Measuring performance in farming: A comparative analysis of dairy production systems in New Zealand and Chile

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Abstract

The purpose of this work was to identify, examine, and compare the key performance indicators and drivers of success of pasture-based dairy systems in New Zealand and Chile. Key similarities and differences between dairy farming systems in these countries were identified by analysing data provided by *DairyBase* and, its Chilean counterpart, *TodoagroBase*. Comparable observations were nested using country-specific classification systems based on existing knowledge, followed by the estimation of efficiency scores for each individual observation within these classes using Data Envelopment Analysis (DEA). Efficiency scores were then attached to the original datasets and used as the response variable in several country-specific Regression Partitioning Trees. This procedure identified the most relevant benchmarks in each country and showed that there are various pathways to high efficiency. Knowledge gains provided by this research are expected to influence farming practices and management, research and extension, and to encourage future cooperation between the two countries.

Dairy farmers in New Zealand and Chile benefit from low-cost production advantages because of their favourable environment for pasture-based dairying, efficiently and profitably producing milk at a lower cost than the world's average. However, a large variability in farming systems within the countries was identified, as were different benchmarks. In New Zealand, herd productivity and labour played key roles in defining efficiency, while in Chile, herd productivity and supplements fed per litre of milk produced were key indicators explaining efficiency. In New Zealand, operating cost per kg of milk solids, return on Assets (ROA), operating profit margin (OPM), operating profit per hectare, and asset turnover (ATR) were also major indicators. In Chile, gross farm revenue per cow, cost of production per litre of milk produced, wages per litre, operating profit per cow and ATR were also highlighted. The absence of indicators such as ROA in Chile was noticeable.

Reasons for different key performance indicators occurring in each country stem from history to geography, and have resulted in differences in values and goals. New Zealand farmers are profitability and cost-focused, looking alternatively to both OPM and the capital invested. Chilean farmers are revenue-focused and respond strongly to milk:feed price ratio and to the efficiency in the use of supplement. In both countries, the systems are evolving in similar ways, gradually increasing intensification levels and specialisation. In both countries, consistently high performing farms are efficient at producing both milk and revenue, and are more likely to have higher herd productivity and labour efficiency than poorer performers. In New Zealand, consistently efficient farms also had significantly better asset use as reflected by their ROA and ATR. In Chile better performers used significantly less supplement per litre of milk produced.

Keywords: pasture-based, farming system, efficiency, benchmarks, New Zealand, Chile

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TABLE OF CONTENTS

List of Tables

List of Tables in Appendices

List of Figures

List of Figures in Appendices

1. Introduction.

A farming system might simplistically be defined as the particular combination of resources operating over time, under similar socioeconomic conditions and producing a certain set of outputs (Cochet & Devienne, 2006; National Research Council, 2010). Most importantly, farming systems are complex entities, exposed and sensitive to all types of external fluctuations and particularly prone to potential rapid change in system drivers. Research in this field has often been identified as high-priority, and, as such, it continues to be encouraged. The National Research Council [NRC] (2010) stated:

> Agricultural research and development programs should aggressively fund and pursue integrated research and extension on farming systems that focus on interactions among productivity, environmental, economic and social sustainability outcomes. Research should explore the properties of farming systems and how they could make the systems robust and resilient over time (p. 22).

Support for these concepts can be found worldwide and in almost every industry, coming from major entities that promote extension and research such as Dairy NZ (2010) and Consorcio Lechero (2010). Irrespective of the industry, the availability of relevant information is increasingly needed, since the farm business ability to succeed and sometimes to survive rests on making informed decisions (Dillon, Hennessy, Shalloo, Thorne, & Horan, 2008). Some of this information may be provided by empirical research, and particularly by the long term assessment of different farming systems (NRC, 2010). According to Thorne and Fingleton (2006), there is an increasing requirement for transparency and information-sharing around the world in response to increasing trade liberalisation and globalisation which have led to farmers seeking more resilient and profitable farming systems. International efficiency analyses and benchmarking activities have the added value of encouraging increased sampling of firms from a range of geographies, policies and market contexts, allowing comparisons of performance and the development of methods for improved systems (McGuckian, 1996). This suggests that international comparisons of business performance are actually useful excercises.

