

# Economic Analysis of Scale and Technical Efficiencies of Dairy Farms

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# Economic Analysis of Scale and Technical Efficiencies of Dairy Farms

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## ABSTRACT

The Dutch dairy sector, like many EU dairy producing countries, has seen some structural changes in the past decades. The structural changes have important policy implications on efficiency, economic viability, and sustainability of farms. For the pre-quota abolition period 2011-2014, there was an immense consolidation of small-sized farms which has led to the increase in the number of farms within the large-scale categories. Moreover, milk yield and production per cow increased phenomenally over the period. However, market conditions in terms of demand and prices do not match up with improved yield and production. Essentially, the reasons behind these increased sizes are not straight forward. Meanwhile, should the current pattern of structural changes in the dairy sector persist or not, improve scale and technical efficiencies could lead to tangible profit margins. Therefore, the study was set to assess the effects of scale on productivity and technical efficiency, and determine the whether it is economically profitable to increase. Scale or size was measured as the average number of cows per herd. We applied econometric SFA, specifying the true fixed-effect and true random-effect panel data models for the study. The empirical results indicate scale economies and increasing returns to scale existed for the sample dairy farms studied for the years 2011 to 2014. The analysis showed that increasing sizes of the farms was profitable. The mean technical inefficiency determined by the TFE model was 0.09% suggesting farms are 91% technically efficient. Irrespective of the sizes of holdings, farms in the different size classes (small, medium and large) had the same level of performance in technical efficiency. Analysing the results, we conclude that cost benefits could be more important motivation to increase than efficiency gains. Intensification and automatic milking robots were key determinants of technical efficiency of dairy farms, showing negative and positive correlations with technical efficiency respectively.

**Key words:** scale, economies of scale, technical efficiency(TE), stochastic frontier analysis(SFA), true fixed-effect (TFE), true random-effect (TRE), elasticity of scale, returns to scale (IRS)

# CHAPTER ONE

## INTRODUCTION, OBJECTIVE AND RESEARCH QUESTIONS

### 1. Introduction and objective of study

The Dutch dairy industry is a strong backbone to the agricultural sector and still, offers a promising potential to contribute to the socio-economic development of the country. The sector raked in €6.3 billion to GDP, employs 13800 of the population, contributed 8.0% to trade balance and constitutes an integral part of the dietary culture of the people (ZuivelNL, 2016; CBS, 2016). In view of the immense contributions to economic development, the sector receives ample support from the government as well as concerned domestic, regional and international stakeholders to sustain the growth of the industry.

Over the years, the dairy sector has seen immense structural changes (Jongeneel et al., 2010). This has inspired farms and stakeholders in the sector to be more concerned about rationalizing their production to stay as competitive, profitable and sustainable as possible. A paramount development with significant impact in the dairy industry is the termination of the quota system in the European Union. Studying the Dutch dairy sector, major structural developments are evidenced in decreasing number of farmers and farms and phenomenal growth in scale with many farms investing in capacity through sector modernization, expansion or new buildings (ZuivelNL, 2016). Milk yield and production has increased phenomenally from 2770kg/year/cow in 1905 to 7919kg/year/cow in 2009 among Dutch dairy farms (Geert, 2011). The trend for the EU region is similar, and analysts attribute these changes to growth in most productive herds, contraction of the least productive ones and contrasted national dynamics (Eurostat, 2016). Meanwhile, the demand and market conditions for dairy products is not matching up with the increasing growth in production leading to an imbalance between demand and supply. CBS (2016) reported a marked decrease in the price index of milk. Compared to 2014, milk price index went down by 17.2%, and 12.4% compared to the average of the previous 5 years. The milk quota scheme might have achieved certain policy goals from a broader economic and sectoral development perspective. Nevertheless, this could potentially have limited farmers from fully exploiting the benefits of scale for factor productivity improvements (Rasmussen, 2011).

The structural changes have critical policy implications on farms and the sector in general regarding farm efficiency, profitability and long-term survival of the industry. For instance, cost

can decrease when size and efficiency increase synchronously with better training, improved technology and spending more time on the farm (Singbo & Larue, 2016; Mosheim & Lovell, 2016). From a study on the US dairy production, it was observed that dairy farms with less than 200 cows had their contribution decreasing from 60% (in 1998) to 34% (in 2007) whereas farms with more than 2000 cows increased from 7% to 23%.

The motivations behind these changes are mixed (Singbo and Larue, 2016). Conflicting findings and views have been presented by different authors for the structural changes (Coelli et al., 2005; Musheim & Lovell, 2009; Parman et al., 2014). Under conditions of these structural changes, studies suggest improvements in efficiency and profitability of farms are essential sustainability factors in production areas (Alvarez et al., 2008). Studies show that efficiency levels vary across farms in the sector (Tauer & Mishra, 2006; Fernández et al., 2005). Fernandez et al., (2005) analysed farm efficiencies using input distance production frontier method with both desirable output (milk production) and undesirable outputs (pollutants) and observed a wide variation in technical efficiency among Dutch dairy farms. Eurostat (2016) report suggests that milk yield showed apparent contrast across EU regions. Productivity was highest ranging 9000kg/cow/year to 10500kg/cow/year in several regions of Denmark, Spain, Portugal and Lombardia (IT) and Thessalia (EL) but was lowest ranging from 1200kg/cow/year to 2500kg/cow/year in five regions in Italy. The wide variation in efficiency levels gives an indication of possible opportunities to improve the economic fortunes of farms. The differences in performance cannot be attributed to a single factor as an economic, environmental or social factor (Tremblay et al., 2016). Therefore, rationalizing the use of inputs and outputs as well as an optimal appraisal of the relationship between them geared towards maximizing output are key factors for efficient production systems (Michalickova, et al., 2014).

Researchers estimate technical efficiency of farms to gain insight into economic, environmental and technological transformation processes in farming and the alternative improvements feasible by adopting various options of technology and farm practices (Lansink & Reinhard, 2004). Furthermore, analyzing the efficiency level of farms provides an insight into the potential impact of new technology on performance. Therefore, studying scale effects and technical efficiency levels of the farm is important from both policy and practical points of view. Policy makers can base on such knowledge to allocate public interventions to improve farm productivity and farm

income (Solis et al., 2009). The task is, therefore, to help farms to identify and understand factors that truly reflect the actual characteristics of the farm, fairly approximate the relationship between input and output and combine the actual performance and ideal efficiency of the farms.

Unequivocally, should the current patterns in the structural changes of farms remain the same in the years ahead or not, improvement in scale and technical efficiencies among farms could generate tangible profit margins and hence it is pertinent to investigate the scale of farms and efficiencies among dairy farms. The current paper, therefore, aims to analyze the key determinants of economic performance by investigating scale, and technical efficiency of dairy farms. As smaller farms are amalgamating could possibly indicate there are economic benefits of increasing size of farms. Therefore, as part of the objective, this study will also assess whether scale economies exist and whether the increasing farm sizes is economically profitable.

