk in 2016, which means 5.2 per cent higher than in 2015 (ZuivelNL, 2016). A small decrease in the processed amount of milk (-0.5%) was spotted in 2017 (ZuivelNL, 2017). As shown in Table 1, much of the extra milk was used to produce cheese and non-skimmed milk powder after the abolished milk quota system. Cheese production increased by more than 5%, and non-skimmed milk powder production increased by 20% (ZuivelNL, 2016). In 2017, less milk was used for the production of cheese, butter and butter oil, skimmed milk powder and condensed milk. However, non-skimmed powder production increased dramatically by over 13% (ZuivelNL, 2017).

Table 1. Dutch industrial dairy production (million kg) from 2015 to 2017 (ZuivelNL, 2016; ZuivelNL, 2017)

	2015	2016	2017	2016/2015	2017/2016
Milk delivered to factories	13,331	14324	14,297	7.5%	-0.2%
Milk available for processing	13,307	14172	14100	5.2%	-0.5%
Drinking milk and other fresh milk products	985	1,000	1,029	1.6%	2.9%
Cheese	845	890	865	5.3%	-2.6%
Butter and butteroil	217	232	223	4.9%	-3.8%
Non-skimmed milk powder	136	166	187	20.1%	12.6%
Skimmed milk powder	69	70	67	2.4%	-4.5%
Condensed milk	408	372	367	-8.8%	-1.4%

The total revenue in the Dutch milk processing industry achieved €6.4 billion in 2016 which was virtually the same as the level in 2015 (ZuivelNL, 2016) and €7.7 billion in 2017 which accounted for a significant increase of 20% compared to 2015 and 2016 (ZuivelNL, 2017). Specifically, the revenue per 100kg of processed milk in 2016 was more than 5% lower than in 2015. That was due to the lower price applied in the market, although there was a substantial increase in the processed milk amount (ZuivelNL, 2016). On the other hand, the revenue per 100kg of processed milk in 2017 came to a level which was almost 21% higher than in 2016. This was mainly because of the sharply increased revenue for fat-related products, including cheese, butter and butter oil, and whole milk powder, which occupied almost two-thirds of Dutch processed milk (ZuivelNL, 2017).

2.3.2 Dairy products prices changes

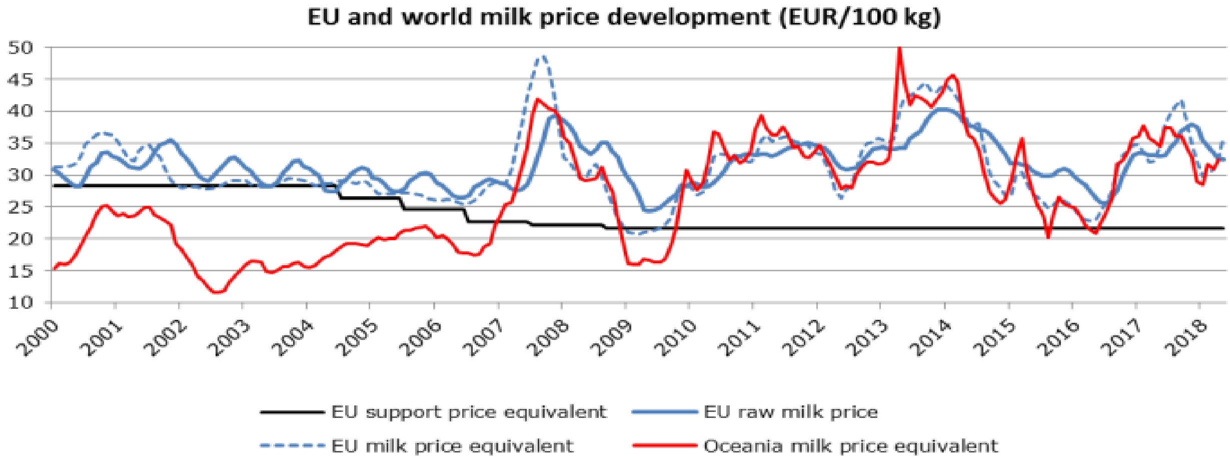

Figure 1: EU and world milk price development (Source: DG Agricultural and Rural Development, based on European Commission and USDA)

During 2000 and 2018, the EU raw milk price presented as the full blue line had been suffered a lot of ups and downs. Milk equivalent price in the graph denoted as blue dash line is based on butter and SMP prices. It can be seen that the evolution is almost the same following the raw milk price with different degrees of oscillations. As shown in Figure 1, the EU raw milk price is described per 100kg. Because of the reduction in skimmed milk powder (SMP) and butter intervention prices, the EU raw milk price was fluctuating seasonally around 31 euro before 2004. Between 2003 and 2009, there was a decrease of 23% in the EU milk support price (full black line) leading to a convergence of EU and world dairy products prices to 35 euro in 2008. The general commodity price increased, and lower milk production in Oceania contributed to this price recovery. Followed by the most severe dairy crisis in 2009, the EU raw milk price sharply decreased to 26.5 euro due to the sharp increase in milk production, particularly in Oceania. After this crisis, milk prices survived and increased steadily up to 37.3 euro in 2014. From 2009 to 2014, driven by robust Chinese demand and imports of dairy products, world consumption kept on growing faster than production. However, there was a sudden drop in Chinese purchases, together with the introduction of the Russian import ban in August 2014. In a context of the relatively long-term growing supply, dairy products prices were unable to reply to this sudden change of demand, therefore, decreased dramatically to less than 25 euro in 2016. In 2017, the global market recovered slightly by good demand, and both the EU milk price and dairy products prices reached 34.9 euro on average (EU, 2018).

2.3.3 Export and import

The total amount of import value was €2.6 billion in 2016 and €3.7 billion in 2017. The occupied import religions for the Netherlands are the same as the most prominent export destinations (ZuivelNL, 2016). The total export value increased by almost 3% in 2016 and 22% in 2017 (ZuivelNL, 2016; ZuivelNL, 2017). The export amount varied among the different product groups. In 2016, 9% more cheese was exported and sold in the EU. Owing to the sharp increase in volume, the effect of the average lower price level was offset. The cheese exportation achieved almost half of the total export value. Moreover, the significantly higher export volume was also shown for butter and butter oil and non-skimmed milk powder (ZuivelNL, 2016). The remarkable increase in total export value in 2017 was due to all major product groups' increases. The export value of cheese increased by almost 14% was as a result of the sharp rise in the average price level. In particular, the export value of butter and butter oil showed an effective increase of 44% (ZuivelNL, 2017).

The EU is by now the most important sales region for the Netherlands to export dairy products. The higher intra-trade had happened in the neighbour countries: Germany, Belgium and France, which took almost 75% of the total export value. In the global market, the Netherlands is also an active exporter with a share of more than 5 per cent. The most important destinations for Dutch dairy products outside the EU are China (including Hong Kong), the United States, and Saudi Arabia in 2016 and China (including Hong Kong), Japan and Algeria in 2017 (ZuivelNL, 2016; ZuivelNL, 2017).

2.3.4 Structural change

Until now, the Dutch dairy industry consisted of 25 companies, with a total of 53 dairy plants in the Netherlands (ZuivelNL, 2017). There is a long history of the existence of dairy cooperatives in the Netherlands, accounting for more than 130 years. Since the 1950s, they possessed a joint market share of more than 80%. They still hold nearly 86% nowadays (ZuivelNL, 2017). However, the number of dairy cooperatives had decreased dramatically, with only five processing cooperatives left occupying 27 plants. Fewer transaction costs with a strong bargaining power make cooperatives stay the central position in the Dutch dairy processing industry. Besides, cooperatives can generate benefits by organising processing activities on behalf of the farmers because the efficient scale to perform processing activities exceeds the size of an individual farm (Bijman, 2018). According to (Soboh, Lansink, & Van Dijk, 2014), the cooperatives are, on average, less efficient relative to their technology than investor-owned firms to theirs. Moreover, cooperatives can increase their output by 24% while using the same batch of inputs. Investor-owned firms can grow their output by 21% with the same bundle of inputs.

2.4 Impacts of trade liberalisation on the dairy processing, sugar and fishery industry

Trade liberalisation in general aims to increase competition and shift production away from low- and towards high-productivity business (Ahmed, 2006), for example by removing the quota system, reducing tariffs or removing non-tariff barriers (Acharya, 2015). Productivity and profitability, however, are related in the sense that a more productive business typically is also more profitable, and under ceteris paribus condition, faster growth in productivity often translates into faster growth in profitability (O'donnell, 2010). For the following sections, studies on the profitability, productivity and efficiency change because of quota removal in other European dairy processing industries are reviewed firstly. Then two examples of the sugar industry and fishery industry are presented to show the impact of different trade liberalisations. Quota removal in the sugar industry and exchangeable quota management in the fishery indicated that the less-efficient firms would gradually and eventually exit the industry and more efficient firms stay in the market and boost their productivity.

2.4.1 Dairy processing industry

A strong regulation through the Common Agricultural Policy (CAP) characterises the European dairy processing industry as the second largest sector within the food manufacturing industry. The recent abolishment of the dairy quota system in 2015 is regarded as the way that EU liberalises its dairy market (Kapelko, Oude Lansink, & Stefanou, 2017). It comes in a period of ongoing globalisation when the competition from major exporters like Australia and South America increases and new opportunities rises in emerging markets like China, India and Russia (Kleibeuker, 2007). At the same time, dairy markets are becoming increasingly volatile due to unstable prices and the changing customer preferences on higher value-added dairy products. This can affect the technical efficiency of dairy manufacturing firms through the effect on profitability and investments in product innovation (Devlieghere, Vermeiren, & Debevere, 2004; Kapelko & Lansink, 2017).

There is a vast amount of studies both from the theoretical and empirical point of view to investigate the impact of market liberalisation on the dairy processing industry. (Shrestha & Hennessy, 2008) theoretically simulated the free milk quota market to show a prospective expectation on the efficiency movement between regions in Ireland. Dairy production was constrained by production quotas in Ireland as in all other EU member states. Since the early 1980s, milk quota transfers between farmers had been allowed and coupled with different degrees in member states. In Ireland, quota trade starting from January 2007 was regionalised and described as "ring-fenced" meaning that farmers were not allowed to trade milk quota outside from their designated milk processor. Dairy farmers were only permitted to trade quota intra-regionally rather than inter-regionally, which had significant implications on the efficiency of the milk processing sector as a whole. It was known that a large number of farms were not able to expand or exit the industry due to the ring-fenced quota trade. Therefore, the study (Shrestha & Hennessy, 2008) aimed to simulate a national but not regional free exchange quota and expected that trade flow would go from inefficient regions to more efficient regions. The results showed that the free tradability of quotas would have positive benefits for the efficiency levels of the whole sector. Under a free quota scenario, quota indeed has been moved from inefficient regions to efficient regions and lead to a geographical concentration of milk production.

Free quota context would increase production volume; however, full liberalisation would decrease the competitiveness of some farms; thus, the production volume would decrease further. Nevertheless, the improved productivity at farm or industry level will help to improve the competitive position. (Hirsch & Hartmann, 2014) studied the persistence of firm-level profitability, specifically in the European dairy processing industry. The article characterised the EU dairy processing industry by burdensome regulations and a high number of cooperatives.

The introduction and increased milk quotas bring fluctuations on milk price, which influence all firms in the processing industry. This impact will be more significant for firms that are more dependent on the cost structure of raw material milk, for example, firms that mainly produce bulk products like butter and milk powder. The article indicated that the EU trade liberalisation policies would continue to push EU milk price downwards and therefore, inevitably increase efficiency both at farm and processing level to maintain profitability.

2.4.2 Sugar industry

The European sugar market is one of the most regulated ones among the whole EU agricultural market. The production capacities were heavily controlled by both the applied production quota system and import protection (Judzińska, 2012). One of the pillars of the CAP to regulate sugar market is the Common Market Organization (CMO) which guarantees the price for sugar producers within the EU which was significantly higher than the world market price and restricted imports from the third countries. CMO guarantees that the EU is self-sufficient in sugar production and protect income for growers (Moyer & Josling, 2017). However, the applied CMO made EU sugar market stagnated and isolated from the fast-developing world market. It also resulted in a continually decreasing number of sugar plants operating on the EU market that only 100 sugar beet plants survived in 19 EU countries. Five multinational companies were in charge of nearly 75% of the full quota (Benešová, Řezbová, Smutka, Tomšík, & Laputková, 2015). EU sugar market was highly concentrated under the quotas, which made the production and the market relatively effective and forced the less efficient companies to leave the industry (Femenia & Gohin, 2013). However, this led to the market imperfection because the highly concentrated market reduced the level of competitiveness and let quota holders be extremely profitable. After several transformations of the policy, the production quotas had been ended on October 2017 (Commission, 2015).

Several studies have predicted changes after removing sugar quota. (Nolte, Buysse, & Van Huylenbroeck, 2011) simulated a scenario investigating the effects of releasing EU sugar quota on internal prices, production and imports. The study indicated that the quota abolition would increase the EU's production obviously, from 13.3 to 15.5 million tons by 2019/20, and correspondingly reduce preferential imports. By using the data from 2003 to 2013, (Wimmer & Sauer, 2018) analysed the reallocation of beet production in case of the abolition of sugar quota to test the relative importance of farm-level productivity and profitability between firms in Germany. The article firstly illustrated the theoretical link between productivity and profitability followed by the research from (O'Donnell C. , 2008), which indicated the difference in profitability depends on both the terms of trade (the relative output price to input price) and the difference in productivity as well as the technology. The results showed that profitability change is primarily driven by terms of trade, while productivity remains rather stable during the study period. The sector's productivity was mainly determined by farm productivity. The effect of reallocation resource on the sector's productivity could be ignored, implying that the announcement of quota abolishment in 2006 did not contribute to more efficient resource allocation.

2.4.3 Fishery

Fisheries play an important role in providing food and income in many EU countries (Voulgaris & Lemonakis, 2013). Within the EU, member states' fish stocks are a shared resource so that the Council of Ministers of the EU controls the total allowable catches (TAC) and the quota allocation for each member state. Multi-dimensional effects can be achieved through trade liberalization in the international fish trading context, especially the impacts on resource sustainability and productivity. Trade liberalisation like removing tariffs can bring economic benefits in fisheries, which is more notable for fish-exporting developing countries. Liberalisation was treated as a serious contributor to employment, income and economic growth, which further increase the investment in producing and processing of fish and fish products (Ahmed, 2006).

(Andersen, Nielsen, & Lindebo, 2009) indicated that productivity could be improved and more economic gains can be achieved through the introduction of property right-based management. In fisheries, management is a fundamental determinant of productivity. The overcapacity in EU fisheries indicates that most economically viable quotas stay fully occupied by the owner country; therefore, there are only a few unused quotas which can be exchanged away. The possibility of country-level quota exchange between member states was firstly introduced in 1983 (EEC, 1983). Exchanged fishing quotas between EU member states occupied 4% of total turnover in EU fisheries, which are necessary to boost economic gains and increase productivity among member states (Andersen, Nielsen, & Lindebo, 2009). Most importantly, allowing transferability of quotas between individual fishermen from different countries can further increase the specialised economic gains. Under individual transferable quota (ITQ) system, fishermen tend to boost their productivity and efficiency by buying quotas from other fishermen who were relatively inefficient or tried to cease the production and left the industry (Areal, Tiffin, & Balcombe, 2012).

Several studies have been researched whether positive efficiency and productivity change occurred in the implementation of ITQs. In the U.S. mid-Atlantic surf clam and ocean quahog fishery, (Brandt, 2007) found out that technical efficiency increased during the pre-ITQ period since owners behaved strategically in order to obtain quota share. (Walden, Kirkley, Färe, & Logan, 2012) studied the same fishery again to show that there was a positive productivity change immediately after the implementation of ITQs. Furthermore, some studies examined the determinants of productivity and efficiency in the fishery. (Voulgaris & Lemonakis, 2013) did research in Greek fisheries and suggested that productivity increases with the size of the firm, and exports are critical for firms' productivity as well as profitability. Small Greek fisheries with low fixed assets, good financial condition and export orientation can be relatively efficient in terms of investing capital assets and using resources. (Tingley, Pascoe, & Coglan, 2005) determined the factors which affect most on the technical efficiency in the English Channel fisheries. Essential factors include vessel and skipper characteristics. More efficient skippers tend to operate on the larger vessels because the boat size had a generally positive impact on efficiency. Moreover, active gear types, education and training level also influence efficiency.