Dairy farming is important for a number of reasons including the nutritional value of milk, the significance of its global production, and the trade that the sector underpins. Milk is perhaps the most important single agricultural commodity in the world: 40 per cent of the world's population consumes milk daily (Blasko, 2011), contributing significantly to human health and food security (Swinnen & Squicciarini, 2012). The milk industry is large and has a strong growth forecast; according to Blasko (2011), 711 million tonnes of milk were produced in 2010, and future production may rise to over 794 million tonnes in 2017. This increase in supply would be supported by a demand that is projected to escalate in both developing and developed countries (Popp, 2010). As a consequence, the dairy sector has a promising outlook, even though additional supply is expected to drive prices down from current levels beyond 2012 (Ministry of Agriculture and Forestry [MAF], 2011; Organisation for Economic Co-operation and Development [OECD], 2011).

Increasingly, milk producers operate in a global economy, interacting through diverse linkages boosted by free trade policies. This setting provides both opportunities and threats, and forces successful farmers to continually assess their external environment and internal resources to meet their long term goals (Kay, Edwards, & Duffy, 2012; Olson, 2010). Focusing on the positive side of this dichotomy, globalisation represents an opportunity for those farming systems, countries and regions to specialise where they have a comparative advantage. For producers of commodities in general and dairy farmers in particular, cost advantage provides a competitive strength, and low-cost leadership is the generic strategy that best fits their external environment (Langemeier, 2010; Olson, 2010; Shadbolt, 2011). As pasture is the cheapest source of ruminant feed, pastoral farming systems are well-suited to that strategy of cost leadership. In particular, dairy farming systems show a strong inverse relationship between costs and grazing because feed is the highest single cost component (Dillon, et al., 2008; Lapple, Hennessy & O'Donovan, 2012; van Vuuren, 2006). Therefore, the recognition of the advantage of low-cost production is important and dairy producers that benefit from a favourable climate for pasture production need to exploit this as a comparative advantage (Lapple, et al., 2012).

Furthermore, pasture-based farming systems are less controversial than supplement intensive farming systems in terms of human food security, animal welfare, and environment. Consequently, pasture is used worldwide as the main source of feed for a range of animal production systems including dairying. However, given the biological nature of agriculture great variation can still be found among pasture-based systems. A particular farming system can be distinguished from the rest, in terms of environment and technology, by looking at the resources available and system configuration. Griliches (1987) defined technology as the state of knowledge concerning ways of converting resources or inputs into product or output. The output achieved by using that knowledge, relative to the maximum amount of output physically achievable by mastering a given technology and inputs, is defined as efficiency (Diewert & Lawrence, 1999). Exogenous conditions that are likely to affect efficiency are soil, climate, and other physical parameters (Fraser & Cordina, 1999) which vary across the terrain and affect the technology adopted (Sumner & Wolf, 2002). Therefore, assuming the existence of different technologies is customary in inter-country comparisons in the same way that the spatial dimension is clearly significant in terms of efficiency (Alston, 2002).

1.1 The Country Context

Many rural economies have developed with agricultural production as their main activity, including those in New Zealand (NZ) and Chile. The urban and rural populations are distributed similarly in both countries (86% NZ, 89% Chile), but the labour force occupied in agriculture in Chile is almost double that of NZ (13% to 7%) (Central Intelligence Agency [CIA], 2011). In turn, the contribution of agriculture to Gross Domestic Product (GDP), including downstream activities, is around 15% in both countries. The countries also have a number of other commonalities relevant to the macro-environment in which they operate. NZ exports are delivered to more than 150 countries as a consequence of a consolidated modern open market system; developing countries are the main destination while key markets are China, the United States (US), Japan, and the European Union (EU) (Blasko, 2011). Similarly, Chile has shown a longstanding commitment to trade liberalisation, having 59 bilateral or regional trade agreements with various regions and countries including the EU, the US, MERCOSUR[1], China, India, South Korea, Mexico, Singapore, and New Zealand (Agosin & Bravo Ortega, 2009).