## 1.2 Research Question.

**Research question 1:** What is the technical efficiency level of dairy farms?

**Research question 2:** What are the key factors driving farm sizes, and technical efficiency among farms?

**Research question 3:** Is the recent trend of increasing farm sizes economically profitable?

## 1.3 Study Outline

The remaining part of the study is structured as follows. Chapter two discusses literature study. On the section about the structural changes in the dairy sector, an overview of the developments across the Dutch dairy sector is provided. Under the section captioned measures of economic size, I provide a discussion of measures of farm size and indicators of scale economies. The section also discusses the relationship between scale and technical efficiency of farms. The final section of this chapter discusses empirical findings of the drivers of the herd size evolution and factors that influence technical efficiency among dairy farms. Chapter three (3) describes the method of data analysis. First, we provide a brief discussion on the concept of efficiency and the methods of efficiency analysis. Next, we discuss SFA and panel data models that will be used to determine parameter estimates of the inputs and outputs and the explanatory variables. Finally, the chapter will be concluded with a description of the data to be analysed, and the output and input variables to be included in the panel model. In chapter four, the results of the analysis will be presented and

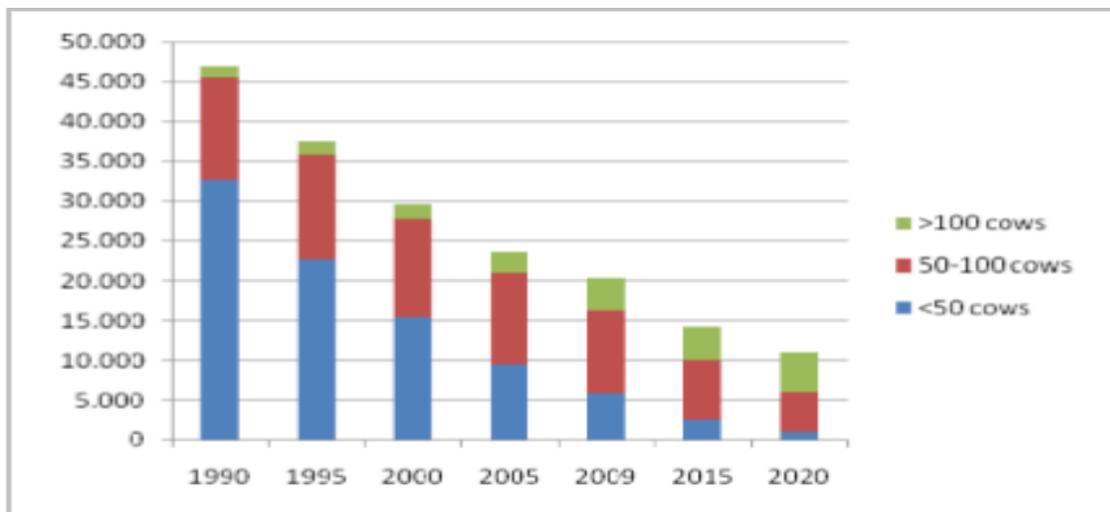
discussed. When discussing the results, we consider in a broader perspective the relevant theories, concepts, and findings established by other authors about the subject. In chapter five, I put forward the summary of the key observations from the current study, and propose recommendations where applicable.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Structural developments in the dairy sector

The EU dairy sector has experienced structural changes over the past decades (CBS, 2016; Jongeneel et al, 2011). The number of farms has declined since 1983 among EU countries. In the Netherlands, the number of dairy farmers dropped by 1.7% in 2015, to about 18000. The average size of farms increased substantially. Strongest decline was seen in Italy (-81%) and Denmark (-85%). The increasing trend in average farm sizes was highest in all EU-9 countries with Germany and Ireland showing the strongest increase in scale. Within EU countries wide variations in the farm sizes were observed. The number of cows per herd has been popularly used to define class sizes for dairy farms. In the Netherlands, medium-sized farms (50-100 cows) had the largest number of farms as at 2007 (Jongeneel et al., 2010). Based on this trend, it was projected that number small farms (< 50 cows) could decrease from about 70% in 1990 to less than 10%, whilst the share of the large farms (> 100 cows) could increase from 3% to about 45% in 2020. The number of Dutch farms with more than 150 dairy cows grew from 1700 to 1900(CBS,2016).



Source: Silvis et al., (2009) cited in Jongeneel et al., (2010)

**Figure 1:** depicting the number of Dutch dairy farms and size classes for 1999-2020.

Milk prices were stable in most EU countries from 1990's to 2000. Italian farmers received highest prices because of specific conditions on the Italian dairy market (specialized cheese and imports

of milk and dairy products). In the Netherlands, milk prices were stable over the period of 2000 to 2007 (Jongeneel et al., 2010). However, milk prices declined from (€32/100kgmilk) in 2001 to about (€28-€29/100kgmilk) in 2006 (11% decrease). A possible cause of the price decline was that the intervention price level was no longer binding. Prices were highest in 2007 but decreased in the second part of 2008. In 2009 the price of milk reached the lowest level, percent decrease amounting to about 30% lower than in the peak year 2007. Meanwhile, the decreasing milk price was much compensated for by the milk premium and the increasing sizes. The second quarter of 2015 observed a sharp drop in milk prices. The slowdown of economic activities and large stocks in China, as well as low oil prices together, put the milk prices under pressure (CBS, 2016).

Farm incomes declined from €80,00 in 2007 to €60000 in 2008 and were lowest in 2009. Returns to milk in total returns were very high for countries like the Netherlands, Denmark, and UK. These countries had on average more specialized farms than other EU countries which imply they were more price dependent. Whilst farms in Germany and France have on average relatively high cost of production, dairy farmers in Denmark and Netherlands have relatively high (fixed) cost on interest and rent payments. The high cost of rent and interest payments in the Netherlands reflects the EU's supply management policy since Dutch farmers have for many years invested in the quota at a high price level.

A key driver of these structural changes among others is the enactment of the milk quota system in the European Union. The quota system was formally added to the dairy policy of the European Union (EU) in 1984. The policy was characterized by an import tariff, export subsidies, and intervention buying. By the quota scheme, each dairy producer had a farm specific quota, and farms attracted the "super levy" (a punishable fine) to be paid by a farm for supplying beyond its quota). In the Netherlands, like Germany, the quota was distributed to the milk producers based on the 1983 production, less 7 percent. The allocation of the quota was initially through the market system until the quota tradability became flexible and well-functioning, and a quota lease was established. By the lease system, reference quantities are transferred to the new owner where the whole farm is transferred. If only part of the farm is transferred, an amount proportional to the number of hectares used is transferred.

Empirical studies on dairy production have identified different impacts of the quota scheme on farm level adjustments. Generally, findings are that the milk quota scheme coupled with high

product price led to large rent and that only the initial holders of the quota can benefit from the scheme (Naylor, 1993; Barichello, 1995). Richards et al., (1997) found that the quota scheme could have been a source of high production cost and economically inefficient production system. According to Colman (2000), the quota system imposed structural rigidity since it leads to farms keeping economically inefficient animals in the herd in production longer than is necessary. This has the potential of reducing the availability of more economically efficient farms. The structural rigidity of the quota scheme means the existence of inefficient dairy production system hinders the expansion of the efficient farms. Summarizing, the quota system, on one hand, slowed down structural change and introduce some inefficiencies.

Barichello (1995) however found a positive relation concerning the impact of the quota scheme on dairy production. He suggested that the value of the quota provides an incentive for farms not to produce thereby creating space for others to grow and leading to accelerated changes in herd size distributions. Moreover, the restrictions led to accelerated developments in operational efficiencies, such as more efficient roughage production, improved feed quality, and genetic selection through breeding. The extent of these impact depended on the flexibility of the transfer scheme. Jongeneel et al., (2010) projected that following the abolition of the quota scheme, the dairy sector will be faced with a declining and fluctuating milk prices. Under the no quota era, the pattern of increasing herd size observed especially among the Dutch and German farms and the accompanying decreasing average cost of production per unit cost is most likely to persist.

## 2.2 Parameters of Economic size

Empirical studies in economics and management have identified alternatives of measuring the size of the farm (Edwards et al, 2015; Keszthelyi, 2014). Elasticities of scale and returns to scale are important measures of size and scope in a multi-input and one output production process (Rasmussen, 2011). The economic concept of returns to scale is a purely technical concept and may not precisely measure the optimal size of a farm. The economic size is described as the size with the least long run average cost. The parameter that measures changes in size as production changes are the economies of scale (Chambers, 1988). Keszthelyi (2014) analysed farm problems using standard output to benchmark farms within EU region. It was observed that the traditional parameters of size do not reflect the real economic size since they are not correlated with the performance of the farm. This author suggested that a good measure of economic size could be the

earning capacity of the farm. The finding agrees with that of Edward et al., (2015) who also found that gross farm income as a measure of the farm is more useful than the physical measure of determining and comparing farm sizes. Wu and Prato (2006) who studied cost efficiency and scope economies of crop and livestock farms and used farm-specific gross incomes as a measure of farm size. Edwards et al (2015) identified alternative parameters which measure the size of farm namely total farm assets, total acres farmed, livestock numbers, total labour used, quantity sold or share of market size and value of farm production.