2.5 Lessons learned from the dairy industry and other industries

Chapter 2 has firstly provided the policy reformation in the dairy sector, beginning with CAP, quota system and new manure policy after the removal of the quota system. The emphasis is to analyse the effect of the abolished milk quota system in the Dutch dairy processing sector in section 2.3. There are significant growths in milk deliveries and processed amount among products groups after the milk quota removal, although there is a new phosphate ceiling amount to control further growth. Moreover, the dairy products price and raw milk price have oscillated fiercely while converging to the world milk price.

Dairy processing industry functions as a critical role in EU food manufacturing industry, which attracts many researchers to investigate the efficiency and productivity change both from a theoretical perspective and empirical application under a liberalised environment. Milk quota is deemed as an impediment to boosting dairy processors' technical efficiency and productivity growth. The volatile milk price inevitably influences processors' income. Researchers simulated the free milk quota market for example in Ireland or studied the liberalized policy for instance in Spain to show that dairy processing sector can benefit more from an abolished quota system to improve efficiency and productivity (Shrestha & Hennessy, 2008; Kapelko & Lansink, 2013; Kapelko & Lansink, 2017; Kapelko, Oude Lansink, & Stefanou, 2017).

The sugar industry and fishery have been reviewed to collect relevant information and serve as references for the dairy industry because of a similar quota application and abolishment situation. Sugar industry removed the quota on October 2017 which was introduced in 1968 immediately by the Common Market Organization. Compared with the duration of applied milk quota in the dairy industry (30 years), the sugar industry had been heavily regulated for nearly 50 years. Quota in the sugar industry is comparable to the milk quota in the dairy industry because both quotas target to tackle oversupply and align production in the world market. The structure of these two industries is also similar, considering the sugar and dairy markets are both controlled by a few companies which occupy 75% quota amount and over 80% market share respectively.

Several studies investigated the prospected impacts on sugar industry after the removal of the quota system. The production was estimated to grow from 13.3 to 15.5 million tons by 2019/2020 (Nolte, Buysse, & Van Huylenbroeck, 2011). Terms of trade were the primary source of profitability change while productivity level was holding stable from in the case of abolition of sugar quota (Wimmer & Sauer, 2018). In fishery, the total allowable catches (TAC) and the quota allocation between member states are controlled by the Council of Ministers of the EU. Property right-based management like individual transferable quota (ITQ) scheme can effectively improve productivity in the fishery (Andersen, Nielsen, & Lindebo, 2009). It boosts productivity due to the exit of less productive vessels.

All in all, this research is expected that productivity has increased in the Dutch dairy processing sector after the milk quota system abolishment in 2015. The study from (Van Bekkum & Nilsson, 2000) indicated that governmental intervention has fiercely influenced dairy processors' development all over the world by causing changes at the farm level. In the Netherlands, five dairy cooperatives occupied more than 80% market share in the whole dairy processing industry. Milk quota applied to the farm level, which constrained the maximum amount of milk delivered from farmers to processors, was the indirect governmental intervention on controlling the dairy processing sector's development. After removing quotas, dairy processors receive more milk from farms, which means there are more milk processed to produce dairy products. According to the supply and demand theory (Marshall, 1890), a higher supply of the dairy products in the market would cause the prices going down, which harm no matter farmers or processors' profitability.

Furthermore, the research from (O'Donnell C. , 2008) indicated that both productivity and terms of trade are the critical drivers of the firm's profitability. Under the condition of an adverse price influence, processors would increase their productivity to offset the negative effect of volatile milk price to improve profitability. Thus, the productivity of the whole dairy processing sector is expected to be improved after the milk quota abolishment. According to the general theory of transferability and mobility of the quota from (Alston, 1981) and (Oskam & Speijers, 1992), a more freely traded quota could reduce the inefficiency. When the quota is abolished, the market will be relatively free, which means the efficiency would be increased further.

Considering there is limited research focusing on the empirical impacts of the milk quota abolishment after 2015 on profitability and productivity change in the Dutch dairy processing sector, in the following chapter, Färe-Primont profitability and productivity index together with DEA will be introduced and applied to examine the expectation and present results.

3 METHODOLOGY

This chapter presented Färe-Primont index as the theoretical framework to analyse the relationship between profitability and productivity and used DEA as the empirical approach to evaluating components of productivity change. Moreover, the data collected in the sample were described in the final section.

3.1 Theoretical framework of Färe-Primont index

According to (O'Donnell C. , 2008; O'donnell, 2012), profitability change can be decomposed into total factor productivity (TFP) index and an index measuring changes in relative prices of outputs and inputs denoted as terms of trade (TT). TFP usually can be expressed as the ratio of an aggregate output quantity index to an aggregate input quantity index, which was referred to be 'multiplicatively complete' (O'Donnell C. , 2008). Any multiplicatively-complete TFP indexes such as Fisher, Törnqvist or Hicks-Moorsteen index can be exhaustively decomposed into technical change and different efficiency changes (O'Donnell C. J., 2011). However, these indexes are not suitable for making multitemporal and multilateral comparisons of TFP because they violate at last one important axiom from index number theory (O'donnell, 2012).

Färe-Primont index proposed by (O'Donnell C. J., 2014) was selected to decompose profitability index and further explained the components of productivity change, mainly because Färe-Primont index satisfies an important axiom from index number theory—transitivity[1] axiom. It allows the index to be used multitemporal comparison, which was needed in this research to compare the results in different years. Following (O'donnell, 2010), the computations of changes were denoted by the prefix "d" in index numbers in Equations (1-7). The formulae of decomposing profitability and productivity change are presented in simplified forms in Equations (1-7) as follows:

Firstly, the profitability index change (dPROF) between firms or periods, *s* and *t*, can be decomposed into the indices of changes in terms of trade (dTT) and total factor productivity (dTFP) using firm or period *s* as a base:

$$\mathrm{dPROF} = \mathrm{dTT} * \mathrm{dTFP} \tag{1}$$

Explicitly, the change in profitability (dPROF) in Equation (1) can be computed as the ratio of, for example, profitability in period t over in time *s* for firm *n*. This can be expressed as in Equation (2):

$$\mathrm{dPROF} = \frac{\mathrm{PROF}_{nt}}{\mathrm{PROF}_{ns}} = \frac{P_{nt}Q_{nt}}{W_{nt}X_{nt}} \div \frac{P_{ns}Q_{ns}}{W_{ns}X_{ns}} = \frac{dP}{dW} \times \frac{dQ}{dX} = \mathrm{dTT} * \mathrm{dTFP} \tag{2}$$

[1] Transitivity means that a direct comparison of the productivity between two firms or periods will yield the same result of productivity change as an indirect comparison through a third firm or period.

where P and Q are the price and quantity of outputs; and W and X are the price and quantity of inputs. Therefore, $dP = P_{nt}/P_{ns}$ is an output price index, $dW = W_{nt}/W_{ns}$ is an input price index and dTT $= dP / dW$ is terms of trade index measuring the change in outputs prices relative to the change in inputs prices. Following the same structure, $dQ = Q_{nt}/Q_{ns}$ is an output quantity index, $dX = X_{nt}/X_{ns}$ is an input quantity index and dTFP $= dQ/dX$ is an index capturing the change in outputs quantity relative to the change in inputs quantity. The index demonstrates profitability growth if dPROF > 1; favourable relative price change if dTT >1; and productivity growth if dTFP >1 (Coelli, Rao, O'Donnell, & Battese, 2005).

Secondly, the total factor productivity (dTFP) index in Equation (1) can be further decomposed into indices of technical change (dMP) and technical efficiency change (dTFPE):

$$\mathrm{dTFP} = \mathrm{dMP} * \mathrm{dTFPE} \tag{3}$$

where $\mathrm{dTFP} = \left(\frac{\mathrm{MP}_{nt}}{\mathrm{MP}_{ns}}\right) \times \left(\frac{\mathrm{TFPE}_{nt}}{\mathrm{TFPE}_{ns}}\right)$. The term $\left(\frac{\mathrm{MP}_{nt}}{\mathrm{MP}_{ns}}\right)$ is dMP which measures the difference of technical change of firm n between the maximum TFP that is possible using the technology available in period t and the maximum TFP that is possible using the technology available in period s; and the term $\left(\frac{\mathrm{TFPE}_{nt}}{\mathrm{TFPE}_{ns}}\right)$ is dTFPE which measures overall efficiency change of firm n in period t compared with period s under the same technology.

Finally, according to (O'Donnell C. J., 2012), the index of efficiency change (dTFPE) can be decomposed into various indices of efficiency change components as specified in Equations (4-7):

$$\mathrm{dTFPE} = \mathrm{dOTE} * \mathrm{dOME} * \mathrm{dROSE} \tag{4}$$

$$\mathrm{dTFPE} = \mathrm{dOTE} * \mathrm{dOSE} * \mathrm{dRME} \tag{5}$$

$$\mathrm{dTFPE} = \mathrm{dITE} * \mathrm{dIME} * \mathrm{dRISE} \tag{6}$$

$$\mathrm{dTFPE} = \mathrm{dITE} * \mathrm{dISE} * \mathrm{dRME} \tag{7}$$

where Equation (4) and (5) are output-orientated denoted by the prefix "O" and Equation (6) and (7) are input-orientated denoted by the prefix "I". In general, output-orientated approach measures efficiencies focusing on the maximum level of outputs that can be produced using a given level of inputs and a given production technology relative to the observed level of outputs. While input-orientated approach focuses on the level of inputs necessary to produce observed output level under a reference technology. The decomposition of TFP index can also from output direction or input direction, as shown in Figure 2 adapted from (O'Donnell C. J., 2012). For example, a multiple-input-multiple-output firm A can be technical efficient when it moves to point C located on the production frontier (output direction) or move to point B (input direction). The same for scale efficiency and mix efficiency as denoted in the figure. Moreover, for residual scale efficiency (e.g. output direction) is $\frac{\text{slope OV}}{\text{slope OE}}$ as denoted by the purple line in the figure; and residual mix efficiency (e.g. output direction) is $\frac{\text{slope OD}}{\text{slope OE}}$.

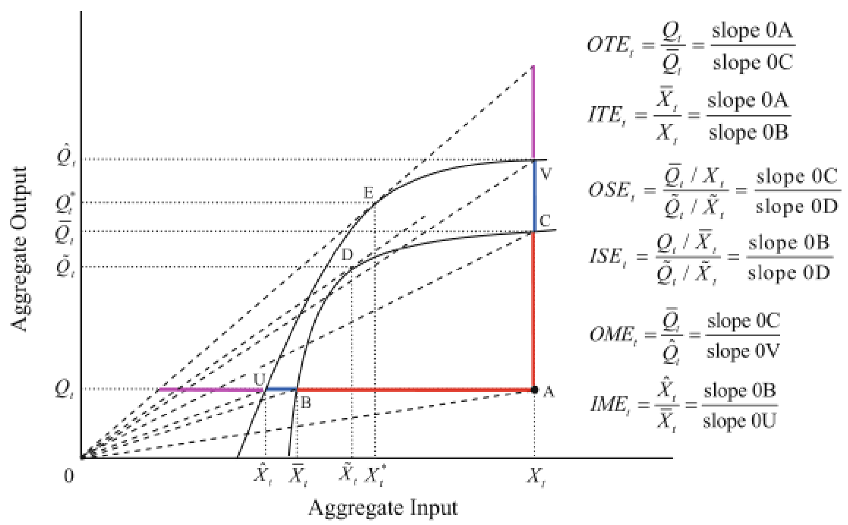

Figure 2: Output- and input-orientated decomposition of TFP for a multiple-input-multiple-output firm (O'Donnell C. J., 2012)

Considering this research investigated from an output-orientated approach, Equation (5) was selected to decompose dTFPE. Therefore, the full formula of decomposing TFP index is shown in Equation (8):

$$\text{dTFP} = \text{dMP} * \text{dOTE} * \text{dOSE} * \text{dRME} \qquad (8)$$

Indices of Equation (8) are briefly explained below following the efficiency concepts defined by (O'Donnell C. , 2008) and (Islam, Xayavong, & Kingwell, 2014):

- OTE is output-orientated technical efficiency that captures the potential change in TFP for a given input level by the best practice use of existing technology. By keeping the output mix constant and the input level constant, it is measured by the difference between observed TFP and the maximum TFP possible with existing technology.
- OSE is output-orientated scale efficiency that captures the potential change in TFP when output level can be altered to achieve the maximum TFP with existing technology. It keeps the input and output mixes constant but allows the levels to change.
- RME is residual mix efficiency that captures the differences between TFP at a technically and scale-efficient point and the maximum TFP that is possible through changing input and output mixes with existing technology.

The R package "Productivity" version 1.1.0 (Dakpo, Desjeux, & Latruffe, 2017) was used to decompose Färe-Primont index, analyse relationships between profitability and productivity change and evaluate components of TFP index.

3.2 Nonparametric approach of Data Envelopment Analysis (DEA)

In practice, decomposing TFP index into measures of technical change and efficiency changes comes to estimating the production frontier. The two main approaches to estimating production frontiers and calculating efficiency and productivity are Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). DEA approach was developed after (Charnes, Cooper, & Rhodes, 1978) based on the works of (Debreu, 1951) and (Farrell, 1957) to construct efficiency frontier with the best performing firms among observations using linear programming. Whereas, (Aigner, Lovell, & Schmidt, 1977) and (Meeusen & van Den Broeck, 1977) proposed SFA approach using regression. Both procedures have advantages and disadvantages. The selection of the method depends on both the industry to be examined and the suitability of dealing with the dataset (Madau, Furesi, & Pulina, 2017).

SFA approach is parametric, which means it requires parameterisation of the production frontier, and various distributional assumptions need to be made on the functional forms of the production frontier. The main advantage of this approach is its ability to handle the random noise and differentiate it from inefficiency by taking into account the stochastic variation of the output (Darku, Malla, & Tran, 2013). However, results could be unreliable if the sample size is small (O'donnell, 2012). In contrast, DEA is a non-parametric approach because it does not need any explicit assumptions about the functional form of the frontier or distributions of random error terms. The frontier is implicitly assumed to be linear, and all noise effects are implicitly assumed to be zero (Coelli, Rao, O'Donnell, & Battese, 2005). The main advantage of this approach is that there are no statistical issues related to estimating the production frontier (O'donnell, 2012). The disadvantage of DEA is the inability of distinguishing inefficiency from noise because it does not allow for statistical noise. The exhaustive distinction between DEA and SFA approach was summarised in Appendix 1. Considering the sample is too small to construct an SFA model, DEA approach was determined to apply in this study in order to estimate changes in productivity and efficiency in the Dutch dairy processing sector although it is computationally challenging as results could be sensitive to outliers in the study; and technical efficiency estimates could be upwardly biased in small samples.

An output-orientated DEA was used due to the researcher’s interest and research context. Dairy processors received more milk from farmers after milk quota abolishment in 2015. Therefore, the level of their inputs increased. By a given increased level of inputs, output-orientated DEA estimates efficiencies, which is based on processors’ capacity that allowed by technology to maximise production of dairy products. An input-orientated approach minimising the use of inputs given a certain level of output might also be appropriate for the research. However, with empirical evidence of the increased dairy products production in 2016 and 2017, the emphasis was put in a scenario without milk quotas to check whether dairy processors improve their productivity by an increased level of inputs. Thus, this research opted for an output-orientated DEA approach to measure the components of Färe-Primont TFP index.

Output-orientated CRS model is constructed below (9) (Coelli, Rao, O'Donnell, & Battese, 2005):

$$\max_{\phi_i,\lambda} \quad \phi_i$$

$$\text{s.t.} -\phi_i \boldsymbol{y}_i + \boldsymbol{Y\lambda} \geq \boldsymbol{0} \tag{9}$$

$$\boldsymbol{x}_i - \boldsymbol{X\lambda} \geq \boldsymbol{0}$$

$$\boldsymbol{\lambda} \geq \boldsymbol{0}$$

where *N* firms are supposed in the sample. Each firm uses *K* inputs (as $\boldsymbol{x}_i$ is a $K \times 1$ input vector for firm *i*) to produce *M* outputs (as $\boldsymbol{y}_i$ is an $M \times 1$ output vector for the firm *I*). **X** is a $K \times N$ matrix to present the whole inputs used in the dataset and **Y** is a $M \times N$ matrix to show all outputs produced. $\boldsymbol{\lambda}$ is a $N \times 1$ vector of weights relative to efficient observations. By adding the restriction $\sum_j \lambda_j = 1$ to the CRS model, the model can be modified into VRS DEA model. This is called convexity constraint, which guarantees that the projected firm will be a convex combination of efficient firms.