NZ's land area is about one third that of Chile and its population less than one quarter of Chile's population (CIA, 2011). In addition, the adjusted self-sufficiency in milk supply data shows that, while NZ's contribution to dairy world trade is large, the Chilean contribution is negligible (CIA, 2011). The level of development in the dairy industry is a major difference between the two countries. NZ accounts for just over 2% of the total world milk production, but makes up to one-third of the world's cross-border trade in dairy products (Blasko, 2011). Nationally and internationally, the NZ dairy industry is seen as a pastoral giant, where cohesiveness and co-operation abound and the transparency of milk pay-outs operates as a powerful driver for collective action (MAF, 2011). Virtually all NZ milk is processed into dairy products and exported. The NZ Institute of Economic Research (2011), estimates that the dairy industry contributes NZ$ 10.4 billion of export earnings or 2.8% of the national GDP including downstream activities such as marketing and transport to the economy. In contrast, dairy production in Chile has traditionally supplied the domestic market demand but several factors including social, political, and economic instability have adversely affected the development of its dairy industry (Dobson, 2003). In 1977, Chile produced 1,003 million litres of milk that were 100% internally marketed (Zegers & von Baer, 1978), and nowadays dairy still provides a

[1] MERCOSUR stands for Mercado Comun del Sur, meaning The Southern Common Market. It is an association between Argentina, Brazil, Paraguay, Uruguay and Venezuela, as full members. Bolivia, Chile, Ecuador and Peru have the status of associated countries, while Mexico is also included as an observer. The objectives of MERCOSUR are to allow for the free movement of goods, services and factors of production between the countries through the elimination of customs duties and non-tariff restrictions; to establish a common external tariff and to adopt a common trade policy in relation to third States or groups of States (MERCOSUR, n.d.)

minor input into the Chilean government revenue (Banco Central de Chile [BCCL], 2012). However, dairying is seen as a sector full of growth opportunities, with Chile having recently become a net exporter of milk products (Barton, Gwynne & Warwick, 2007).

1.2 Research Motivation

This research is motivated by the need for further knowledge about pasture-based dairy farming systems. A major premise is that a rigorous analysis of the past may contribute to knowledge gains, which could directly influence future farming practices and management, policy making, research, and marketing programmes. A second premise is that NZ and Chilean pastoral dairy farming systems may mutually benefit from being benchmarking partners. Therefore, an exploration of these systems was proposed here based on key metrics testing performance. This summary set of performance indicators allowed the different farming systems to be compared. Despite the use of only quantitative measures to analyse the farming systems, this thesis aims for a holistic view by incorporating rich contextual information. This study intends to use a systems approach, including external environment considerations and diagnoses of the techno-economic performance, to search for the reasoning behind common practices leading to the production of milk.

1.3 Statement of Purpose

The purpose of this study is to identify, examine and compare key performance indicators and drivers of efficiency of pasture-based dairy systems within New Zealand and Chile. This will be achieved using standardised metrics and methodology to look at empirical data generated by two national databases over five consecutive seasons.

1.4 Research Questions and Specific Objectives

The research questions in this study were:

1. Which are the most relevant benchmarks to assess and compare dairy farming systems in Chile and NZ?
2. Are these benchmarks the same in both countries?
3. If the benchmarks were not the same, why this would be?
4. How can ‘performance’ best be measured in NZ and Chile?
5. What is the relative efficiency of the normal NZ and Chilean pasture-based dairy farming system?

The specific objectives were:

1. To gain a deeper understanding of pastoral based dairy farming systems in NZ and Chile, in terms of their internal resources, key performance indicators, and drivers of success.
2. To identify differences and similarities between the country-specific farming systems.

Some key assumptions were:

1. A farming system may be described with reasonable accuracy, after understanding physical and socio-economic factors as part of the whole agrarian system context, and through reviewing accounting records.
2. The use of large databases would allow general conclusions to be drawn from statistical inference.
3. Benchmarks can be used to identify performance gaps, while benchmarking practices can identify how to close these gaps (for example, imitation of superior practices or correction of low-grade practices) (Camp, 1989)
4. The assessment of the external environment and the on-farm competitive advantages, are important for reaching meaningful conclusions. The environment and strategic management both influence a farming system’s structure and shape competitive advantages (Porter, 1985, in Shadbolt, 2011), which if effectively exploited, will allow a farm to outperform competitors and exhibit greater performance over time (Pertusa-Ortega, Molina-Azorin & Claver-Cortes, 2010).