### 2.3 Scale economies and Technical Efficiencies of farms

The concept of economies of scale in relation to technical efficiency of dairy production has received great attention in economic and management studies (Chavas, 2001). Some authors are of the view that farm sizes restructuring across the dairy sector are due to potential gains in economic efficiencies but not scale or scope economies of the farm. Different authors argue otherwise. Studies show economies of scale and scope play an important role in assessing the potential benefit of farm's growth and diversification strategies and are central to the determination of efficient market structures (Trieb, et al., 2016). Economies of scope is an important determinant of sector specific restructuring and deregulation worldwide. Scale economies can be described as the potential reduction in per unit average cost due to increasing size or scale of the farm (Parman et al., 2014). Economies of scale exist when the long run average cost curve is decreasing over a range of outputs (Decreasing cost and increasing returns to size). Where long run average cost curve is increasing over a range of outputs (increasing cost and decreasing returns to size), diseconomies of size is said to exist (Beccalli et al., 2015). Economies of scope describe cost savings accruing to the farm through actual production of multiple products jointly than separately (i.e. costs and benefits accruing to the farm from joint production). Economies of scope may arise from prudent exploitation of resources required for the production of goods and services.

Based on the farm's cost-output relations, the production function of a decision-making unit may exhibit a constant, increasing, or decreasing returns to scale (Rasmussen, 2011). A constant return to scale exists if scaling all input amounts by a fixed positive factor leads to a proportionate increase in output by that factor (Elasticity of scale equals 1). If the amount of output increases more than the proportionate amount of the factor of the corresponding inputs, an increasing return to scale exist (Elasticity of scale is greater than 1). Where the proportionate amount of the output

is decreasing relative to the proportionate increase in factor of the input a decreasing return to scale exit (Elasticity of scale is less than 1). Farms that are operating under increasing returns to scale can improve efficiency by increasing size whereas farms that are operating under a decreasing size can improve efficiency by decreasing size or scale of production (Carter, 2000).

Although an optimal scale may not essentially correspond to a technically optimal size of farm, net income may increase when the scale of production increases along the scale line until the economically optimal scale is reached. The technical optimal scale describes the scale of production at which the elasticity of scale equals unity. Comparing the optimal scale of production and technical optimal size give an indication of the economic potential of consolidating small dairy holdings with specific sizes into the technical optimal scale of production (Rasmussen, 2011).

Parman et al., (2014) applied a nonparametric cost frontier method to analyse multi-product and product-specific scale economies, economies of scope and cost efficiency of Kansas farm. These authors found that multi-product smaller farms (farms with less than \$250 in gross revenue) observed relatively greater cost savings through joint production than larger farms. Besides, increase in farm sales offered a higher motivation to grow due to additional cost savings, and the cost reductions were more important incentive to increase size than efficiency gains.

Rasmussen (2011) investigated the technical optimal scale for the crop, dairy and pig farms for a sample of Danish farmers and found that dairy farms were more technically efficient than crop and pig farms. Besides, it was observed that dairy farms could not get closer to efficient output scale for the period 1985 to 2000 when the scale size only increased from 35-62. However, the years 2000 to 2006 when mean herd size increased from 62 to 97, farms got closer to the efficient scale.

Singbo & Larue (2016) observed an increasing return to scale (sub-optimal sizes) among Quebec dairy farms with a 9% growth in total factor productivity. Their empirical results showed that although farmers were highly technically efficient, the input-mix effect was the most important contributor to factor productivity but not technical and scale efficiency. Besides, the marginal and average cost of milk becomes smaller as milk output increases. Their results agree with the findings of Hadley et al, (2013) who also observed that, for a sample of UK hog producers surveyed, input mix effect was the key source of factor productivity.

Mosheim & Lovell (2016) applied shadow cost model to analyse scale effects of TE and AE in explaining the variation in the cost of production across a sample of US farms. It was observed that large scale farms were more efficient than small scale farms. The mean contribution of farms with less than 200 dairy cows fell from 60% in 1998 to 34% in 2007 whereas the mean contribution of farms with at least 2000 cows increased from 7% to 23%. According to (Triebbs et al., 2016), economies of scale and scope are the reasons why large integrated banks are more efficient. This suggests that a disintegration into parent outlets can lead to the risk of individual bank failures. In view of these findings, it could be mentioned that the largest herd size class are an “absorbing state” (having a diagonal probability close to 1). Davidova et al., (2002) and Lerman (2002) found a positive correlation between scale and farm efficiency.

Jongeneel et al., (2010) on the contrary observed that the optimal farm size was not in the largest size class distinguished in the data. They found that for Netherlands, a herd of more than 100 dairy cows might be less optimal than a herd within the class of 70-100 dairy cows. van Zyl et al, (1996) and Munroe, (2001) also observed a negative correlation between farm size and total factor productivity.

#### 2.4 Drivers of scale and determinants of technical efficiency

Empirical studies on dairy farming have identified various factors that influence farm sizes and efficiency. The findings of the motivations behind the herd size evolution are not straightforward (Chavas & Hall, 2001). However, scale economies of developed countries have been observed to be “L-shaped” suggesting an increasing return to scale to a certain threshold of farm size and then assumes a constant return to scale (Latruffe et al., 2005; Rasmussen, 2011). Contrary to the L-shape, Latruffe et al., (2005) observed a U-shaped cost-output curve for livestock and crop farmers in Poland. The U-shaped cost curve means that farms of extreme ends, i.e. the smallest and largest farms as most efficient farms. Their results agree with the findings of Lerman (2002) that medium sized farms are more inefficient.

Cost economies are the key drivers of the consolidation of farms across the dairy sector (Mosheim and Lovell, 2009; Singbo and Larue, 2016). Mosheim and Lovell (2009) found scale economies were the main determinant of size among US dairy farms. Their results confirmed the L-shaped cost curve of scale economies in developed nations. Their model showed diseconomies of scale as herd sizes reach a certain threshold, even with the largest farms in their sample with herd sizes of

more than 2000 cows. Singbo & Larue, (2016) suggested that although Quebec dairy farmers were efficient managers, important savings in cost of production can be achieved through a significant increase in the scale of operation. Hemme et al., (2004) found that increasing farm size constitute an important strategy that family businesses adopt to reduce the cost of operation. Addition to the economies of scale, business models of many firms in the financial sector is driven by economies of scope and deregulation (Gambacorta & van Rixtel, 2013). Buch & Delong (2010) suggest that diversification strategy adopted by most global banks is associated with increased consolidation and concentration that results in fewer, larger and more complex conglomerates. Mercieca et al.,(2007) observed a negative relationship between economies of scope and firm business models and a mixed impact on economies of scale. The business models of large and complex global banks appear to be partly motivated by regulatory considerations.

Efficiency advantages are the next essential driver of the scale of farms (Singbo et al., 2016; Wu and Prato, 2006). Wu & Prato, (2006) who studied cost efficiency and scope economies of crop and livestock farms in Missouri found that increased number of consolidated specialized farms replacing small traditional farms were mainly because of efficiency advantages. Their results showed that the low cost efficiency observed in both crop and livestock farms are the results of the improper scale of operation and inappropriate input mix.

Economic policies, regulations, and programmes imposing restrictions on land acquisition and use have played a critical role in determining sizes and efficiencies of farm holdings (Singbo and Larue, 2016; Beccalli et al, 2015; Rasmussen, 2011; Zimmermann & Heckeley, 2012; Wu and Prato, 2006). As was found by Rasmussen (2011), the increasing sizes of Danish farms in the past 30-40 years is because the restriction on agricultural lands use was progressive eased. Regulated by the supply management policy, Singbo and Larue (2012) observed that the Canadian milk production was limited through production and tariff rate quotas. Latruffe et al., (2005) found that improvements in the land lease policy and farmers pension's regulation could eradicate the incentive to keep the fragmented operational structure. The restriction arising from the EU milk quota system, for instance, hindered farms from producing beyond certain levels. Zhu, et al., (2012) studied efficiency and productivity differentials of a government supported subsidy programme among 3 EU countries and found that the intervention (subsidy) had a negative correlation on technical efficiency. Access and availability of capital, land, and other factors of

productivity restrains growth. However, Løyland & Ringstad (2001) on the contrary observed that economies of scale achieved among Norwegian dairy farms were due to the agricultural policy and regulations that allowed profitable production even for the smallest farm holdings that are possibly challenged by diseconomies of scale. Jongeneel et al., (2011) found that policy changes and macroeconomic conditions are important drivers of the herd size evolution aside technical changes.