3.3 Data

25 dairy processing firms from the Netherlands were used to generate panel data covering the period 2009-2017 from the Orbis database. Orbis is the world's most potent and comparable resource for company financial data prepared by Bureau van Dijk, which has information on around 300 million companies across the globe. The data was collected from annual reports which were produced by the chamber of commerce in the country. Due to the incompleteness of 25 dairy processing firms' data, companies' websites and other websites were used to collect missing data. Because R 'Productivity' package (Dakpo et al., 2018) can only deal with balanced panel data, finally there were 8 observations qualified to form the sample among which 4 were cooperatives (FrieslandCampina; CONO Kaasmakers; DOC Kaas; Rouveen), and the other 4 were investor-owned firms (Vreugdenhil; Arla; Farm Dairy; Hochwald).

One output (operating revenue) and three inputs (fixed assets, material costs and employment costs) were selected in the analysis. Both output and inputs were initially expressed in nominal prices as thousand euros from the Orbis database. In this study, they were expressed in implicit quantities by dividing their corresponding price indexes provided by (Eurostat, 2014) from monetary value. Each price index in 2009 was divided from itself to create a base of 1. Output and inputs are described below:

1) Operating revenue; dairy processing firms in the Netherlands are engaged in the manufacture and sale of dairy products and other related products like cheese, butter, fluid milk and yoghurt (mainly exclude ice cream). The detailed information on products and services from each company are listed in Appendix 2. The available data of output only reports the total revenues and does not distinguish different product categories of total outputs. According to the Orbis database, operating revenue is calculated as the sum of net sales and other operating income from firms' profit and loss account statements. Some companies' operating revenues were collected from their Dutch annual financial reports. Operating revenue called "som der bedrijfsopbrengsten" is the sum of "netto-omzet" and "overage bedrijfsopbrengsten". In case some companies did not report "overige

bedrijfsopbrengsten" (other income), "netto-omzet" (net sales) was used as operating revenue. Therefore, the output used in the model was measured as total operating revenue from selling all products produced by the company divided by the consumer price index (CPI) for milk, cheese, eggs in the Netherlands. The index of consumer prices (Index, 2015=100) from Eurostat was monthly available from 2009 to 2017. So, the annual index was calculated by the sum of the monthly price index divided by 12.

2) Fixed assets; were selected from firms' balance sheets as the value of both tangible assets like land, buildings and machinery, and intangible assets such as goodwill, patents and brands. The monetary value of fixed assets was divided by the annual price index of the agriculture, forestry and fishing gross fixed capital formation (Index, 2010=100) to become quantity.

3) Material costs; were based on the costs of purchasing input materials before starting the processing operation. This input mainly consisted of the cost of purchasing raw milk by the processors. Because of missing data from the Orbis database, the researcher used 'kosten van grond-en hulpstoffen' from firms' profit and loss account statements as material costs. In the case of unclarity of financial statements, for example, firm DOC Kaas's material costs in 2016 and 2017 were used 'melkgelden' in the report. The monetary value of material costs was divided by the annual index of production value at a nominal price (Index, 2010=100) to create quantity.

4) Employment costs; were collected by the sum of wages and salaries, social security and pension costs. Firm CONO Kaasmakers did not have pension costs in the profit and loss account statements; therefore, only wages and salaries and social security were gathered as employment costs. One thing important to mention is for firm DOC Kaas; there were no employment costs in 2016 and 2017 since the annual reports indicated that "In 2017 heeft DOC Kaas B.A. (even in 2016) geen personeel in dienst." This could cause outliers in the sample due to value 0 existing in 2016 and 2017 compared with other years. The monetary value of labour costs was divided by the nominal value of the annual labour cost index (LCI) (Index, 2012=100) to achieve quantity.

Table 2 provides the arithmetic mean of quantities of operating revenues, fixed assets, material costs and employment costs per firm. Table 3 shows the price index used to divide from monetary value to get quantities in Table 1 for each output and input. Eight observations were included in the balanced panel dataset from 2009 to 2017.

Table 2. Descriptive statistics of arithmetic mean in thousand euro

No. of observation	Company name	Operating revenue	Fixed assets	Material costs	Employment costs
1	FrieslandCampina	10,072,590.540	3,845,368.332	5,557,413.685	894,823.084
2	CONO Kaasmakers	185,193.593	46,531.113	122,350.342	12,286.856

3	DOC Kaas	387,586.659	86,119.521	85,708.716	11,812.199
4	Rouveen	118,389.614	15,424.088	3,312.1731	8,171.515
5	Vreugdenhil	198,643.236	30.336	167,433.828	362.083
6	Arla	211,783.609	43,010.268	104,725.745	24,065.737
7	Farm dairy	93,702.674	14,105.661	63,867.013	5,146.907
8	Hochwald	115,179.250	9,441.579	75,514.789	19,140.572

Table 3. Price indices of output and inputs from 2009 to 2017 (Source: Eurostat, 2014)

Years	Consumer Price Index (CPI)	Gross fixed capital formation index	Producer price for milk index	Labour cost index (LCI)
2009	1.000	1.000	1.000	1.000
2010	0.982	1.021	1.172	1.019
2011	0.993	1.320	1.304	1.034
2012	1.015	1.219	1.213	1.054
2013	1.032	1.104	1.401	1.070
2014	1.084	1.159	1.423	1.068
2015	1.076	1.051	1.150	1.093
2016	1.055	0.960	1.074	1.102
2017	1.121	0.989	1.298	1.122

4 RESULTS

This chapter presents the decomposition of Färe-Primont profitability and productivity index by first showing overall results of 8 observations in the sample and then the annual index for each firm from 2009 to 2017. The exhaustive data for 8 firms and 7 firms without Hochwald can be found in Table A.4.1 and Table A.4.2 in Appendix 4.

4.1 Decomposing profitability index

Färe-Primont profitability index is decomposed into terms of trade index and total factor productivity index. Overall results and firm-specific results for each index are shown in the following sections, respectively.

4.1.1 Overall results

Table 4 shows the index of profitability (dPROF) and its components of terms of trade change (dTT) and total factor productivity change (dTFP) from 2009 to 2017. These measures are calculated as the geometric mean of all observations every year. For all data, 2009 is the base year, which means the values of each index are equal to 1 in 2009. Illustration of data in this chapter is mainly based on geometric mean because of the ratio-based Färe-Primont index, while exhaustive annual results calculated by both arithmetic mean and median are presented in Appendix 3.

Table 4. Geometric mean of Dutch dairy processing industry's dPROF, dTT and dTFP from 2009 to 2017

Year	dPROF	dTT	dTFP
2009	1.000	1.000	1.000
2010	1.101	0.691	1.593
2011	1.076	0.617	1.745
2012	1.046	0.658	1.591
2013	1.039	0.582	1.785
2014	1.025	0.629	1.630
2015	0.999	0.710	1.406
2016	0.856	0.560	1.529
2017	0.856	0.485	1.766

The results of annual change indices in Table 4 were compared to 1 in 2009, where an index below 1 indicates deterioration or regress; an index equal to 1 indicates stagnation, and an index above 1 indicates progress or growth. For instance, profitability in 2017 was 85.6% of the profitability in 2009, indicating profitability deterioration over the study period. The evolution of profitability change and its components based on the geometric mean is shown in Figure 3. Figures based on the arithmetic mean and medians are shown in Appendix 5.

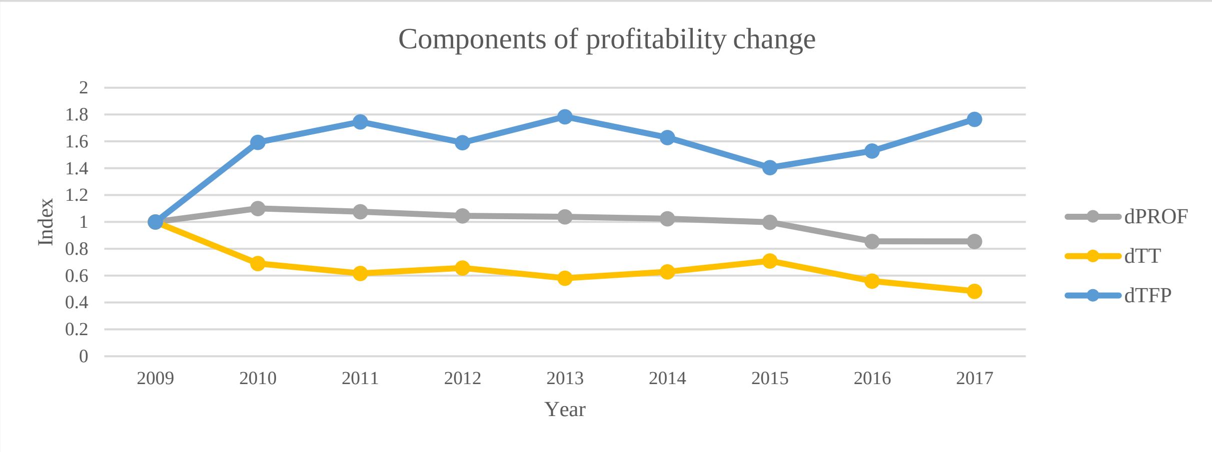

Figure 3: Evolution of Dutch dairy processing industry's annual dPROF, dTT and dTFP

Figure 3 shows that dPROF decreased gradually from 2010. Especially after 2015, it declined sharply compared to other years. Profitability regress (dPROF<1) was spotted after 2015 when milk quotas had officially been abolished. The main reason causing the profitability regress was chronic unfavourable dTT, indicating the aggregate output price relative to aggregate input price was smaller than 1. Alongside each year's dTT, a severe price deterioration was clearly illustrated. In Figure 3, although there were mild increases like from 2013 to 2015, the whole trend of dTT was decreasing until the lowest point (0.485) in 2017 indicating the terms of trade in 2017 was only 48.5% of TT in 2009. The unfavourable dTT compensated the positive influence of dTFP on profitability. An annual larger than 1 index revealed an overall result of consistent productivity progress. Whereas, an unfavourable dTT entirely determined the outcome of profitability regress from 2009 to 2017.

4.1.2 Firm-specific results

By plotting each firm's data (see Table A.4.1 in Appendix 4), the evolution of unambiguous annual dPROF and its components of dTT and dTFP are shown in following figures.

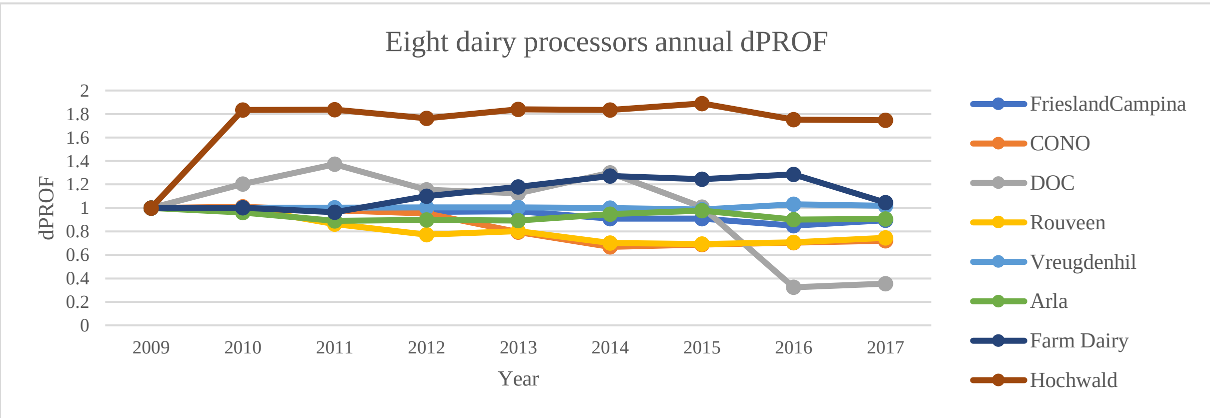

Figure 4: Eight dairy processors annual dPROF from 2009 to 2017

Figure 4 shows that firms' dPROF fluctuated between 0.6 and 1.4 except DOC and Hochwald.

The remarkable fluctuation was recognized in DOC, and a significant deviation from the average dPROF interval was spotted in Hochwald. There were two distinct profitability change periods for DOC company: one was profitability progress period between 2009 and 2014; and the other was severe profitability deterioration period after 2015 when it dropped sharply to the lowest point (0.324) in 2016. Hochwald's dPROF mildly fluctuated around an average of 1.80, indicating significant profitability growth during the study period. Generally, the sample can be identified with two groups of companies, demonstrating either general profitability growth during the study period (above the line of index=1) like Hochwald, Farm Dairy and firm DOC (before 2015); or profitability stagnation and regress (on/below the line of index=1) such as firm DOC (after 2015) and the other companies.

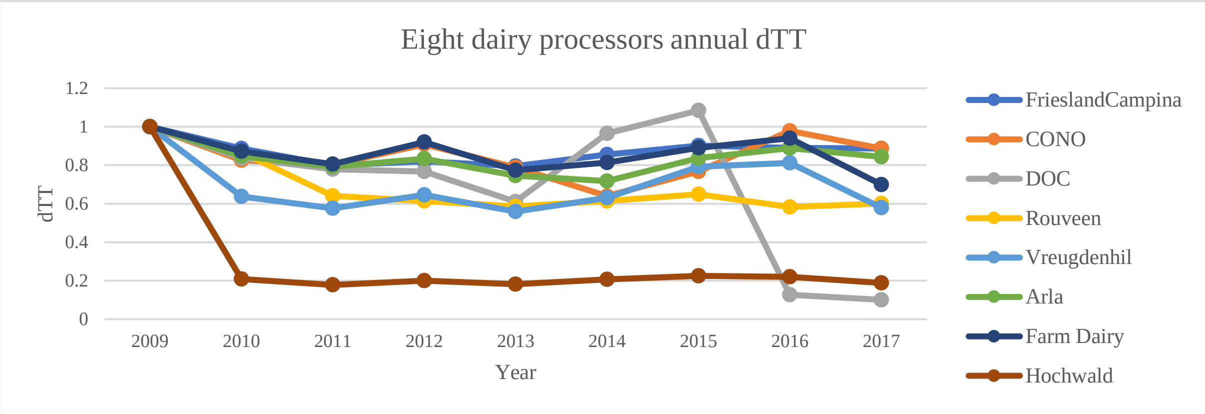

Figure 5: Eight dairy processors annual dTT from 2009 to 2017

Figure 5 shows that almost all eight firms experienced unfavourable terms of trade every year except DOC having a favourable dTT in 2015 (1.084). Generally, dTT fluctuated within an interval of 0.6 and 1 excluding DOC and Hochwald. DOC's dTT increased prominently from 2013 to the highest point in 2015. However, it declined sharply to the lowest in 2016. As for Hochwald, its dTT slightly fluctuated around the level of 0.2 without any changes. Together with other firms' constant unfavourable dTT, the results showed an unfavourable dTT over the study period for the Dutch dairy processing industry.

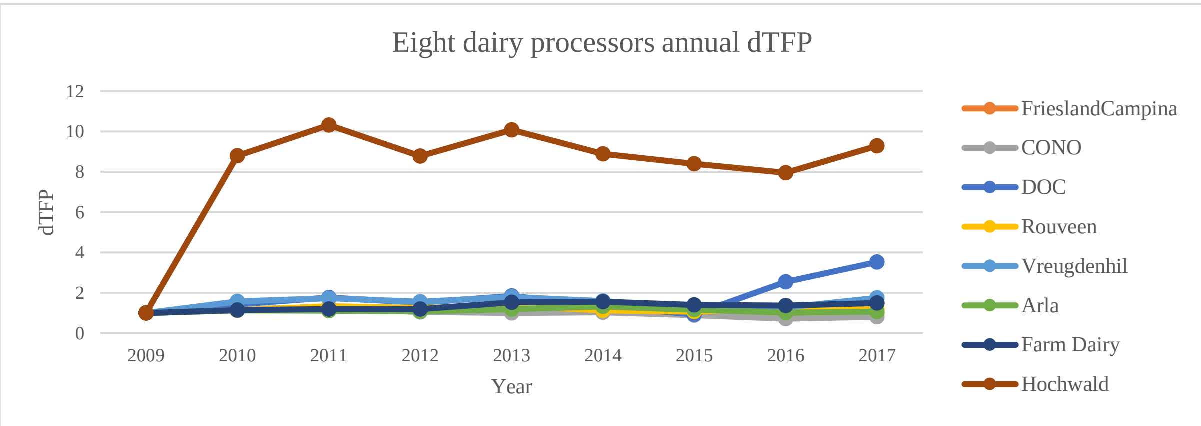

Figure 6a: Eight dairy processors annual dTFP from 2009 to 2017

Figure 6a illustrates the remarkable profitability progress in Hochwald company since its dTFP was always above 8 except in 2009. Other firms' dTFP fluctuated between a range of 0.7 and

2 except for DOC in 2016 and 2017 whose dTFP was almost 4. To present other firms' changing pattern clearly, Hochwald company was excluded from the sample and reran the analysis. The exhaustive data can be found in Table A.4.2 in Appendix 4.