1.5 Outline of the Study

The justification and purpose for the study have been set out in this chapter. In Chapter Two, the relevant literature on pasture-based dairy systems, farming systems approaches, performance measurement, the macro-environment, and benchmarking as a farm management tool, is discussed. The method used to assess performance and answer the research questions is presented in Chapter Three. The results and summary statistics for the major performance indicators are presented in Chapter Four, Five and Six. The results of the metafrontier analyses and the cross-country comparison are described in Chapter Seven. In Chapter Eight the main findings are discussed and compared with the literature. Finally, in Chapter Nine the conclusions from this study are drawn and areas of improvement and further research are suggested.

2. Literature Review.

In this chapter the generalities of pasture-based dairying are described and the farming systems approach is conceptualised; these ideas build up the research framework for introducing a summary of commonly used metrics for appraisal in pasture-based systems, including physical, financial, and efficiency indicators. This is followed by an overview of the NZ and Chilean macro-environments and dairy industries which sets the scene and enables a richer discussion about specific key features that, in one way or another, have shaped dissimilar dairy farming systems. Finally, this literature review addresses the competitiveness of pastoral systems and the applications of benchmarking on farm management and farming systems research.

2.1 Pasture-Based Dairy Systems

Pasture-based dairy systems have always been dominant in Oceania and most parts of South America. Recently, these systems have gained interest in other parts of the world where dairies have traditionally been based on confinement systems. Pastoral dairies typically feature outdoor herds all year round, have a match between milk production and pasture growth, and generally have lower feed, culling and total production costs than other systems (Harris & Kolver, 2001). Consistently, in Oceania and South American countries, this type of dairy farming has below world's average costs and a share of feed around 60% of total costs, while in the world this share ranges between 45-74% (IFCN, 2011).

The criteria for systems to be described as 'pasture-based' can vary, partly due to pasture production differing by regions due to differences in plant growth which depends upon climate and soil. According to Taylor and Foltz (2006), pasture-based dairy systems are those which use pasture as the primary feed source during the grazing period. Other authors are more specific and require animals to directly obtain a minimum of 40% of their forage needs during the summer months from pasture (Hanson, Cunningham, Ford, Muller, & Parsons, 1998). Alternatively, a 'grazing operation' may be one where at least 25% of the annual forage requirement is obtained via pasture and the animals graze for at least four months of the year (Dartt, Lloyd, Radke, Black, & Kaneene, 1999). Pasture-based farming systems are physically feasible only if there is a suitable climate throughout the year, and they are optimally established in the temperate regions (Holmes, 2003). Temperate pastoral systems, like those developed in Oceania and South America, typically show a higher commitment to grazing, which usually makes up more than 70% of the diet (IFCN, 2011).

In addition, pasture is also a flexible description that encompasses low to highly productive swards and poor to high quality botanical mixtures or monocultures (Waghorn, Burke, &

Kolver, 2007). Typical temperate species are usually C3[2], with best performances at an optimum temperature of 20-25°C, outside which photosynthesis and, hence, production decreases considerably below 10 and above 30°C. Conner, Hamilton, Sheehy, Stuth, and Kreuter (1998) defined the temperate zone as regions where the annual mean sits around 15°C and where winter temperatures that may fall below 5°C. Characteristically, the average rainfall across the temperate zone fluctuates from 500 to 1,000 mm (although large deviation can be expected), evapotranspiration may vary greatly between seasons, and water deficit in the summer may be more or less important as it interacts with soil properties. Four well-defined seasons with potentially large seasonal amplitude, soil water retention ability and rainfall patterns through the seasons are the other vital features defining a temperate environment (Carter, Murphy, & Cheal, 2003).

Overall, temperate grasslands include a variety of environments resulting from factors such as season, latitude, altitude, aspect, and distance from the sea. In spite of this highly variable environment, the normal conditions are very favourable for livestock production. Consequently, temperate grasslands around the globe have developed relatively low input systems shaped by several different management strategies that cope with this natural variability. These strategies, in turn, have logically allowed for a range of farming systems to take place differing, for example, in how much pasture they grow, supplement they use, and the amount of desirable and undesirable outputs they produce.