Managerial ability and competence have an important relation to the scale and technical efficiency of farms. Alvarez & Arias, (2003) studied the diseconomies of size with fixed managerial ability for a sample of Spanish dairy farms and found that increasing farm size while keeping managerial ability unchanged can lead to diseconomies of size. The educational level of farmers has a bearing on their managerial capacity. Studies show that a lower educational level of farmers is an important cause of inefficient farm management practices (Latruffe et al, 2005; Khumbakar et al., 2001). Large scale farms managed by highly educated farmers tend to show higher allocative and technical efficiencies (Kumbhakar et al, 1991). Kalaitzandonakes et. al.,(1992) used production frontier to evaluate farm size and efficiency relationship and observed a positive correlation between farm size and technical efficiency for nonparametric, deterministic parametric, and stochastic methods.

Blayney & Normile, (2004) suggested a mixture of technological, efficiency and scale changes as the key drivers of structural revolution. These authors did not find empirical evidence of scale economies and their variation across regions which are crucial technological indicators.

Regarding technical inefficiency of farms, literature studies have identified 3 broad groups of explanatory variables that explain inefficiencies across farms (Wu & Prato, 2006; Latruffe et al, 2005). These are farm characteristics and technology (e.g. farm size, debt structure, farm specialization), human capital (labour, managerial ability), and farm environmental conditions e.g. altitude, soil quality). Variables such as age, education, type of farm explain the socioeconomic characteristics of the farmer, and are traditionally added to explain inefficiencies of the farm. Hansson, (2007) analysed the determinants of efficiency in terms of the environmental factors affecting farms and noted that farms are influenced by internal, operational and external environmental factors. Internal factors describe those factors that are under the direct control of the farmer whereas the external environmental factors correspond to macroeconomic factors over

which farmers have no control. The operational environmental factors describe market situations over which the farm may have some control.

Specifically, farm size, extent of farm specialization, amount of milk produced per cow, degree of intensification, feeding quality and system, labour requirements, milking frequency, management skills and capacity, price of milk, price of inputs, climate variables, soil type, genetics of animal, geography, micro-social problems (personal problems of the manager, presence of successors, farmers attitude), cost of farm debt among others are key determinants of technical efficiency level of farms (Geert, 2011; Hulten & Olhmer, 2003; Gloy et al., 2002; Hasson, 2007; Ohlmer & Olson, 1994; Galanopoulos et al., 2006; Cabrera et al., 2010; Latruffe et al., 2005; Špička & Smutka, 2014; Wilson, 2010; Wison, 2009; Thomassen et al., 2016; Alvarez et al., 2008; Keszthelyi, 2014; Wronski et al., 2007; Singbo et al, 2016). Moreover, input mix has been found to be an important source of inefficiency of the farm (Hadley et al., 2013). Input mix inefficiency reflects diseconomies of size from the input perspective. These authors observed that the inefficiency (0.736) associated with input mix was significantly greater than the corresponding technical (0.975) and scale (0.975) inefficiencies for the sample of English pig farmers.

## CHAPTER THREE

### MATERIALS AND METHOD OF DATA ANALYSIS

#### 3.1 Efficiency Analysis

The concept of efficiency analysis is very intuitive from the production theory (Coelli et al., 2005). Efficiency analysis ranks decision-making units by comparing all farm resources employed to producing a given set of outputs and constructing a frontier based on the input-output space. The production frontier represents the maximum output achievable from a given set of input. This can be described as technical efficiency (TE). Given input specific prices and technology, the ability of a firm to apply farm resources in optimal proportions can be termed allocative efficiency (AE). The Technical and allocative efficiencies combined measures economic efficiency (overall efficiency used by Farrell). Efficiency can be measured from two perspectives. Determining efficiency based on farmers ability to expand output keeping input amount fixed is described as an output-oriented technical efficiency whereas the ability to reduce the amount of inputs without a change in output is called an input-oriented technical efficiency. Farms on the production frontier define the best management practices. Farms below the production frontier are inefficient because of poor management (Tauer & Mishra, 2006; Coelli et al, 2005). TE takes values between 0 and 1. A value of 0 suggests technical inefficiency whereas a value of indicates 1 fully efficient farms. As a dairy farm may be too large that it might be operating in decreasing return to scale part of the frontier, and or too small that it might fall within increasing return to scale portion of the production frontier, efficiency can be improved further by changing the scale of the production. Thus, a scale efficiency shows whether a dairy farm is producing at the optimal scale. This can be achieved by keeping input mix fixed whilst varying scale of production.

When analysing impacts of farm sizes on technical efficiencies of farms in the dairy sector, analysts have extensively employed the frontier estimation methods. The method allows identification of the production technologies of the farm. Following this approach, farms are assumed to be operating with a common technology. The problem is that this approach neglects the theoretical and possible occurrence of farms engaged in different activities employ different production technologies (Saal & Parker, 2006; Bottasso, et al, 2011; Weninger, 2003). The assumption of common technology when heterogeneous technologies exist can possibly lead to

biased estimations and analysis of scale economies (Triebs, et al., 2016). Triebs et al. (2016), propose relaxing the assumption of common technology for a rather flexible model that estimates flexible technologies for the observed farm types (Specialised and integrated farms) when estimating scale and scope economies, Weninger (2003) suggested that using an integrated approach that specifies a shared empirical multi-product cost function where mixed and specialised farm data can be pooled to determine the parameters of the function can be extremely useful.

### 3.2 Stochastic Frontier and Technical Inefficiency Estimation

Analysts in the field of management and economics have often applied two broad methods when evaluating efficiencies among farms. These are the non-parametric data envelopment analysis (DEA), (Bogetoft, 2012; Ray et al, 2015; Coelli et al, 2005) and the parametric stochastic frontier analysis (SFA), (Belotti et al., 2012; Cabrera, et al., 2010; Coelli et al., 2005; Kumbhakar and Lovell., 2003)

To analyze scale economies and efficiency level of dairy farms, we employ the econometric stochastic frontier analysis (SFA). SFA is parametric and makes a priori explicit specification about the functional form of the production function and applies maximum likelihood estimation procedure to estimate the parameters of the model (Belotti et al., 2012; Kumbhakar and Lovell, 2003; Coelli et al., 2005). The maximum likelihood (ML) estimation is the most popular in empirical work since the estimates are consistent and are asymptotically efficient. Developed by Aigner et al., (1977) SFA is found to be particularly useful for studying performances of agri-related enterprises because of its ability to cater for stochastic noise, accommodate hypothesis testing, and permits a single step estimation of inefficiency effects (Bojnec & Latruffe, 2013). SFA accounts for variations in the distribution of inefficiencies by the inclusion of variables that are supposed to affect the distribution of inefficiency. Often, this has been achieved by using the two-step approach where in the second step, explanatory variables expected to be associated with the inefficiency are regressed with the efficiency scores estimated from the first step. This approach has been identified to have many shortcomings as it leads to biased results (Wang and Schmidt, 2002). An important way forward is to focus on model extensions based on simultaneous estimation. Huang & Liu, (1994) suggest the true fixed and random-effect panel models are more effective and proposed parameterizing the mean of the truncated inefficiency distribution.