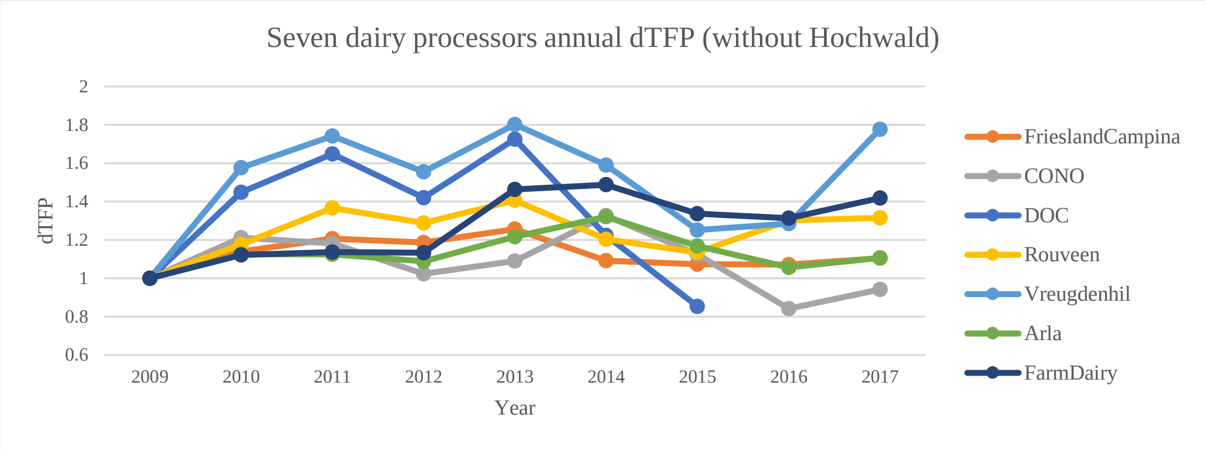

Figure 6b: Seven dairy processors annual dTFP from 2009 to 2017

Figure 6b shows the evolution of dTFP for seven firms. Because DOC's dTFP in 2016 and 2017 were positive infinity, they were excluded from the figure in case of clarity. The lowest point was spotted in firm CONO with a value of 0.841 in 2016. Similarly, dTFP of DOC in 2015 dropped to the lowest at 0.853 whereas it increased to the infeasible level of dTFP in 2016 and 2017. The evolution of dTFP in these firms presented a similar pattern. There was an increasing tendency before 2013 then it gradually decreased until 2016, and finally it transited to a slightly higher level.

4.2 Technical change and efficiency changes

Färe-Primont TFP index is decomposed into technical change and different efficiency changes. Overall results and firm-specific results for each index are shown in the following sections, respectively.

4.2.1 Overall results

The dTFP is decomposed into technical change (dMP), output-orientated technical efficiency change (dOTE), output-orientated scale efficiency change (dOSE) and residual mix efficiency change (dRME). These indexes are presented in Table 5 successively, where dTFPE is the overall efficiency change index (dTFPE = dOTE × dOSE × dRME). The evolution of dTFP and dTFPE with their components are presented in Figure 7 and Figure 8a & 8b, respectively. The data in Table 5, Figure 7 and Figure 8a & 8b are based on geometric means. For more illustrations, Appendix 3 and 5 show the detailed data and figures based on arithmetic means and median values, respectively.

Table 5. Geometric mean of Dutch dairy processing industry's dTFP and its components from 2009 to 2017

Year	dTFP	dMP	dTFPE	dOTE	dOSE	dRME

2009	1.000	1.000	1.000	1.000	1.000	1.000
2010	1.593	1.575	1.011	1.013	0.985	1.013
2011	1.745	1.741	1.003	0.999	0.986	1.018
2012	1.591	1.554	1.023	1.037	0.971	1.016
2013	1.785	1.796	0.993	0.963	0.964	1.071
2014	1.630	1.586	1.027	1.015	0.963	1.052
2015	1.406	1.245	1.130	1.067	1.014	1.044
2016	1.529	1.269	1.205	1.081	1.001	1.113
2017	1.766	1.759	1.004	1.064	0.991	0.952

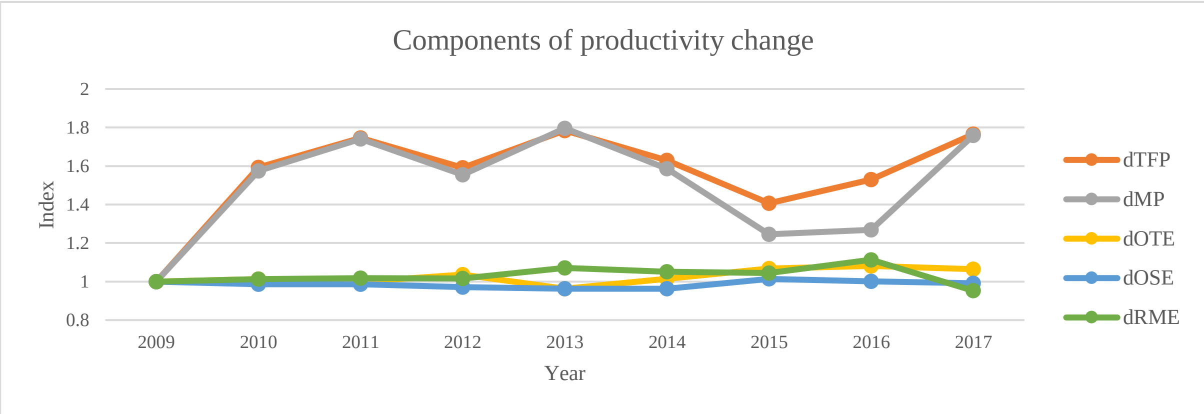

Figure 7: Evolution of Dutch dairy processing industry's annual dTFP and its components

An annual growth rate of 7.109% ($d\ln \text{TFP} = \ln 1.766\,/(2017 - 2009) \times 100$) was observed on dTFP over the study period. Although the variation was quite significant, as shown in Figure 7, the productivity change was always larger than 1 over 9 years. The illustration of dTFP can be divided into three periods. The first period from 2009 to 2013 led dTFP to reach the highest point in 2013. However, it fell to the lowest (1.406) after two years. The last period from 2015 to 2017 demonstrated a fast recovery of dTFP that it almost returned to the highest point in 2017. It is evident to declare an overall result of impressive productivity progress during the whole study period.

Moreover, it is clear to see from Figure 7, the evolution of dMP overlapped dTFP except there was a deviation after 2014. Technical change is a measure of movements in the production frontier, which is associated with changes in the stock of scientific knowledge or other characteristics of the production environment. It is evident that technical progress was the dominant source of overall productivity growth. An annual growth rate of 7.059% ($d\ln \text{MP} = \ln 1.759\,/(2017 - 2009) \times 100$) in dMP indicated that the Dutch dairy processing industry strove hard on technology progress to boost its productivity.

Figure 8a presents the evolution of technical change and efficiency change by implicit decomposing dTFP. Meanwhile, Figure 8b illustartes the explicit development of different efficiency changes.

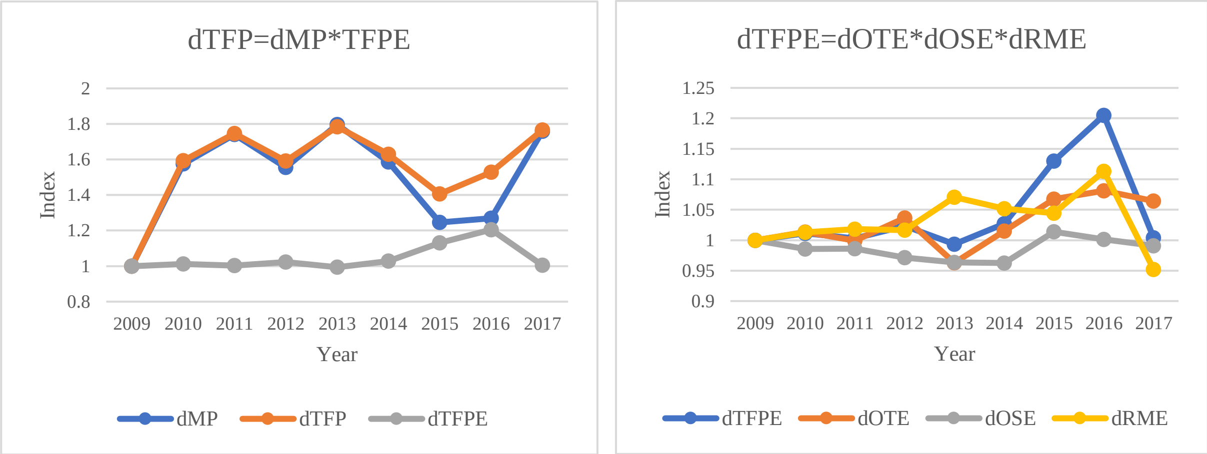

Figure 8a & 8b: Brief decomposition of Dutch dairy processing industry's dTFP and dTFPE

Figure 8a shows that the line of dMP and dTFP started to separate because the decline of dMP was faster than dTFP after 2014. Both dMP and dTFP reached the lowest points, which were 1.245 and 1.406 respectively in 2015. Efficiency changes (dTFPE) of the industry showed a dead stagnation because it parallelly moved around 1 before 2014. A sharp efficiency growth contributed to a growth in dTFP from 2015 to 2016 when dMP was stagnant.

Figure 8b shows that dOTE and dRME were the main sources of dTFPE evolution. Technical efficiency change (dOTE) captures the movements of the units towards (>1) or away from (<1) from the production frontier. Scale efficiency change (dOSE) and residual mix efficiency change (dRME) determines the movements around the restrictive production frontier or unrestrictive production frontier. Before 2012, the line of dTFPE was almost entirely covered by dOTE and dRME when dOSE kept falling downwards until 2014. However, dOTE and dRME showed opposite trends between 2012 and 2015. dOTE suddenly dropped to its lowest point (0.963) indicating a technical efficiency regress while dRME had a noticeable rise and reached its second-highest point (1.071) in 2013. Plus, it is surprising to see that dOSE presented a sudden increase from 2014 to 2015, although it declined again immediately after 2015. Nevertheless, a significant decline in dRME in 2016 finally caused dTFPE drop from the top (1.205) in 2016 to the bottom (1.004) in 2017.

Generally, expect a growth in dOTE which had 6.4% more technical efficiency change in 2017 compared to 2009, both regress on dOSE (0.991) and dRME (0.952) were observed in 2017 since the indices were smaller than 1. This implied that on average, companies moved closer to the frontier (dOTE>1) under the existing technology. However, they did not operate at the most efficient scale (dOSE<1), and they failed to move closer to the unrestricted frontier without constraints on inputs mixes (dRME<1) to further increase efficiency.

4.2.2 Firm-specific results

Following figures elaborate on the evolution of technical change and efficiency changes for each dairy processor in the sample. The exhaustive results can be found in Table A.4.1 in Appendix 4. In particular, Figure 10b and Figure 11d show the evolution of seven firms' annual dTFPE and dRME excluding Hochwald. Seven firms' exhaustive data can be found in Table A.4.2 in Appendix 4.

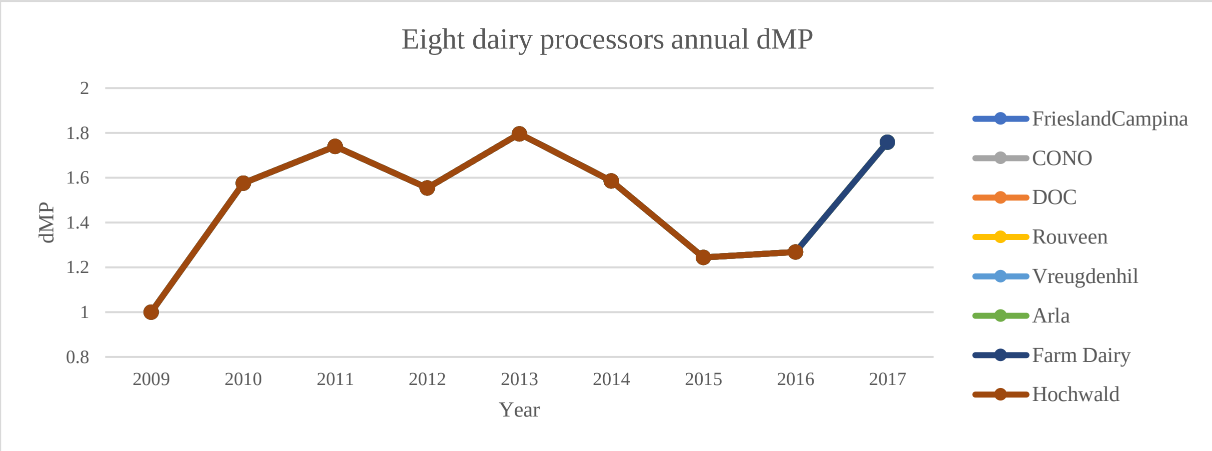

Figure 9: Eight dairy processors annual technical change

Figure 9 shows that each firm had the same dMP from 2009 to 2017. Although the evolution of dMP showed some ups and downs, its annual value was significantly larger than 1, indicating every firm in the sample experienced the technical progress. dMP showed an increasing trend from 2009 to the top (1.802) in 2013, followed by a sharp decline to the bottom (1.251) in 2015. Then it recovered to the highest dMP again in 2017. Each firm tended to improve its technology; thus, in return, the overall result maintained a significant positive productivity growth during the study period. However, 8 firms' dTFPE evolution in Figure 10a was excessively inactive compared with MP changes in Figure 9.

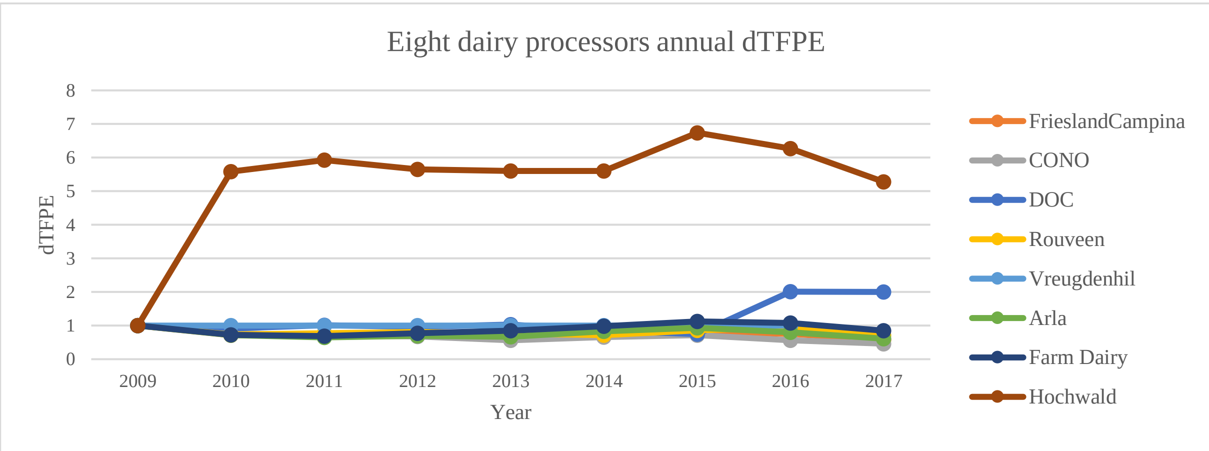

Figure 10a: Eight dairy processors annual efficiency changes

Figure 10a demonstrates that 8 firms' dTFPE expect Hochwald were all stagnant. Hochwald firm showed a spectacular strength among other firms as its dTFPE was above 5 all the time. However, the mainstream of dTFPE was determined by the other 7 dairy processors. Almost every firm's dTFPE was below 1 except there was a deviation in DOC whose dTFPE was equal to 2 in 2016 and 2017.