The main criticism of the SFA approach is that there is no justification for the predetermined functional form for the inefficiency term, ( $U_{it}$ ). Moreover, the identification of the possible sources of the inefficiencies ( $U_{it}$  and  $V_{it}$ ) is dependent on how the shape of their distribution is involved in specifying the shape of the distribution. Possibly, identification problems may arise when shapes are similar especially for small sample normal gamma cross-sectional model. However, development of more functional forms such as the truncated-normal (Stevenson, 1980) and the two-parameter Gamma functional forms (Greene, 1980) are contributions to addressing the problem. Pitt & Lee, (1981) were the first to extend the idea to panel data. Assuming the explanatory variables remain unchanged, an output-oriented general stochastic frontier model for panel data is specified as

$$Y_{it} = f(X_{it}; \beta) \cdot \exp(V_{it} - U_{it}), \text{ where } i = 1, \dots, N; t = 2, \dots, T \quad (1)$$

Where  $Y_{it}$  is a vector of observed output(s);  $X_{it}$  is a vector of production inputs;  $\beta$  is an input-specific parameter to be estimated or a  $K \times 1$  vector of corresponding coefficient vector.

$V_{it}$  is a zero-mean random error which is independently and identically distributed,  $N(0, \delta_v^2)$ . It captures stochastic noise (factors beyond the control of a dairy farmer such as weather, input and output prices, managerial competence and skills, soil quality, cow genetics, etc.  $U_{it}$  mostly  $\geq 0$ ; is a non-negative random term independently and identically distributed as  $N^+(U, \beta_\mu^2)$  which is intended to determine the effects of time-invariant production inefficiencies measured from output orientation and is assumed to exhibit a half-normal distribution.  $V_{it}$  and  $U_{it}$  are independent of each other (Belotti et al., 2012, Ray et al 2015). As noise represents effects on productivity outside the control of the farmer, it is unlikely to be related to inefficiency. The degree of freedom advantages among others makes panel data models more preferred over a cross-sectional data.

The stochastic  $TE_o$  can be estimated from the error term;

$$TE_o = Y_{it} / [f(X_{it}; \beta) \cdot \exp\{V_{it}\}] = \exp\{-U_{it}\} \quad (2)$$

This is described as the technical inefficiency measure with a value closer to 0 denoting more technically efficient production and is simply the ratio of observed output ( $Y_{it}$ ) and maximum feasible output ( $Y_{it}^*$ ). Given that  $U_i \geq 0$ ; Therefore,  $0 \leq \exp\{-U_i\} \leq 1$ . To separate technical efficiency from the stochastic noise, Battese & Coelli (1992) proposed the estimator also known as the time decay;

$$TE_i = E[\exp.(-U_i)/(V_{it} - U_{it})] \quad (3)$$

The maximum likelihood estimation of the equation provides estimators for the variance. Caudill et al., (1995) extended this approach to study the influence of determinants on technical inefficiency,  $U_{it}$  using a multiplicative heteroskedasticity framework expressed as;

$$\begin{aligned} U_i &\sim N^+(0, \sigma_u^2) \\ \sigma_{ui} &= \sigma_u \exp.(Z_i; \psi) \end{aligned} \quad (4)$$

Where  $U_i$  is a realization from truncated normal random variable;  $Z_i$  is a vector of exogenous variables (including a constant term);  $\psi$  is the vector of unknown parameters to be estimated (also known as the inefficiency effects). Equation (4) is very important because the variable  $Z_i$  may account for possible interactions with input variables and allows hypothesis testing about the neutrality of input usage of inefficiency.

### 3.3 Empirical Estimation of the Functional Form

Determining the parameter estimates requires a precise specification of the form of the production function. In this study, we applied the transcendental logarithmic (Trans-log) Cobb-Douglas production function which is the functional form extensively employed in management and economic studies when analyzing the performance of the decision-making units. The appeal of the Cobb-Douglas trans-log functional form is its flexible nature, demanding few assumptions about the production function. This functional form offers a greater insight about input-output relations since the parameter estimates indicate the output elasticities (Begotof, 2012; Kumbahar and Love, 2003). Besides, the Cobb-Douglas trans-log form follows well after theory since the multiplicative structure makes it easy to relate to Farrell's technical efficiency. The functional form can be specified as;

$$\ln Y_{it} = \beta_o + \sum \beta_j \ln X_{it} + V_{it} - U_{it} \quad (5)$$

$$\ln Y_{it} = \beta_o + \sum_{j=1}^6 \beta_j \ln X_{jit} + \frac{1}{2} \sum_{j=1}^6 \sum_{k=1}^6 \beta_{jit} \ln X_{jit} \ln X_{kit} - U_{it} + V_{jit}$$

Where  $Y_{it}$  is the output variable, total gross margin per farm in Euros;  $X_{it}$  are the input variables defined above;  $V_{it}$  is stochastic noise, and  $U_{it}$  is the technical inefficiency term;  $j$  is the input number;  $t$  is time;  $i$  is the number of observation.

Schmidt and Sickles (1984) established that estimating SF model with a time-invariant inefficiency can also be performed by specifying the conventional time-varying fixed-effects estimation techniques. The fixed-effect models allow inefficiency to correlate with the frontier regressors and avoids the distributional assumptions about  $U_{it}$  term. We specify a “true” fixed/random-effect time-variant frontier model as proposed by Greene (2005a) as;

$$Y_{it} = \alpha_i + X'_{it}\beta + \varepsilon_{it}. \quad (6)$$

$$\varepsilon_{it} = V_{it} - U_{it} \quad I = 1, \dots, N; t = 1, \dots, T$$

$$V_{it} \sim IID N(0, \psi^2)$$

$$U_{it} \sim IID F_u(\mu, \sigma^2);$$

Where  $Y_{it}$  is a vector of outputs;  $X_{it}$  is a  $1 \times k$  vector of exogenous inputs;  $\beta$  is a  $k \times 1$  vector of technology parameters to be estimated;  $\alpha_i$  is the unit fixed-effect;  $V_{it}$  is the idiosyncratic error;  $U_{it}$  is one-sided disturbance denoting inefficiency possibly following a half normal, exponential or truncated-normal distribution.  $V_{it}$  is normally distributed with the variance  $\psi^2$ . The relation makes it possible to disentangle the time-varying inefficiency from unit specific time variant unobserved heterogeneity. The truncated normal (“tnorm”) distributional form was specified to simultaneously introduce exogenous variables and estimate the technical inefficiency.

To analyze scale economies and efficiency among dairy farms, an exploratory research was conducted to analyze the essential inputs and outputs characteristic of the dairy production. Following the literature study about dairy husbandry and the available data, the empirical model of this study includes 1 output and 7 input variables. The output variable is *milk income* defined as the annual total revenue from milk produced, measured in euros; *labour cost*, defined as the annual total costs of labour (comprising family and hired labour) working on the farm, *Crop*, defined as the total of crop related costs, consisting of fertilizer, crop protection, and seed costs, measured in euros; *Feed*, defined as the total of purchased feed costs, measured in euros; *Capital*, defined as the total of cost of farm debt, taxes and depreciation of machinery and buildings,

measured in euros; *Variable cost*, defined as the total of veterinary expenses and energy costs measured in euros; *Cow*, defined as the total monetary value of the average number of adult cows per herd per farm, in euros. The total of variable cost, cow, feed cost and crop related cost are expressed as **Other costs** (Table 3.1). The inputs and output variables are measured in terms of a dairy cow per year.

As discussed in section 3.2, the econometric true fixed and random-effect panel models allow a unified determination of inefficiency of decision-making units. To analyze the inefficiency effects of scale of production, we included the underlying explanatory variables based on the analysis in section 2.4. Given the current trend of increasing farm sizes, dairy farms are going to be intensive and feed cost per farm could probably increase. We include *intensification*, defined as the cost of the amount of feed fed per dairy cow per year. This approach has been used by Cabrera et al., 2010 and Alvarez et al., 2008. This structural change is an important source of inefficiency and determinant of economic performance of farms. *Pasture size*, defined as the size of grassland used for dairy feeding, measured in hectares. Pasture size measures feeding quality and can impact farm level efficiencies due to feeding inefficiency (Cabrera et al., 2010). *Automatic milking robot*; a dummy variable with a value of 1 implying the use of milking robot, otherwise it takes a value of 0. Automatic milking robot reflects technology or use of best management practice, and efficiency advantages possible with use of improved technology (Tremblay et al., 2016). *Concentrate*, defined as the total cost of concentrate feed fed per farm per year, measured. Feed cost is the single most important cost component of a dairy farm. Studies shows feed cost constitute about 35-50% of a dairy production (Michalickova et al., 2014; Jiang & Sharp, 2013). *AFC*, denotes age at first calving and could introduce inefficiencies due to its impact on costs and overall services of production (Krpálková et al., 2014). *Age*, defined as the age of farm manager, expressed in years. The variables age and level of farmers education level measures experience and managerial ability the farm manager (Tauer & Mishra, 2006). Besides, the education level offers farmers the capacity to choose the least cost input combinations. However, this variable was not available in the Flynth data set.

### 3.4 Data

The data for this study was sourced from the Flynth accountancy firm. Flynth is a Dutch accounting and economic advisory consulting firm that collect, analyze and store variety of high quality

information including farm data and provide management and business investment support. The data is a panel set collected from a sample of Dutch dairy farms for the period 2011 to 2014. To enhance accuracy of our analysis, a selection criteria was applied. The panel was constructed based on operator characteristics, marketing practices, revenue and cost of production, production technology and dairy management practices. Farms should be present at least for two consecutive years to be included when constructing a panel dataset. Farms with uncharacteristic observations (outliers) compared to the entire population in the data set were removed. Also farms with missing observations on key variables were removed. Typically, as a cost function to satisfy a cost minimising solution should be non-negative, non-decreasing in input prices and output, homogeneous of degree one, and concave in input prices (Coelli et al., 2005), farms with negative feed values were not selected. Most farms were specialised milk producers. Therefore, farms were selected if at least 70% of their farm incomes were from the sale of milk. Singbo and Larue (2016) applied this criterion when they studied scale economies and total factor productivity among Quebec dairy farms in Canada. The final dataset used for the analysis included an unbalanced panel of 2046 Dutch dairy farms which were used for the analysis. STATA statistical package was employed to estimate the parameters of the models specified above. To confirm the analysis of the parameter estimates of the output elasticities, the *lincom* function in STATA was applied to estimate output elasticities. Table 3. 1 below gives the descriptive statistics of the variables used for the analysis.

Table 3.1 Descriptive statistics of variables for a panel of 2046 dairy farms

Variable <sup>1</sup>		Mean	SD	Min	Max
<b>Milk income(Y)</b>	overall	3339	449.51	1653	4642
	between		388.29	1652.83	4382.40
	within		242.21	2465.73	4060.09
<b>Labour cost (X<sub>1</sub>)</b>	overall	90.05	125.99	.6379891	1557.99
	between		121.32	.8792764	1530.81
	within		43.76	-466.7745	761.13
<b>Capital (X<sub>2</sub>)</b>	overall	883.86	439.63	81.51112	7567.29
	between		381.64	132.3056	4076.22
	within		227.41	-1031.974	5539.70
<b>Other Costs (X<sub>3</sub>)</b>	overall	67092	40237	10520	591690
	between		37194	12226	545140
	within		10699	-2448	150684
<b>Intensification</b>	overall	9.48	4.71	0.73	44.28
	between		4.59	0.91	35.04
	within		1.43	-0.81	18.85
<b>AFC</b>	overall	788.86	58.15	660	1050
	between		52.18	690	1050
	within		27.49	556	961.36
<b>Age</b>	overall	50.64	8.46	25	88
	between		8.28	26	87.5
	within		2.31	27.3893	73.64
<b>Concentrate</b>	overall	613.52	136.62	20.01	1269.26
	between		122.58	102.52	1207.99
	within		61.31	198.56	857.28
<b>Pasture Size</b>	overall	43.99	27.41	2.29	472.68
	between		25.44	4.55	459.99
	within		4.27	0.59	84.59
<b>Milking robot</b>	overall	1.78	0.41	1	2
	between		0.40	1	2
	within		0.11	1.03	2.53

<sup>1</sup>Variables are measures on per dairy cow per year; AFC= age at first calving; Other costs = total of crop related costs, feed costs, variable cost and cost of cow; Labour cost= total cost of hired and family labour per cow; AFC=age at first calving; milking robot= a dummy with 1 denoting presence and use of automated milking robot; Age=age of the farmer manager; Pasture size=proportion of land allocated for pasture; intensification= feed cost/cow.

## CHAPTER FOUR

### RESULTS & DISCUSSION

#### 4.1 Results and Discussion

The results of the parameter estimates are shown in Tables 4.1, 4.2, 4.3 and 4.4. All the parameter estimates in the panel model had been computed using the `sfpnl` command in STATA analytical software. Table 3.1 above presented a preliminary analysis of the input-output variables as well as the explanatory variables included in the frontier model. The parameter estimates of the output and inputs had the appropriate signs indicating that the monotonicity assumption is fulfilled at the sample mean.

The result presented in table 3.1 indicates there were significant structural changes in farms over time evidenced in the within and between variations across dairy units for the period 2011-2014 for milk income(output), inputs, as well as the explanatory variables. The output, inputs and exogenous variables all had a greater between variation than within variation. The variable Other costs (consisting of the cost of crop related cost, feed costs, variable cost, COW) per cow showed the least within variation than the between variation. This result implies that generally for individual units (farms), the structural changes were relatively smaller as compared to the changes between different units for the variables over time.

Detailed analysis of the coefficient estimates from the frontier model is presented in table 4.2. Time-variant true fixed and random effect panels data models were fitted for the dataset. Comparing whether the true fixed or random-effect model is appropriate, the Hausman test was applied. The Hausman test results (table 2) showed a statistically significant p-value and led to the rejection of the null hypothesis that the true random-effect model is most appropriate. This indicates that the “true fixed-effect model is econometrically a best-fit model for the frontier than the “true”-random effect model.

Table 4.1 Showing results of the Hausman test

<b>Coefficients</b>				
<b>Variables</b>	(b)	(B)	b-B(Difference)	sqrt(diag(V_b-_B))
	Fixed	Random		S.E.
<b>Labour cost</b>	0.009	0.007	0.003	0.002
<b>Capital</b>	0.027	0.038	-0.011	0.006
<b>Other Costs</b>	-0.056	0.043	-0.099	0.009
<b>Intensification</b>	0.154	0.167	-0.014	0.009
<b>Pasture size</b>	0.109	0.098	0.011	0.020
<b>Milking robot</b>	-0.037	0.037	-0.074	0.050
<b>Milking robot number</b>	0.019	0.037	-0.018	0.018
<b>Age</b>	0.222	0.037	0.185	0.036
<b>AFC</b>	0.036	-0.034	0.070	0.037

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

$$\chi^2(10) = (b-B)'[(V_b-V_B)^{-1}](b-B) = 208.88$$

$$\text{Prob}>\chi^2 = 0.0000$$

The inputs and the output variables included in the stochastic frontier model were converted to logarithmic forms. Therefore, coefficients of the parameters estimate of the inputs depict partial elasticities of the output variable, annual milk income per cow. The coefficients of the input estimated from the model are all positive and had statistically significant probability values. The variable, Other cost per dairy cow per year showed the highest elasticity of output (1.425) compared to Labour cost and Capital. This means that a 1% increase in the variable Other Cost per cow results in a 1.425% increase in the income received from milk sold. Labour cost per dairy cow had the second highest output elasticity (0.210). This means that a 1% rise in labour cost per dairy cow yields a 0.210% increase in milk income. Capital costs, consisting of the cost of depreciation of machinery and buildings, interest charges, taxes paid per dairy cow had an output elasticity of 0.173. That is a 1% increase in the Capital cost per dairy cow resulted in an estimated 0.173% increase in milk income.