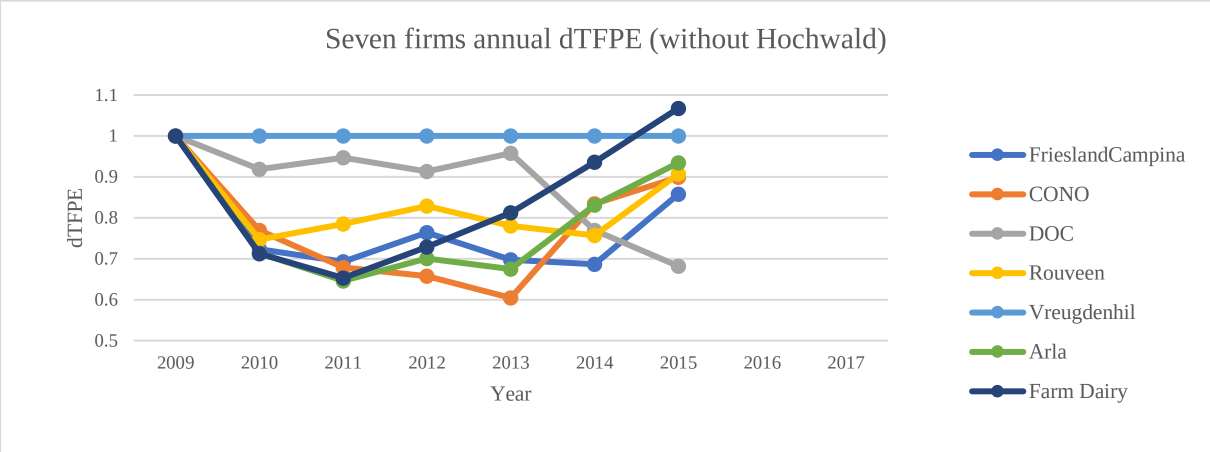

Figure 10b: Seven dairy processors annual efficiency changes

Figure 10b shows 7 firms dTFPE evolution based on the dataset excluding Hochwald company. The results are uniquely different compared to Figure 10a. In 2016 and 2017, dTFPE for each firm was hugely smaller than 0. Vreugdenhil showed continuous stagnation from 2009 to 2015, while other firms had different degrees of oscillations, for example, Farm Dairy sharply increased to above 1 in 2015. Unexpectedly, all dairy processors' dTFPE dropped to the lowest negative values in 2016. DOC distinguished itself from other firms by decreasing to negative infinity in 2016 and 2017. In order to show the evolution clearly, data in 2016 and 2017 were excluded from the figure. Furthermore, dOTE, dOSE and dRME of each firm are presented in the following figures.

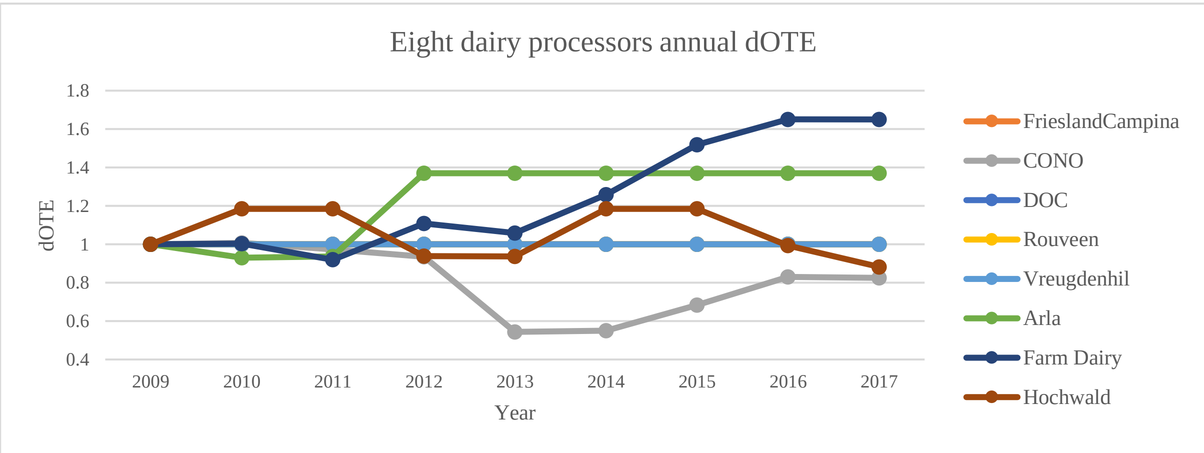

Figure 11a: Eight dairy processors annual technical efficiency change

Figure 11a shows only five lines because dOTE of FrieslandCampina, DOC, Rouveen and Vreugdenhil were all equal to 1 from 2009 to 2017, which can be found in Table A.4.1 of Appendix 4. It indicated that these four firms had a stagnated technical efficiency, while other firms showed some violent oscillations during the study period. Farm Dairy showed an overall remarkable increasing trend from the beginning of an index of 1 to the highest level of 1.650 in 2017; Arla increased to the top of 1.370 and kept this level for the rest of the study period; Hochwald fluctuated between 0.8 and 1.2; and CONO was the only company that had a technical efficiency regress (dOTE<1) all the time.

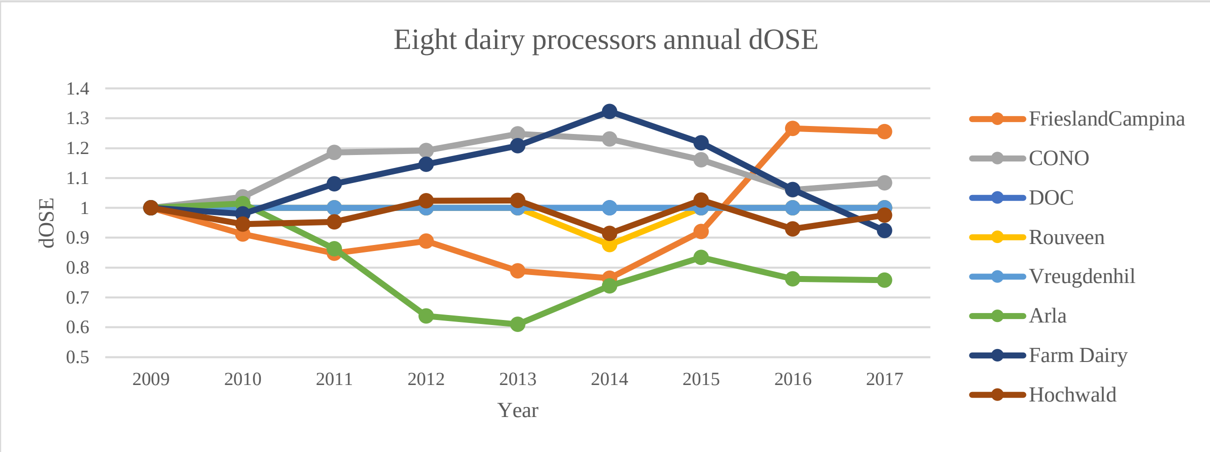

Figure 11b: Eight dairy processors annual scale efficiency change

Figure 11b shows remarkably different variations on eight firms' annual dOSE evolution. DOC, Rouveen and Vreugdenhil held an index of 1 all the time except there was a small deviation in 2014 when Rouveen's dOSE decreased to 0.88. The evolution of dOSE can be illustrated in three groups: the first group consisted of CONO and Farm Dairy whose dOSE were above 1 all the time, and they both increased to the top and decreased to the lowest after 2014; Hochwald in the second group showed a fluctuation around 1; and the last group included FrieslandCampina and Arla whose dOSE demonstrated apparent efficiency regress apart from an impressive sharp growth in FrieslandCampina that its dOSE increased from the bottom in 2014 (0.765) to the top in 2016 (1.266).

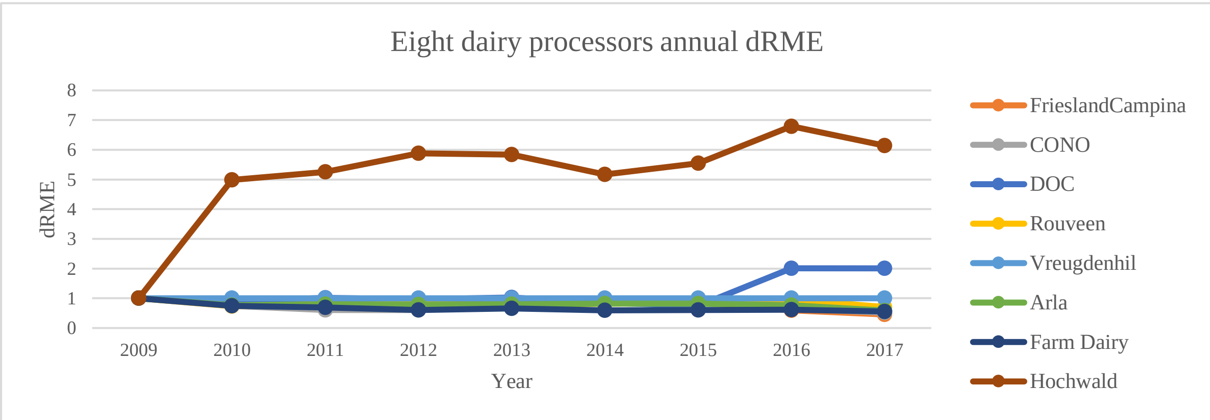

Figure 11c: Eight dairy processors annual residual mix efficiency change

In Figure 11c, Hochwald's dRME demonstrated a continually increasing trend from 2009 to 2017, which separated itself from the mainstream of dRME. In order to distinguish other firms' dRME evolution, Hochwald company was excluded from the dataset and reran the analysis to show the changes of 7 firms.

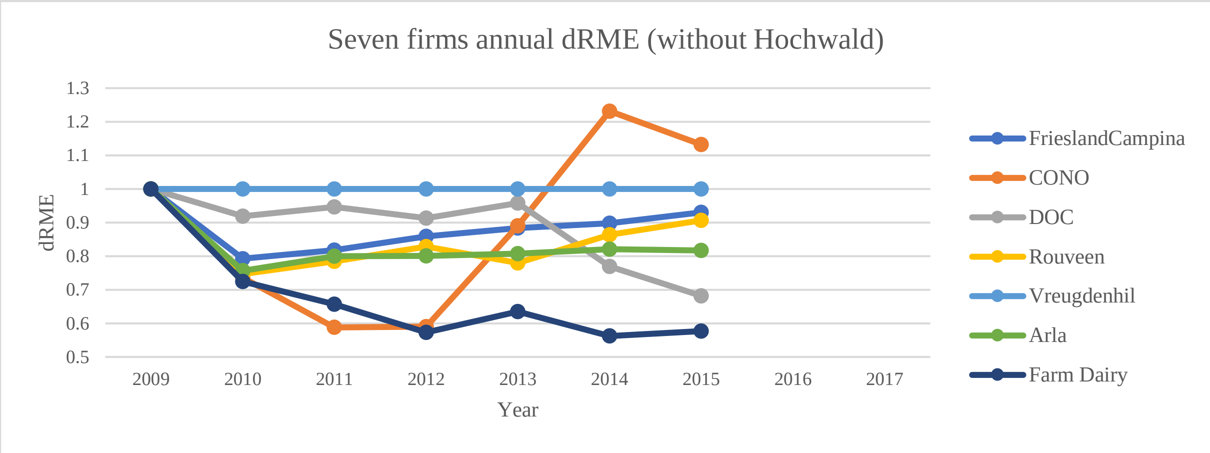

Figure 11d: Seven dairy processors annual residual mix efficiency change

Figure 11d shows that all seven firms' dRME were below 1, indicating efficiency regress except a noticeable increase spotted in CONO from 2012 to 2014. To a certain extent, all firms relatively fluctuated to a certain level of dRME in 2015 and dramatically declined to extremely smaller than 0 in 2016 and 2017 when DOC's dRME notably showed negative infinity. Data from 2016 and 2017 were excluded in Figure 11d in order to show the evolution clearly.

4.3 Robustness check

Considering there were only 8 observations qualified to form the sample in this study, the robustness of results was concerned. The total market share of 8 firms in 2015 (83%) was calculated first to show sufficient representativeness of the whole Dutch dairy processing industry. However, it is evident to recognise Hochwald and DOC as outliers in the sample due to Hochwald's noticeable deviation from the main range of results and the missing data of employment costs in DOC in 2016 and 2017.

Therefore, in order to avoid the problem that one specific firm strongly influences the overall results, Hochwald was deleted from the sample to rerun the analysis. The exhaustive results are shown in Table A.4.2 in Appendix 4. dPROF was the same as the initial results which can be found in Table A.4.1 of Appendix 4. dTFP was found to be slightly different, but the evolution for each firm was the same except for DOC. DOC's dTFP was observed to have positive infinity in 2016 and 2017. As for dTFPE and dRME, 7 firms had relatively vast differences and trends. The differences were extreme in DOC whose dTFPE and dRME showed negative infinity in 2016 and 2017. The changing pattern of 7 firms' dTFP, dTFPE and dRME can be found in Figure 6b, 10b and 11d respectively.

Furthermore, the data from 2016 and 2017 were excluded from the dataset due to the empirical estimation problem in this study as there were no employment costs in DOC in 2016 and 2017. The exhaustive results without 2016 and 2017 can be found in Table A.4.3 in Appendix 4. The results presented the same values as the initial results in Table A.4.1 of Appendix 4 only excluding the data from 2016 and 2017. Therefore, the results were confirmed.

5 DISCUSSION

This chapter aims to critically discuss the main findings and methods used during the study. Section 5.1 explores the effect of milk quota abolishment on dairy processors' profitability. Section 5.2 explains the components of total factor productivity index in practical meaning. The reason why dairy cooperatives and investor-owned firms showed different performances are explored in section 5.3. Lastly, section 5.4 provides alternative methods which can be used in the study.

5.1 Exploring the relation between dairy processors' profitability and milk quota abolishment

A limited amount of previous studies investigated the profitability of dairy processing industries without targeting the influence of milk quota abolishment on the profitability change. The research done by (Hirsch & Hartmann, 2014) studied the European dairy processing industry's profitability persistence based on the 13 years of 1996 through 2008. It concluded that European dairy processing industry held a deficient level of profit persistence, and profits of cooperatives fluctuated especially heavily over time. The results in the thesis research are partially consistent with these findings; it can be found that the evolution of Dutch dairy processing industry's profitability change, as well as cooperatives' profitability change, presented a constant decreasing trend without severe oscillations over the study period. After the abolished quota system in 2015, the Dutch dairy processing industry suffered profitability regress, which failed to meet the expectation of profitability growth. Considering there were not many studies that took milk quota abolishment into account to investigate the profitability change of dairy processing industries, results in this research are not sufficiently available to compare or align with other studies.

It is worth noticing that dPROF declined not only after milk quota abolishment but also during the milk quota relaxing period of 2009-2013. A visible price deterioration caused this consistent profitability decline over the study period. (Hirsch & Hartmann, 2014) prospected that EU trade liberalisation policies could bring fluctuations on milk price. The abolished milk quota system could push EU milk price even downwards. It aligned with the results of this study. The rapidly changing market situation and policy regulations did put a lot of pressure on products price. The most severe dairy crisis in 2009 led to a dramatical drop in milk and dairy products price, and unexpected shrinking demand in the Chinese market in 2014 brought about significant price decline in 2015.

5.2 Exploring technical change and efficiency change components

Considerable productivity growth from 2015 (1.406) to 2017 (1.766) was observed, which met the expectation of increased productivity. Technical change was found to be the primary source of productivity growth in this study. According to the definition provided by (O'Donnell C. , 2016), technology change refers to changes in the size of the meta-technology library, including a set of techniques, methods or systems for transforming inputs into outputs in any given period. Likewise, other economics literature pointed out that any slowdowns, speedups and improvements in the education of the labour force belonged to technical change as well (Solow, 1957). 2013 was the final year of implementing an annual increase of 1% quota policy (Commission, 2009). The increasing quota policy made some room for dairy farmers to produce more milk, indicating the inputs for dairy processors increased followingly. From the original dataset, it is not surprising that there were more employment costs required from 2009 to 2013 in general. This held the same after milk quota abolishment.

Also, the results showed that the distinct motivating factors of efficiency changes variation were dOTE and dRME. An overall technical efficiency growth was observed indicating that dairy processors in the sample can make the best practical use of existing technology by a given level of inputs, especially after 2014. Moreover, it can also mean that dairy processors reduced the number of errors in the production process (O'Donnell C. J., 2011). RME captures the difference between TFP at a technical and scale-efficient point and the maximum TFP that is possible through altering input mixes with existing technology. It was found that dRME over the study period was always larger than 1 except in 2017, indicating dairy processors in the sample failed to change the raw materials allocation or inputs usage structure in 2017 to become more efficient. The overall dOSE was always lower than 1 over the study period. Nevertheless, considering the rigid dairy industry's construction in the Netherlands, dairy processors in the sample were not likely to exploit their economies of scale (O'Donnell C. J., 2011).