As discussed in section 2.2, the elasticity of scale (EOS) and the corresponding return to scale are important indicators of economies of scale in a multiple-input and multiple-output enterprises (Rasmussen, 2011). These measures are important characteristics of the farm since they reflect

productivity. The scale elasticities (sum of all output elasticities) from the true-fixed effect frontier model equals 1.81, a return that is almost double the amount of the long-run average cost of production. The elasticity value (1.81) gives an indication of the presence of increasing returns to scale (IRS) among the sample of Dutch dairy farms for the period 2011 to 2014. The increasing returns to scale realized suggests there is a positive correlation between farm size (average number of cows) and technical inefficiency of the farm (Cabrera et al, 2010). To verify the results of the elasticities, we performed further and more detailed hypothetical analysis of the CRS assumption using *the lincom* command in STATA which emphasized the results. This feature of the *sffpanel* packages provides an advantage to the technique because the parameters estimates of the traditional *translog* production frontier are not sufficient to measure of output elasticities (Belotti et al., 2012). We conjecture that cost advantage could be a key motivation for the amalgamation of traditionally smaller Dutch dairy holdings. As farms are operating at a smaller scale than the optimal, suggests a potential benefit to increase size since productivity and profitability could further be improved until the long run average cost curve flattens. In an earlier study on a similar subject, Fernandez et al., (2005) also found evidence of increasing returns to scale for Dutch dairy farmers. Besides, the results confirm the report of Jongeneel et al., (2010) who predicted an increasing scale and returns to size for Dutch dairy farms up until the year 2020. These authors have also found that Netherland and Denmark are among countries with a relatively high (fixed) cost of interest and rent payments among the major EU dairy producing countries. Increasing returns to scale is then a positive means to improving and stabilizing profitability of farms in traditional production areas. Table 4.2 below presents the results of the true fixed-effect SFA estimation.

Table 4.2 showing production frontier estimates based on True Fixed Effect model

<b>Variable<sup>1</sup></b>	<b>Coef.</b>	<b>Std. Error</b>	<b>z</b>	<b>P&gt; z </b>
<b>Frontier</b>				
Labour cost	0.210	0.004	58.25	<b>0.000</b>
Capital	0.173	0.011	16.25	<b>0.000</b>
Other costs	1.425	0.138	10.28	<b>0.000</b>
<b>Inefficiency Model</b>				
Intensification	3.652	0.316	11.57	<b>0.000</b>
Pasture size	-0.536	0.339	-1.58	0.114
Milking robot	-2.387	0.295	-8.08	<b>0.000</b>
Concentrate cost	-0.342	0.493	-0.69	0.488
Age	-0.818	0.665	-1.23	0.219
AFC	-0.314	1.474	-0.21	0.831
Mu_cons	-2.192	11.446	-0.19	0.848
Usigma_cons	-1.796	0.092	-19.42	<b>0.000</b>
Vsigma_cons	-4.936			
$\sigma_u$	0.407	0.019	21.62	<b>0.000</b>
$\sigma_v$	0.084	.		<b>0.000</b>
$\lambda(\sigma_u/\sigma_v)$	4.805	.		<b>0.005</b>
Log likelihood	-3598			

<sup>1</sup>Depended variable is the milk income per cow per year; AFC= age at first calving; Other Costs=total of feed cost, variable cost, crop related and monetary value of cow; Milking robot=dummy, 1 indicates use of robot; intensification = total feed cost/cow.

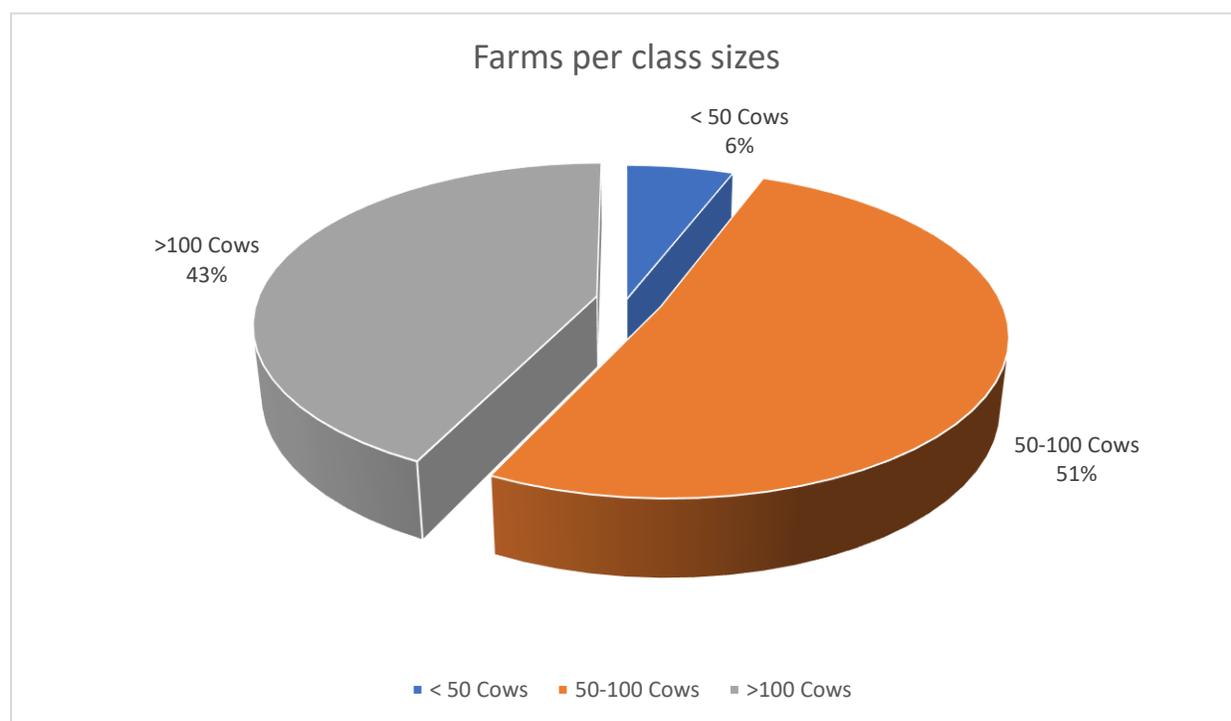
Table 4.3 shows the distribution of TE efficiencies among the sample of dairy farms. The results indicate that 1974 dairy farms (96.48%) are on average 81-100% technically efficient in their production enterprises. We analysed efficiencies of farms classed under different sizes. Our finding was that technical efficiency is not differing much among farms in the different size classes of farms. The small-sized farms (< 50 cows) in this study showed a slightly higher TE (91.93). This result suggests that the Dutch dairy farmers sampled for the study were generally efficient managers irrespective of the sizes of their farm holdings. Table 4.4 describes farm sizes and technical efficiencies scores.

Table 4.3: Distribution of Technical Efficiency

TE Range	Number of Farms	Percent	Cum. Freq
<b>0-49</b>	6	0.29	0.29
<b>50-60</b>	5	0.24	0.54
<b>61-70</b>	10	0.49	1.03
<b>71-80</b>	51	2.49	3.52
<b>81-90</b>	424	20.72	24.24
<b>91-100</b>	1,550	75.76	100.00
<b>Total</b>	<b>2,046</b>	<b>100.00</b>	

Source: own source based on data analysis

The analysis suggests that small-sized farms (<50) have decreased over the period, with most small-sized farms consolidating with other farms or exiting. For the period spanning 2011 to 2014, most of the farmers operated in the medium-sized scale (50-100). The result emphasizes the structural changes as reported by CBS (2015). However, most farms were still in the middle sized dairy farm for the period. Below is figure 2 showing the distribution of size structures of farms.



**Figure 2:** Distribution of dairy farms and sizes

Empirical studies have established that cost of farm production decreases with size and there is a smaller production cost associated with large dairy production than smaller units. This explains why most small-scale farms are exiting their businesses (Mishra and Tauer, 2006; Bailey et al.,

1997). Although all the different sized classes in this study were found to be uniformly efficient technically, they might, however, be different in terms of cost of production. Tauer & Mishra, (2006) studied cost efficiency of US dairy farms and found that efficient small dairy production units produce milk at a slightly greater cost than efficient larger farms, whilst the typically inefficient small dairy units produce at much higher cost than inefficient large dairy units. In line with this argument Bailey et al., (1997) suggest only the large-scale dairy units (500 herd units, and 1000herd units) would be economically viable.