5.3 Exploring the performance of certain dairy processing company

In this study, DOC was considered as an outlier in the sample besides Hochwald. According to DOC's financial reports, there were no employment costs in 2016 and 2017 because it has been emerged by another cooperative DMK GmbH since April 2016. Thus, its employees and resources belonged to DMK company. When applying a ratio-based Färe-Primont index, infeasibilities showed up in the results because of zeros in the inputs. Hochwald was recognised to have the best performance among other firms in the sample, considering its pronounced dPROF and dTFP. The legal form of Hochwald registered in the Orbis database is a private limited liability company. In contrast, Hochwald's official website presents itself as "a cooperatively structured dairy company" whose milk suppliers are not only members of the cooperative, but also owners. With the aim of research consistency, evaluation of the sample structure was based on registered legal forms in the Orbis database.

The sample consisted of four dairy processing cooperatives which were FrieslandCampina, CONO Kaasmakers, DOC Kaas and Rouveen; and four dairy processing investor-owned firms, including Vreugdenhil, Arla, Farm Dairy and Hochwald. In reality, the market has been dominated by five big cooperatives holding a joint market share of more than 80% since the 1950s (ZuivelNL, 2017). In Appendix 6, the performance of cooperatives and investor-owned firms was compared according to their annual dPROF, dTFP, dOTE, dOSE and dRME. The results demonstrated that cooperatives generally suffered profitability regress from 2009 to 2017. Meanwhile, investor-owned firms' dPROF grew at a respectable pace. Likewise, (Hirsch & Hartmann, 2014) had the same conclusion that around 77% of EU dairy cooperatives' long-run projected profit rates were significantly under zero. It should be kept in mind that the goals of investor-owned firms are closely linked to profitability, whereas the cooperatives' primary objective is to process all of its members' products and stabilise price optimally. It is necessary to take differences in cooperatives and investor-owned firms' mission and goals into account when comparing their performance.

To some extent, it is not surprising that cooperatives in the sample were generally not as profitable as investor-owned firms due to their different operational preferences. Another reason behind regressing profitability for cooperatives was that they aim to pay their members the highest possible price under the condition that it can still ensure the viability of the cooperative (Soboh, Lansink, Giesen, & Van Dijk, 2009). This can also be observed in the results of the thesis research that cooperatives had more favourable terms of trade change compared with investor-owned firms. However, in return, it brought the problem that cooperatives had to push the price they paid to their members to the point where no economic profit was generated (Novkovic, 2008).

It was also found that investor-owned firms were overall more productive than cooperatives. This was due to the relatively substantial technical efficiency and residual mix efficiency under the same existing technology in the industry. On the other hand, cooperatives strove to process all their members' milk, which is not helpful to make the best use of their labour force and resources. Moreover, it is worth mentioning that cooperatives gained benefits of scale efficiency, indicating that they comparable worked at an efficient scale. These results are partially in line with (Soboh, Lansink, & Van Dijk, 2014) and (Soboh, 2009) which showed cooperatives were slightly less efficient than investor-owned firms although they had a more productive technology.

Whether it is the profitable structure for the dairy processing industry to let few cooperatives dominate the market is still questionable. Nevertheless, there is a reason on how this structure has become for more than 130 years (Bijman, 2018). It has been claimed from economic historians that the rise and rapid growth of cooperatives in the dairy from 1886 to 1916 was a response from dairy farmers' needs to reduce transaction costs and strengthen bargaining power on account of a high transaction cost of selling to private factories (Van Zanden, 1994; Henriksen, 1999; Fernández, 2014; Ronsijn, 2014). Around 1916, the switch from hand power to steam power in the dairy industry required a larger scale of production, which led to the closure of small hand-power factories. The number of dairy cooperatives started to decline fast because some factories without sufficient scale failed to afford the expensive steam-power machinery. After that, economies of scale, especially in milk processing, was the main argument for cooperatives to merge into larger entities, causing only five cooperatives left in the industry until now (Bijman, 2018).

5.4 Possible alternative methods used in the research

The literature has used diverse methods to determine the performance of dairy processing companies. One group of research, for example from (Soboh, Lansink, Giesen, & Van Dijk, 2009), used financial ratios to measure the financial performance of dairy processing firms and then compared them with each other. Another group of researchers analysed technical efficiency using DEA or SFA (Singh, Coelli, & Fleming, 2001; Doucouliagos & Hone, 2000; Boyle, 2004). In this study, Färe-Primont index, together with DEA, was used to assess the performance of dairy processors in the Netherlands by decomposing profitability and total factor productivity index to capture the profitability change, total factor productivity change, and efficiency changes. This study chose to report results based on geometric means. Considering Färe-Primont index is ratio-based, it is more precise to report results as geometric means although some studies, for instance (Islam, Xayavong, & Kingwell, 2014) used the arithmetic means.

After deleting Hochwald from the sample, dTFP and dRME of DOC in 2016 and 2017 presented infeasibilities. However, it is empirically unrealistic to achieve an infinitive total factor productivity change. TFP index is calculated as aggregate output quantity divided by aggregate inputs quantity. When there were zeros in the inputs like zero employment costs in 2016 and 2017 in this study, aggregate input quantity which was calculated by the ratio-based index would present infeasibility (O'Donnell C. , 2008; O'Donnell C. J., 2012). As for infeasible dRME in the results, it was also due to the problem of aggregate input quantity which was associated with alternations of inputs mix.

A multiplicative-complete total factor productivity index like Färe-Primont index is ratio-based. Its transitivity allows multilateral and multitemporal comparisons. In contrast, Bennet-Lowe total factor productivity indicator is difference-based, additively complete and also transitive (Ang, 2019). Rather than dividing aggregate output quantity by aggregate input quantity to get productivity change, it used the difference between aggregated output quantity and aggregated input quantity. By applying a nonparametric method as DEA, this indicator can be exhaustively decomposed into technical change and efficiency change components as well, which would solve the infeasibility problem in this study. In addition, the decomposition of profitability index can be implemented by an aggregate quantity-price framework (O'Donnell C. , 2008) which used carefully-defined price and quantity aggregates to decompose profitability index into a product of terms of trade index and productivity index. Furthermore, this study used output-orientated DEA to measure different efficiency changes. The input-orientated approach could be an alternative method focusing on the level of inputs necessary to produce observed output level under a reference technology (Coelli, Rao, O'Donnell, & Battese, 2005).

6 CONCLUSIONS

This research aimed to analyse the profitability change of Dutch dairy processing industry from 2009 to 2017 by decomposing Färe-Primont profitability index and further decomposing total factor productivity index into technical change and efficiency changes with the DEA approach. ***The overall result*** *revealed that there was more than 76.6% productivity growth in 2017 compared to 2009. However, severe unfavourable dTT (0.485) determined the profitability regress (0.856) in 2017. Expectations of the results have been partially met. There was an increased TFP but not profitability growth. Specifically, the study answered the following sub research questions.*

Sub research question 1- What has changed after removing milk quotas in Dutch dairy processing industry?

It was observed that after removing milk quotas in the Netherlands, 7.5% more milk delivered to the Dutch dairy processors in 2016 compared to 2015. A small decrease (-0.5%) was spotted in 2017. Total revenue of the dairy processing industry achieved €7.7 billion in 2017, accounting for a significant increase of 20% compared to the years 2015 and 2016. Export value also significantly increased by 22% in 2017. Meanwhile, milk prices fluctuated a lot, particularly after 2015 when both raw milk price and dairy products price dropped to the relatively lowest prices. They recovered back in 2017 due to good demand in the global market. Moreover, new manure policy like Phosphate Production Reduction Decree (PPRD) is regarded as, more or less, a new quota in the market.

Sub research question 2- What is the productivity change in Dutch dairy processing industry?

Sub research question 3- What are the terms of trade changes in Dutch dairy processing industry?

Continuous TFP growth was found over the study period, with an annual growth rate of 7.109%. Compared to 2009, TFP increased by 76.6% in 2017. In contrast, dTT continuously decreased to 0.485 in 2017, indicating aggregate output price relative to aggregate inputs price was unfavourable over the study period.

Sub research question 4- What are technical change and efficiency changes in Dutch dairy processing industry?

Technology progress as the primary source of productivity growth, was observed during the study period with an annual growth rate of 7.059% in dMP. Additionally, 6.4% growth of technical efficiency in 2017 was found to be the primary contributor on the evolution of dTFPE. Regresses on dRME and dOSE (0.952; 0.991) were found in 2017 compared with an index of 1 in 2009. It demonstrated that dairy processors in the sample could innovate their technology or production systems to increase productivity. They could operate with improved technical efficiency but not on the optimal scale. Furthermore, they failed to change their inputs mix to become more efficient.

Recommendations:

There are several vital implications generated from this study, which can be used to recommend dairy processors and policymakers who aim to improve the performance of Dutch dairy processing industry. The sudden abolished quota system put dramatically pressure on dairy processors as they should decide on how to process the increased milk. Additional processing capacity is strongly required. Adjustment production costs are generated in case new or improved production systems are adopted. When it comes to the period of regressing technology, more research and development funding is needed to innovate the technology and shift the production frontier upwards (O'Donnell C. J., 2011; Islam, Xayavong, & Kingwell, 2014). The development of production systems demands science and a process to convert generated knowledge into processors' practice (O'Donnell C. J., 2011). Companies can cope with universities and research institutes to construct research projects to gain knowledge and speed up the innovation procedure.

When applying different policies in the company, it is crucial to stay alert and understand individual dairy processor's status (O'Donnell C. J., 2011). For example, Research and development (R&D) policies are expected to have a more massive effect on rates of technical change than on technical efficiency change. Under the scenario that firms are already entirely technical efficient, education and training programs which help to improve technical efficiency are unlikely to increase productivity.

As for further research, it is possible to include other countries like Belgium, Germany or Denmark, which have similar dairy structures to increase population size. Therefore, the problem of a small sample in this study could be solved. Moreover, stochastic frontier approach (SFA) is highly recommended to apply instead of DEA to solve the sensitivity of measurement errors.

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Appendix 1 The distinction between DEA and SFA approach

Table A.1 The distinction between DEA and SFA approach Source: (Lampe & Hilgers, 2015)

	Data Envelopment Analysis (DEA)	Stochastic Frontier Analysis (SFA)
Elements	Multi outputs and inputs	Single input (output) and multi-output (input)
Algorithm	Linear programming	Regression (typically using maximum likelihood estimation)
Consideration of noise	Noise is included in the efficiency score (deterministic model)	Noise is differentiated from inefficiency (stochastic model)
Functional form	Not specified (everything that might be linearized)	The functional form is specified (e.g. linear, semi-log, double-log)
Factor weights	Individual factor weights for each unit (non-parametric)	No individual factor weights in the basic model (parametric)
Main application field	airport; agriculture; fishery; forestry; supplier selection; environmental performance; energy efficiency; general resource allocation in the companies	banking sector; agriculture; fishery insurance companies; container ports; hospital/health care sector;

Appendix 2 Dairy processing firms’ information

Table A.2 Dairy processing firms’ information (Source: Bureau van Dijk)

Company name	Products and service	Legal form
FrieslandCampina	cheese, yoghurt, milk, milk foam, fruit milk, buttermilk, creams, drinks, and meat from dairy produce	Cooperative company
CONO Kaasmakers	cheese	Cooperative company
DOC Kaas	cheese	Cooperative company
Rouveen Kaasspecialiteiten	creamery butter; cheese products; and dry, condensed, and evaporated dairy products	Cooperative company
Arla Foods	Milk, cream and other dairy products in solid forms, curds, as well as cow’s milk, and other related dairy products	Private limited liability company – BV
Farm Dairy	Fluid milk, yoghurt, fruit yoghurts, buttermilk, custards	Private limited liability company – BV
Vreugdenhil Dairy Foods	Wholesale dairy products, eggs and edible oils and fats	Private limited liability company – BV
Hochwald	dairy products, edible oils and fats	Private limited liability company – BV

Appendix 3 Overall results of Dutch dairy processing industry

Table A.3.1 The arithmetic means of dPROF, dTFP and their components for Dutch dairy processing industry from 2009 to 2017

Year	dPROF	dTT	dTFP	dMP	dTFPE	dOTE	dOSE	dRME
2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2010	1.128	0.748	2.200	1.575	1.397	1.016	0.986	1.334
2011	1.111	0.671	2.492	1.741	1.432	1.002	0.991	1.371
2012	1.076	0.714	2.200	1.554	1.415	1.044	0.986	1.439
2013	1.077	0.630	2.504	1.796	1.394	0.989	0.985	1.472
2014	1.079	0.680	2.244	1.586	1.415	1.045	0.981	1.388
2015	1.050	0.768	2.013	1.245	1.617	1.095	1.020	1.421
2016	0.945	0.680	2.131	1.269	1.679	1.106	1.010	1.672
2017	0.929	0.598	2.527	1.759	1.437	1.091	1.000	1.497

Table A.3.2 The medians of dPROF, dTFP and their components for Dutch dairy processing industry from 2009 to 2017

Year	dPROF	dTT	dTFP	dMP	dTFPE	dOTE	dOSE	dRME
2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2010	1.004	0.842	1.188	1.575	0.754	1.000	1.000	0.776
2011	0.981	0.785	1.288	1.741	0.740	1.000	1.000	0.816
2012	0.985	0.794	1.226	1.554	0.789	1.000	1.000	0.830
2013	0.989	0.678	1.447	1.796	0.806	1.000	1.000	0.846
2014	0.975	0.679	1.335	1.586	0.841	1.000	0.957	0.863
2015	0.983	0.815	1.118	1.245	0.898	1.000	1.000	0.868
2016	0.876	0.851	1.242	1.269	0.979	1.000	1.000	0.862
2017	0.901	0.650	1.369	1.759	0.778	1.000	1.000	0.648

Appendix 4 Exhaustive results of each dairy processor

Table A.4.1 Eight dairy processors' annual dPROF, dTFP and components from 2009 to 2017

Firms	Years	dPROF	dTT	dTFP	dMP	dTFPE	dOTE	dOSE	dRME
FrieslandCampina	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CONO	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
DOC	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Rouveen	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Vreugdenhil	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Arla	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
FarmDairy	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hochwald	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
FrieslandCampina	2010	1.005	0.887	1.133	1.575	0.719	1.000	0.912	0.789
CONO	2010	1.010	0.826	1.223	1.575	0.776	1.007	1.037	0.743
DOC	2010	1.204	0.837	1.439	1.575	0.913	1.000	1.000	0.913
Rouveen	2010	1.000	0.866	1.154	1.575	0.733	1.000	1.000	0.733
Vreugdenhil	2010	1.003	0.637	1.575	1.575	1.000	1.000	1.000	1.000
Arla	2010	0.961	0.847	1.134	1.575	0.720	0.930	1.015	0.763
FarmDairy	2010	1.002	0.872	1.148	1.575	0.729	1.003	0.980	0.741
Hochwald	2010	1.835	0.209	8.793	1.575	5.582	1.184	0.945	4.987

FrieslandCampina	2011	0.982	0.798	1.230	1.741	0.707	1.000	0.847	0.834
CONO	2011	0.981	0.802	1.223	1.741	0.702	0.974	1.185	0.608
DOC	2011	1.372	0.778	1.763	1.741	1.013	1.000	1.000	1.013
Rouveen	2011	0.863	0.641	1.346	1.741	0.773	1.000	1.000	0.773
Vreugdenhil	2011	1.003	0.576	1.741	1.741	1.000	1.000	1.000	1.000
Arla	2011	0.890	0.792	1.124	1.741	0.645	0.936	0.863	0.799
FarmDairy	2011	0.963	0.805	1.197	1.741	0.687	0.919	1.080	0.692
Hochwald	2011	1.838	0.178	10.317	1.741	5.927	1.184	0.953	5.252
FrieslandCampina	2012	0.966	0.820	1.178	1.554	0.758	1.000	0.889	0.853
CONO	2012	0.952	0.909	1.047	1.554	0.673	0.936	1.192	0.604
DOC	2012	1.155	0.767	1.505	1.554	0.968	1.000	1.000	0.968
Rouveen	2012	0.772	0.615	1.256	1.554	0.808	1.000	1.000	0.808
Vreugdenhil	2012	1.004	0.646	1.554	1.554	1.000	1.000	1.000	1.000
Arla	2012	0.899	0.834	1.078	1.554	0.694	1.370	0.638	0.794
FarmDairy	2012	1.100	0.920	1.196	1.554	0.769	1.108	1.146	0.606
Hochwald	2012	1.762	0.201	8.782	1.554	5.650	0.939	1.023	5.881
FrieslandCampina	2013	0.973	0.795	1.224	1.796	0.681	1.000	0.789	0.864
CONO	2013	0.795	0.788	1.009	1.796	0.562	0.544	1.248	0.828
DOC	2013	1.125	0.610	1.844	1.796	1.026	1.000	1.000	1.026
Rouveen	2013	0.803	0.587	1.369	1.796	0.762	1.000	1.000	0.762