The mean technical inefficiency predicted by the model is 0.094 with a standard deviation of 0.061. This means farms are on average 91% technically efficient. Therefore, dairy farms in the sample can potentially improve their milk incomes per cow by 9% at the current level of performance without expanding the available input resource on the farms. The mean technical efficiency scores observed in this study is far greater than and agrees with the technical efficiency value proposed by Bravo-Ureta et al, (2007). These authors have conducted a meta-regressional analysis for both developed and developing countries on livestock and crop enterprises and established a mean technical efficiency level of 84% for dairy farms in developed countries. Compared to this value, the sample of the Dutch farms was more technically efficient. The result is also higher compared to that observed by Reinhard et al., (1999). These authors reported a technical efficiency level of 89.4% in an earlier study when technical and environmental efficiencies were analysed for Dutch dairy farms. It could be conjectured that as higher efficiency levels are technically feasible in other regions and in different enterprises, give an indication of possible improvement in performance among farms.

Table 4.4 Distribution of Class sizes and Technical efficiency of farm

<b>Farm_size</b>	<b>Farms(n)</b>	<b>TE</b>	<b>SD. Dev</b>	<b>Min</b>	<b>Max</b>
<b>&lt; 50 Cows</b>	121	91.93	9.02	74.52	96.66
<b>50-100 Cows</b>	1050	91.46	6.57	55.32	96.96
<b>&gt;100 Cows</b>	876	91.21	6.23	39.48	97.53

**Source:** Study data analysis

The results of the technical inefficiency model are presented at the end of table 4.2. Equation 2 (section 3.2) suggests there is an inverse relationship between technical inefficiency and technical efficiency. Given that the parameter estimates of the explanatory variables are interpreted with

respect to their effects on technical efficiency, a negative correlation with inefficiency implies a positive correlation with technical efficiency and vice versa.

Intensification, defined as the annual cost of feed fed per dairy cow is statistically significant and negatively correlated with technical efficiency. Thus, an increase in the intensification (feed cost per cow) by €1 will reduce the annual milk income per cow by €3.652. This outcome sides with the findings of Krpálková, et al., (2014). These authors studied the associations between age at first calving, rearing average daily weight gain, herd milk yield and dairy herd production, reproduction, and profitability and observed that herds kept under long intensive periods have long conception rates and overall services causing a decreased technical efficiency. Contrary, the finding conflicts with the findings of Reinhard et al.(1999), Alvarez et al (2008) and Carbrera et al (2010). (Alvarez et al., 2008) studied the impact of intensification on the economic efficiency of Spanish dairy farms and found that intensive farms were closer to the cost frontier than extensive farms. Reinhard et al., (1999) applied an econometric analysis to estimate the technical and environmental efficiencies of dairy farms in the Netherlands. These authors observed that intensive Dutch dairy farms were more environmentally and technically efficient than extensive dairy farms.

Automatic milking robot is a dummy with a value of 1 indicating the presence and use of milking robot on dairy farms. Milking robot was statistically significant and positively correlated with technical efficiency. This variable represents technology or improved management practices that influence the productivity of farms. As shown in table 4.2, an additional use a milking robot leads to an increase in annual milk income per cow by an amount of €2.387. The empirical result confirms the findings of Tremblay et al., (2016). These authors studied the automated milking systems of American dairy farms and found an optimal number of robot per pen has a positive impact on milk yield. It was observed that a pen with single robots do not permit alternative opportunities for recommended milking frequency since a timid cow will wait for longer periods to access the robot. Melin et al., (2006) observed that the number of robot per pen can influence the redirection time of cows which is also influenced by the individual characteristics of the cow such as social rank and situation-specific factors such as the time when last milked.

Although statistically insignificant, the variables age and concentrate cost negatively correlated with TE. Age, defined as the age of the farm manager showed a negative correlation with technical efficiency. A negative correlation observed in this study could be possible in situations where

increased age is not proportional with managerial competence and improving their knowledge with modern technologies. The results, however, agree with the empirical findings of the Rasmussen (2011). In addition, this author also observed that old farmers are technically less efficient compared to middle aged and young farmers, with middle aged farmers showing significantly higher technical efficiency than young farmers. Concentrate cost depicts feed cost that forms an integral part of the cost composition of dairy farming and showed a positive correlation with technical efficiency. The result disagrees with empirical findings of Jiang & Sharp (2014) who found that feed cost is negatively correlated with farm efficiency. Pasture size indicates the extent of use of pasture for animal feeding and was positively correlated with technical efficiency. This a common practice in the extensive system of dairy production. As was found by (Geert, 2011), the positive correlation of pasture size and concentrate cost on technical efficiency indicates that improvements in pasture and concentrate feeding could potentially improve milk yield and economic performance of farms. Besides, since the profitability of milk production depends on milk and concentrate prices (Geert,2011), rationing the concentrate feed will improve the observed incomes from milk, and the corresponding technical efficiency. The non-significance observed for the explanatory variables in the inefficient model could be because intensification, automatic milking robot systems, and other exogenous variables were more important in explaining the inefficiencies among farms.

## CHAPTER FIVE

### CONCLUSION AND RECOMMENDATIONS

We have successfully analysed scale and technical efficiencies of dairy farms in the Netherlands and further assessed the potential drivers of scale and determinants of technical efficiencies among farms for the years 2011 to 2014. The econometric stochastic frontier analysis (SFA), with the 'True' fixed and random-effect panel data models, was used in this study. Based on the Hausman test results, the true fixed-effect model was proven to be econometrically best fit for the analysis.

The analysis showed there were significant structural changes across farms for the year 2011 to 2014. The medium sized (50-100) farms had the highest number of farms. This was followed by the large-scale farms (>100 cows), and the small-scale farm (<50). The result confirms the empirical findings established from other studies about consolidations of small scale farms. Between variations were greater than within variations for the output and input variables as well as all the explanatory variables included in the inefficiency model. This suggests structural changes across units were greater than the changes or the variations in individual or specific units over the years.

The variable, Other costs consisting of crop related costs, feed costs, variable costs, and cow had the greatest impact on productivity, milk income per cow per year, with an output elasticity of 1.425. This was followed by labour cost (0.210) and Capital costs (0.173). The elasticity of scale (EOS), the sum of all partial elasticities was 1.81. This value of EOS indicates an increasing return to scale (IRS) and the existence of scale economies. IRS implies the long-run average cost of production decreased in the face of increasing annual milk incomes per dairy cow. The presence of IRS shows farm size, measured as the average number of cows is positively correlated with the productivity of farms and the corresponding technical efficiencies. Therefore, based on the results of this study as well as the study of Jongeneel et., (2010) we conjecture that it was economically profitable to increase size.

The mean technical inefficiency predicted by the true fixed-effect model is 0.009. this indicates farms were 91% technically efficiency. Farms can potentially expand milk income per dairy cow using the current amounts of inputs and the production technology. We found that farms within different size classes of farms are relatively similar in their performances on technical efficiency.

The small-sized farms (< 50 cows) showed slightly higher technical efficiency (91.93). Although no much differences were found in terms of technical efficiency, cost implications could vary between different size classes. Analysing the results of class sizes and technical efficiency and elasticity of scale show that cost benefits could be the most important motivation behind the herd-size revolution than the efficiency gains. Intensification, defined as feed cost per cow, and automatic milking robot were the most important determinants of technical efficiency. Intensification showed a negative correlation with technical efficiency whereas use of automatic milking robot is positively correlated with technical efficiency.

The findings of this study offer useful insights into the possible cost implications, efficiency, and profitability of dairy farms and mark a useful enquiry about scale economies. Further studies on the subject could investigate in-depth the cost gains per unit increase in farm size and the optimal scale of production. As have been established that increasing scale is profitable, a follow-up question that could be of much interest is knowing how profitable it is to increase. Besides, different approaches may be applied to ascertain the correlations of the parameter estimates of the explanatory variables. Large scale study could consider inclusion of more number of variables in the inefficiency model. Besides, it would be useful to investigate the dynamics of the of scale economies in the post-quota period.

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