Vreugdenhil	2013	1.004	0.559	1.796	1.796	1.000	1.000	1.000	1.000
Arla	2013	0.892	0.746	1.196	1.796	0.666	1.370	0.610	0.797
FarmDairy	2013	1.179	0.773	1.525	1.796	0.849	1.059	1.208	0.664
Hochwald	2013	1.840	0.183	10.072	1.796	5.607	0.937	1.025	5.839
FrieslandCam pina	2014	0.909	0.855	1.063	1.586	0.670	1.000	0.765	0.877
CONO	2014	0.668	0.640	1.045	1.586	0.658	0.551	1.231	0.972
DOC	2014	1.299	0.964	1.348	1.586	0.849	1.000	1.000	0.849
Rouveen	2014	0.701	0.614	1.140	1.586	0.719	1.000	0.877	0.820
Vreugdenhil	2014	1.000	0.631	1.586	1.586	1.000	1.000	1.000	1.000
Arla	2014	0.949	0.718	1.322	1.586	0.833	1.370	0.739	0.823
FarmDairy	2014	1.272	0.813	1.564	1.586	0.986	1.258	1.323	0.592
Hochwald	2014	1.833	0.206	8.883	1.586	5.600	1.184	0.914	5.173
FrieslandCam pina	2015	0.910	0.901	1.009	1.245	0.811	1.000	0.921	0.880
CONO	2015	0.687	0.768	0.895	1.245	0.719	0.684	1.161	0.905
DOC	2015	1.008	1.084	0.930	1.245	0.747	1.000	1.000	0.747
Rouveen	2015	0.692	0.649	1.067	1.245	0.857	1.000	1.000	0.857
Vreugdenhil	2015	0.987	0.792	1.245	1.245	1.000	1.000	1.000	1.000
Arla	2015	0.979	0.837	1.169	1.245	0.939	1.370	0.834	0.821
FarmDairy	2015	1.245	0.889	1.400	1.245	1.125	1.518	1.218	0.608
Hochwald	2015	1.890	0.225	8.390	1.245	6.740	1.184	1.026	5.546
FrieslandCam	2016	0.849	0.891	0.953	1.269	0.751	1.000	1.266	0.593

pina									
CONO	2016	0.706	0.978	0.721	1.269	0.568	0.831	1.060	0.646
DOC	2016	0.324	0.127	2.550	1.269	2.010	1.000	1.000	2.010
Rouveen	2016	0.708	0.583	1.215	1.269	0.958	1.000	1.000	0.958
Vreugdenhil	2016	1.031	0.812	1.269	1.269	1.000	1.000	1.000	1.000
Arla	2016	0.902	0.889	1.014	1.269	0.800	1.370	0.763	0.765
FarmDairy	2016	1.286	0.940	1.369	1.269	1.079	1.651	1.061	0.616
Hochwald	2016	1.753	0.220	7.955	1.269	6.270	0.994	0.929	6.792
FrieslandCampina	2017	0.894	0.887	1.008	1.759	0.573	1.000	1.255	0.457
CONO	2017	0.721	0.886	0.814	1.759	0.463	0.824	1.084	0.518
DOC	2017	0.356	0.101	3.529	1.759	2.006	1.000	1.000	2.006
Rouveen	2017	0.746	0.600	1.244	1.759	0.707	1.000	1.000	0.707
Vreugdenhil	2017	1.019	0.579	1.759	1.759	1.000	1.000	1.000	1.000
Arla	2017	0.907	0.844	1.076	1.759	0.612	1.370	0.758	0.589
FarmDairy	2017	1.045	0.700	1.493	1.759	0.849	1.650	0.924	0.557
Hochwald	2017	1.747	0.188	9.292	1.759	5.283	0.882	0.975	6.140

Table A.4.2 Seven dairy processors' annual dPROF, dTFP and components from 2009 to 2017

Firms	Years	dPROF	dTT	dTFP	dMP	dTFPE	dOTE	dOSE	dRME
FrieslandCampina	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

CONO	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
DOC	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Rouveen	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Vreugdenhil	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Arla	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
FarmDairy	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
FrieslandCampina	2010	1.005	0.882	1.139	1.576	0.723	1.000	0.912	0.793
CONO	2010	1.010	0.833	1.212	1.576	0.769	1.007	1.037	0.736
DOC	2010	1.204	0.832	1.447	1.576	0.919	1.000	1.000	0.919
Rouveen	2010	1.000	0.850	1.177	1.576	0.747	1.000	1.000	0.747
Vreugdenhil	2010	1.003	0.637	1.576	1.576	1.000	1.000	1.000	1.000
Arla	2010	0.961	0.854	1.125	1.576	0.714	0.930	1.015	0.757
FarmDairy	2010	1.002	0.893	1.122	1.576	0.712	1.003	0.980	0.724
FrieslandCampina	2011	0.982	0.814	1.206	1.741	0.693	1.000	0.847	0.818
CONO	2011	0.981	0.830	1.181	1.741	0.679	0.974	1.185	0.588
DOC	2011	1.372	0.833	1.647	1.741	0.946	1.000	1.000	0.946
Rouveen	2011	0.863	0.632	1.366	1.741	0.785	1.000	1.000	0.785
Vreugdenhil	2011	1.003	0.576	1.741	1.741	1.000	1.000	1.000	1.000
Arla	2011	0.890	0.792	1.125	1.741	0.646	0.936	0.863	0.800
FarmDairy	2011	0.963	0.848	1.136	1.741	0.653	0.919	1.080	0.657

FrieslandCampina	2012	0.966	0.814	1.187	1.555	0.764	1.000	0.889	0.859
CONO	2012	0.952	0.931	1.022	1.555	0.658	0.936	1.192	0.590
DOC	2012	1.155	0.814	1.420	1.555	0.913	1.000	1.000	0.913
Rouveen	2012	0.772	0.599	1.288	1.555	0.829	1.000	1.000	0.829
Vreugdenhil	2012	1.004	0.646	1.555	1.555	1.000	1.000	1.000	1.000
Arla	2012	0.899	0.826	1.089	1.555	0.700	1.370	0.638	0.801
FarmDairy	2012	1.100	0.971	1.133	1.555	0.729	1.108	1.146	0.573
FrieslandCampina	2013	0.973	0.775	1.256	1.802	0.697	1.000	0.789	0.884
CONO	2013	0.795	0.730	1.089	1.802	0.604	0.544	1.248	0.891
DOC	2013	1.125	0.652	1.725	1.802	0.958	1.000	1.000	0.958
Rouveen	2013	0.803	0.571	1.406	1.802	0.780	1.000	1.000	0.780
Vreugdenhil	2013	1.004	0.557	1.802	1.802	1.000	1.000	1.000	1.000
Arla	2013	0.892	0.733	1.216	1.802	0.675	1.370	0.610	0.807
FarmDairy	2013	1.179	0.805	1.464	1.802	0.812	1.059	1.208	0.635
FrieslandCampina	2014	0.909	0.833	1.091	1.589	0.686	1.000	0.765	0.898
CONO	2014	0.668	0.504	1.326	1.589	0.834	0.551	1.231	1.232
DOC	2014	1.299	1.062	1.223	1.589	0.770	1.000	1.000	0.770
Rouveen	2014	0.701	0.582	1.203	1.589	0.757	1.000	0.877	0.864
Vreugdenhil	2014	1.000	0.630	1.589	1.589	1.000	1.000	1.000	1.000
Arla	2014	0.949	0.718	1.321	1.589	0.831	1.370	0.739	0.821

FarmDairy	2014	1.272	0.855	1.487	1.589	0.936	1.258	1.323	0.562
FrieslandCampina	2015	0.910	0.848	1.073	1.251	0.857	1.000	0.921	0.931
CONO	2015	0.687	0.611	1.125	1.251	0.899	0.684	1.161	1.132
DOC	2015	1.008	1.182	0.853	1.251	0.682	1.000	1.000	0.682
Rouveen	2015	0.692	0.610	1.134	1.251	0.906	1.000	1.000	0.906
Vreugdenhil	2015	0.987	0.788	1.251	1.251	1.000	1.000	1.000	1.000
Arla	2015	0.979	0.837	1.169	1.251	0.934	1.370	0.834	0.817
FarmDairy	2015	1.245	0.932	1.336	1.251	1.067	1.518	1.218	0.577
FrieslandCampina	2016	0.849	0.793	1.071	-5.6881E+28	-1.88259E-29	1.000	1.266	-1.48694E-29
CONO	2016	0.706	0.839	0.841	-5.6881E+28	-1.5E-29	0.831	1.060	-1.7E-29
DOC	2016	0.324	0.000	Inf	-5.6881E+28	-Inf	1.000	1.000	-Inf
Rouveen	2016	0.708	0.545	1.301	-5.6881E+28	-2.3E-29	1.000	1.000	-2.3E-29
Vreugdenhil	2016	1.031	0.802	1.285	-5.6881E+28	-2.258E-29	1.000	1.000	-2.258E-29
Arla	2016	0.902	0.853	1.057	-5.6881E+28	-1.9E-29	1.370	0.763	-1.8E-29
FarmDairy	2016	1.286	0.979	1.314	-5.6881E+28	-2.31E-29	1.651	1.061	-1.32E-29
FrieslandCampina	2017	0.894	0.810	1.104	-5.6881E+28	-1.94177E-29	1.000	1.255	-1.54762E-29
CONO	2017	0.721	0.766	0.942	-5.6881E+28	-1.7E-29	0.824	1.084	-1.9E-29
DOC	2017	0.356	0.000	Inf	-5.6881E+28	-Inf	1.000	1.000	-Inf
Rouveen	2017	0.746	0.568	1.314	-5.6881E+28	-2.3E-29	1.000	1.000	-2.3E-29
Vreugdenhil	2017	1.019	0.574	1.776	-5.6881E+28	-3.122E-29	1.000	1.000	-3.122E-29

Arla	2017	0.907	0.820	1.106	-5.6881E+28	-1.9E-29	1.370	0.758	-1.9E-29
FarmDairy	2017	1.045	0.737	1.418	-5.6881E+28	-2.49E-29	1.650	0.924	-1.64E-29

Table A.4.3 Seven dairy processors' annual dPROF, dTFP and components from 2009 to 2015

Firms	Years	dPROF	dTT	dTFP	dMP	dTFPE	dOTE	dOSE	dRME
FrieslandCampina	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CONO	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
DOC	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Rouveen	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Vreugdenhil	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Arla	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
FarmDairy	2009	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
FrieslandCampina	2010	1.005	0.887	1.133	1.575	0.719	1.000	0.912	0.789
CONO	2010	1.010	0.826	1.223	1.575	0.776	1.007	1.037	0.743
DOC	2010	1.204	0.837	1.439	1.575	0.913	1.000	1.000	0.913
Rouveen	2010	1.000	0.866	1.154	1.575	0.733	1.000	1.000	0.733
Vreugdenhil	2010	1.003	0.637	1.575	1.575	1.000	1.000	1.000	1.000
Arla	2010	0.961	0.847	1.134	1.575	0.720	0.930	1.015	0.763
FarmDairy	2010	1.002	0.872	1.148	1.575	0.729	1.003	0.980	0.741
FrieslandCam	2011	0.982	0.798	1.230	1.741	0.707	1.000	0.847	0.834

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CONO	2011	0.981	0.802	1.223	1.741	0.702	0.974	1.185	0.608
DOC	2011	1.372	0.778	1.763	1.741	1.013	1.000	1.000	1.013
Rouveen	2011	0.863	0.641	1.346	1.741	0.773	1.000	1.000	0.773
Vreugdenhil	2011	1.003	0.576	1.741	1.741	1.000	1.000	1.000	1.000
Arla	2011	0.890	0.792	1.124	1.741	0.645	0.936	0.863	0.799
FarmDairy	2011	0.963	0.805	1.197	1.741	0.687	0.919	1.080	0.692
FrieslandCampina	2012	0.966	0.820	1.178	1.554	0.758	1.000	0.889	0.853
CONO	2012	0.952	0.909	1.047	1.554	0.673	0.936	1.192	0.604
DOC	2012	1.155	0.767	1.505	1.554	0.968	1.000	1.000	0.968
Rouveen	2012	0.772	0.615	1.256	1.554	0.808	1.000	1.000	0.808
Vreugdenhil	2012	1.004	0.646	1.554	1.554	1.000	1.000	1.000	1.000
Arla	2012	0.899	0.834	1.078	1.554	0.694	1.370	0.638	0.794
FarmDairy	2012	1.100	0.920	1.196	1.554	0.769	1.108	1.146	0.606
FrieslandCampina	2013	0.973	0.795	1.224	1.796	0.681	1.000	0.789	0.864
CONO	2013	0.795	0.788	1.009	1.796	0.562	0.544	1.248	0.828
DOC	2013	1.125	0.610	1.844	1.796	1.026	1.000	1.000	1.026
Rouveen	2013	0.803	0.587	1.369	1.796	0.762	1.000	1.000	0.762
Vreugdenhil	2013	1.004	0.559	1.796	1.796	1.000	1.000	1.000	1.000
Arla	2013	0.892	0.746	1.196	1.796	0.666	1.370	0.610	0.797
FarmDairy	2013	1.179	0.773	1.525	1.796	0.849	1.059	1.208	0.664

FrieslandCampina	2014	0.909	0.855	1.063	1.586	0.670	1.000	0.765	0.877
CONO	2014	0.668	0.640	1.045	1.586	0.658	0.551	1.231	0.972
DOC	2014	1.299	0.964	1.348	1.586	0.849	1.000	1.000	0.849
Rouveen	2014	0.701	0.614	1.140	1.586	0.719	1.000	0.877	0.820
Vreugdenhil	2014	1.000	0.631	1.586	1.586	1.000	1.000	1.000	1.000
Arla	2014	0.949	0.718	1.322	1.586	0.833	1.370	0.739	0.823
FarmDairy	2014	1.272	0.813	1.564	1.586	0.986	1.258	1.323	0.592
FrieslandCampina	2015	0.910	0.901	1.009	1.245	0.811	1.000	0.921	0.880
CONO	2015	0.687	0.768	0.895	1.245	0.719	0.684	1.161	0.905
DOC	2015	1.008	1.084	0.930	1.245	0.747	1.000	1.000	0.747
Rouveen	2015	0.692	0.649	1.067	1.245	0.857	1.000	1.000	0.857
Vreugdenhil	2015	0.987	0.792	1.245	1.245	1.000	1.000	1.000	1.000
Arla	2015	0.979	0.837	1.169	1.245	0.939	1.370	0.834	0.821
FarmDairy	2015	1.245	0.889	1.400	1.245	1.125	1.518	1.218	0.608
Hochwald	2015	1.890	0.225	8.390	1.245	6.740	1.184	1.026	5.546

Appendix 5 Arithmetic means and medians of Dutch dairy processing industry's dPROF and dTFP decomposition

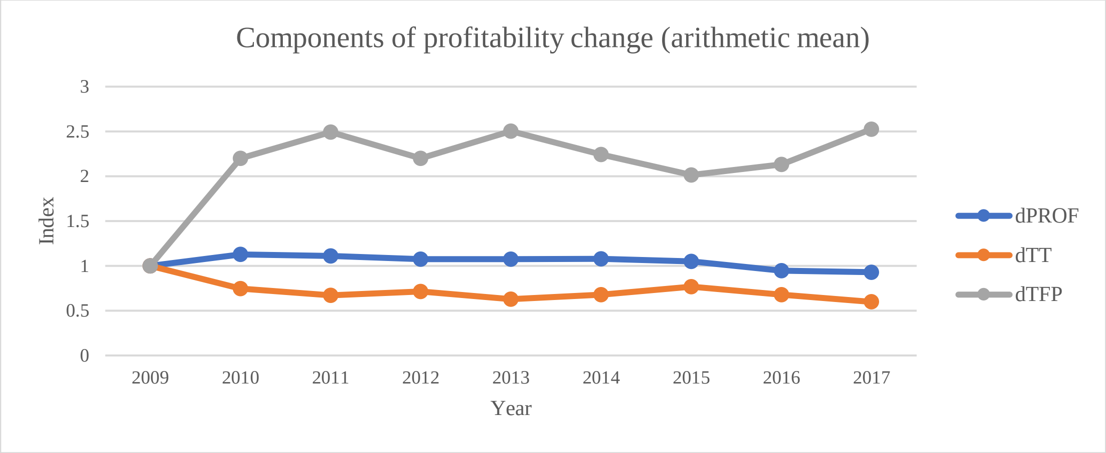

Figure A.5.1 Evolution of Dutch dairy processing industry's annual dPROF, dTT and dTFP (arithmetic mean)

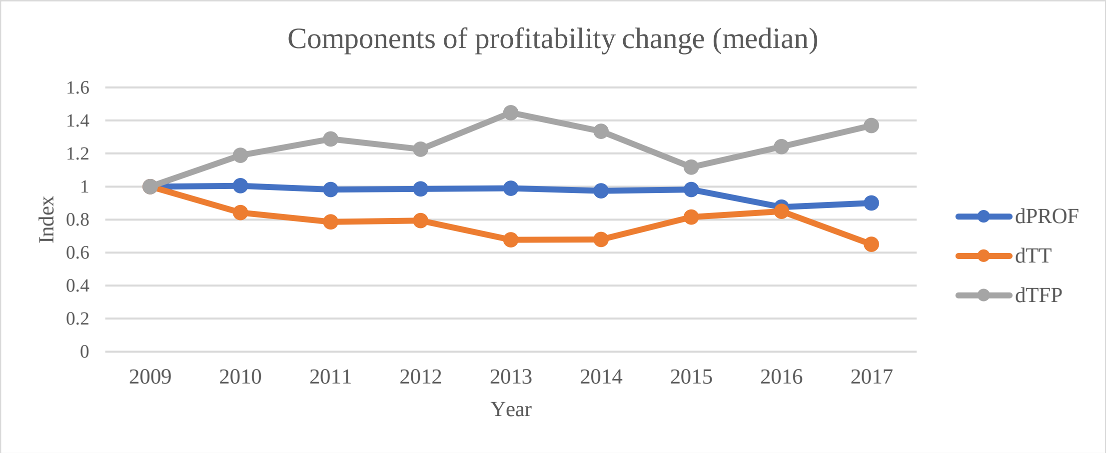

Figure A.5.2 Evolution of Dutch dairy processing industry's annual dPROF, dTT and dTFP (medians)

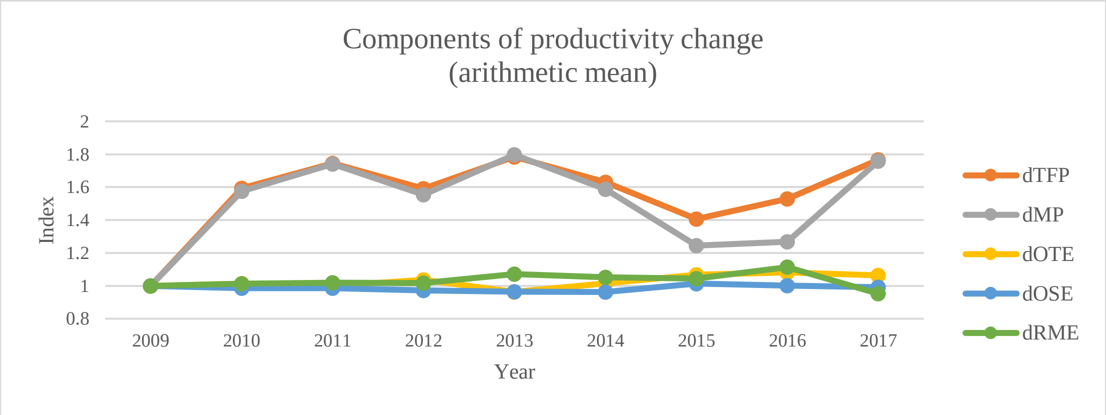

Figure A.5.3 Evolution of Dutch dairy processing industry's annual dTFP and its components (arithmetic means)

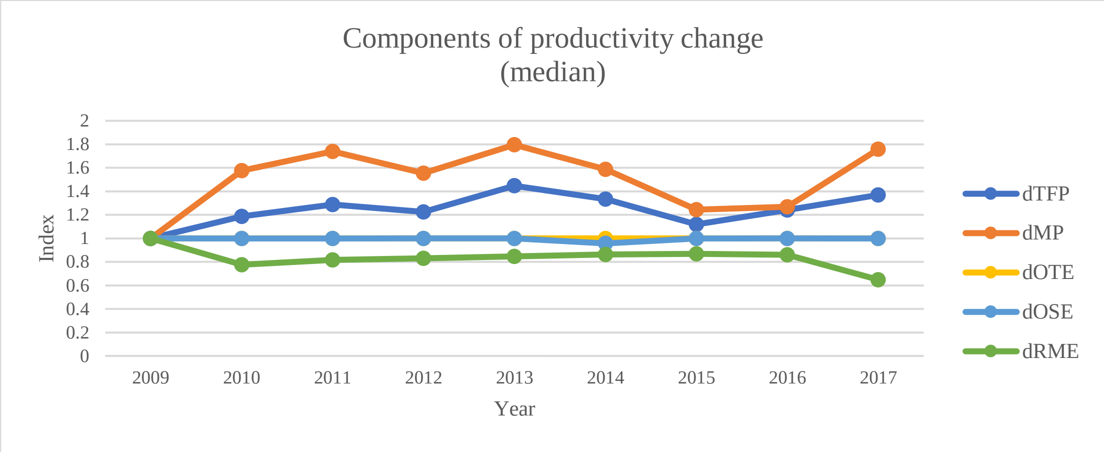

Figure A.5.4 Evolution of Dutch dairy processing industry's annual dTFP and its components (medians)

Appendix 6 Indices comparison between cooperatives and investor-owned firms

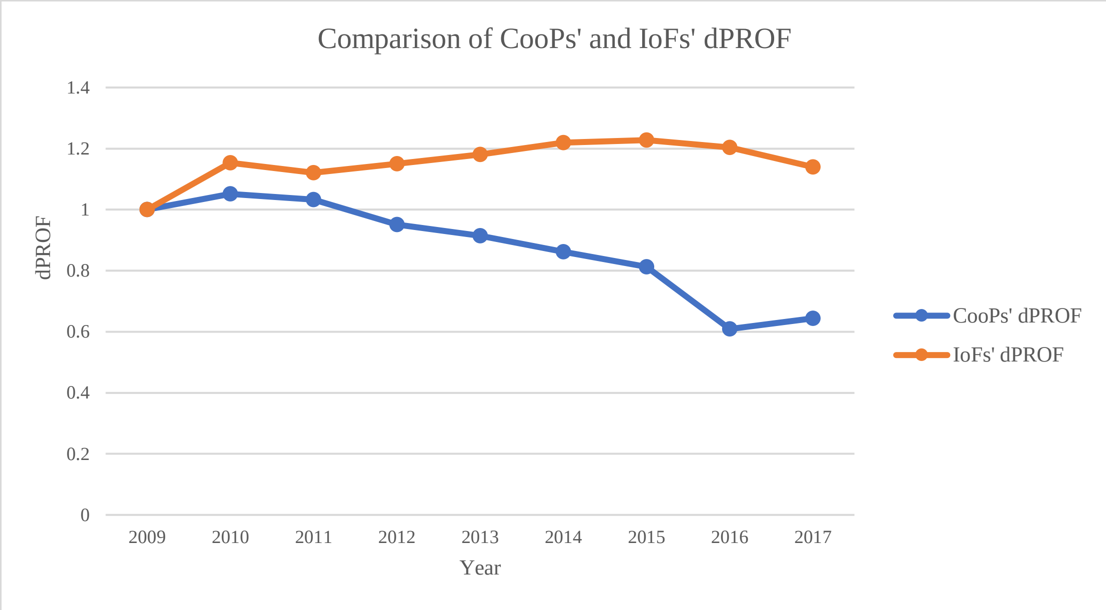

Figure A.6.1 Evolution of cooperatives and investor-owned firms' annual dPROF

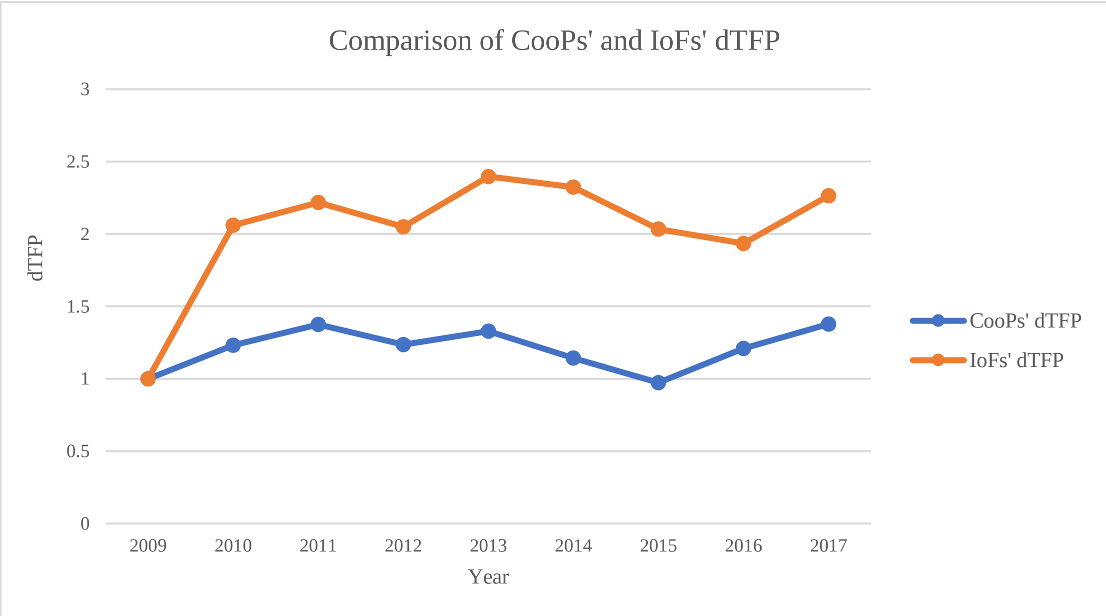

Figure A.6.2 Evolution of cooperatives and investor-owned firms' annual dTFP

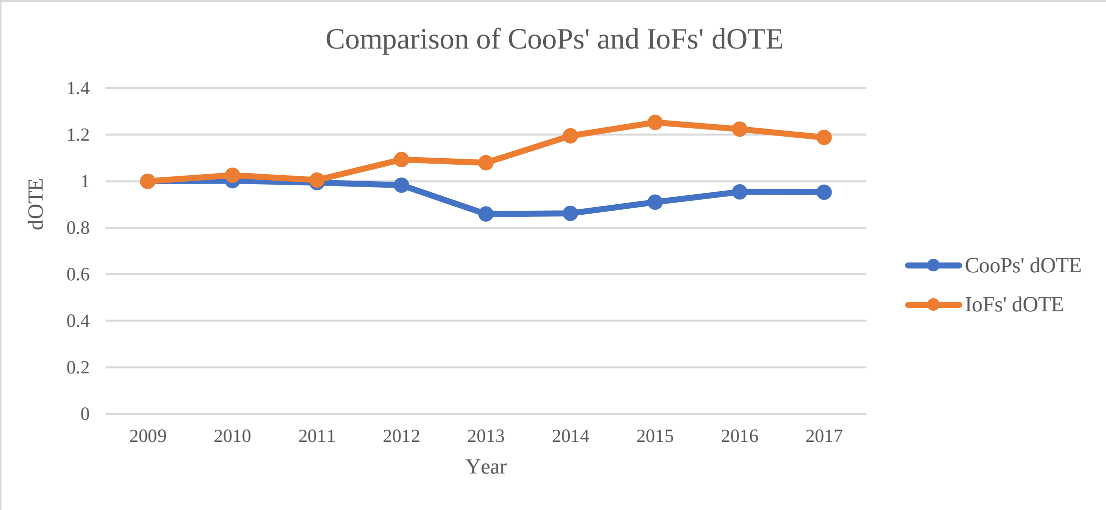

Figure A.6.3 Evolution of cooperatives and investor-owned firms' annual dOTE

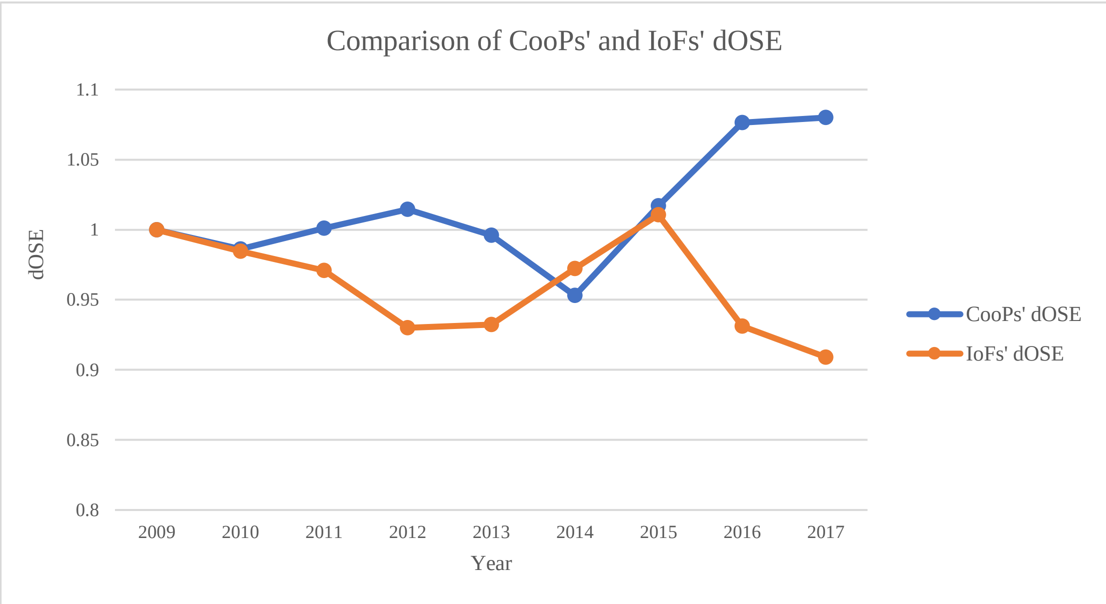

Figure A.6.4 Evolution of cooperatives and investor-owned firms' annual dOSE

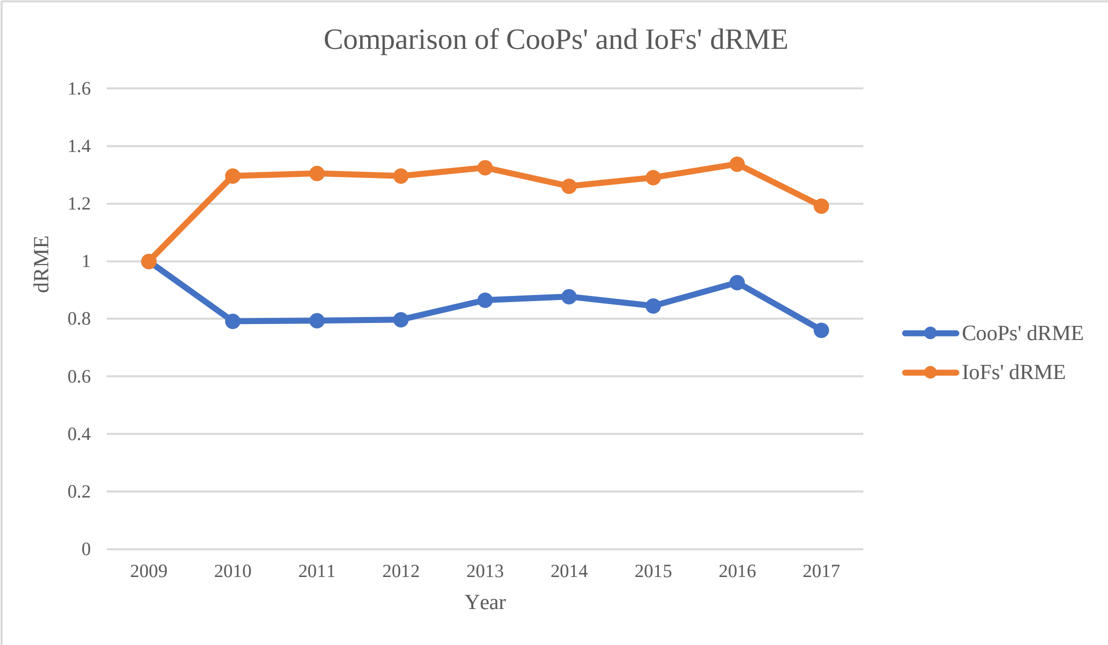

Figure A.6.5 Evolution of cooperatives and investor-owned firms' annual dRME