2.1.1 Milk output from pasture.

This section reviews the definition of milk and milk components, as well as some aspects related to milk quality and measurement. Milk is the normal mammary secretion of milking mammals, including all commercially available types from cows, goats, sheep, and mares. Raw milk is that which has not been in any way processed, reconstituted, or recombined (Draaiyer, Dugdill, Bennett, & Mounsey, 2009). The composition and characteristics of milk largely vary as a function of species, breed, and other factors. Table 1 focuses only on raw bovine milk and presents average figures for parameters of interest.

[2] According to the online Dictionary of Botany, C3 is a type of plant that produces phosphorglyceric acid as the first step in photosynthesis, which contains three carbon atoms. Most C3 plants exhibit photorespiration when temperature is greater than 25^{o}C and, therefore, are relatively inefficient photosynthetically compared to C4 plants, particularly at higher temperatures.

Table 1

Average Figures for Normal Raw Milk at 20°C

Parameter	Value range (%)
Water	85.5 - 89.5
Fat	3.2 - 5.5
Solids Non-Fat	8.2 - 10.0
Total Solids or Milksolids	10.5 - 14.5
Protein	2.6 - 3.6
Lactose	4.6 - 5.0
Acidity	6.6 - 6.7
pH	0.14 - 0.18
Specific gravity	1.032
Somatic Cell Count (000)	100 - 300

Adapted from: Draaiyer et al., 2009.

Milk is both a suspension and a solution, fundamentally composed of water and solids that are mainly fat, protein, and lactose. As a result, milk quantity can be measured in volume or weight and, on average, one litre of milk produced by a Friesian type cow weighs 1.03 kg (Porter, 1991). Most payment systems in the world are based on volume as fluid milk is required for home consumption. However, as even these systems include milk solids (MS) in some way, it is also appropriate to measure the mass of milk solids, or the weight of milk (Draaiyer et al., 2009). MS content can be measured by using estimation readings from the lactometer, or by drying the milk and weighing the solids, and by using rapid testing methods (Siddique & Gulfraz, 2009). While fat has traditionally been the first compositional quality parameter to be included in a milk payment system, non-fat solids (SNF[3]) has recently become an important parameter.

Milk composition and hygiene are major quality factors, and, as such, milk payment systems often offer bonuses or penalties based on quality grading systems. The somatic cell count (SCC) measures the number of somatic cells (SC) present in a sample of milk, typically comprising three quarters white blood cells and one quarter epithelial cells from the secretory

[3] SNF are the portion of MS minus the fat component; SNF includes proteins, lactose and minerals.

tissue of the udder (Draaiyer et al., 2009). A high concentration of SC per millilitre of milk indicates an abnormal condition in the udder and can make the milk susceptible to rejection (Le Marechal, Thiery, Vautor, & Le Loir, 2011).

Milk output from pasture shows distinct variability both in volume and quality, affecting production costs and returns. A lower degree of control over intake and diet quality can be expected in pasture-based feeding systems, along with poorer individual cow performance (Gazzarin, Frey, Petermann, & Hoeltschi, 2011). Milk produced from pasture also shows higher variability in fat and protein contents over time; a lower proportion of saturated fatty acids (Wyss, Mauer, Frey, Reinhard, Bernet, & Hofstetter, 2011) and lower total somatic cell counts than milk from indoor systems (Pedernera, Garcia, Horagadoga, Barchia, & Fulkerson, 2008; Wyss et al., 2011). All of these vary for the different farming systems but they particularly vary over time responding to seasonality, a common attribute of all pasture-based dairy systems.

2.1.1.1 Seasonality.

Supply fluctuation is a common feature among food commodities, although it is not always part of a seasonal pattern. Milk production from pasture is seasonal in nature. Seasonality can be the result of natural, economic, social, or institutional causes, and is defined as the systematic, but not necessarily regular, movement or set of movements within a year or less that happen in a temporal series (Marin, Cavalheiro, & Anschau, 2011). In Chile, seasonality can be expressed as the ratio, litres of milk produced in Spring-Summer relative to litres produced in Autumn-Winter (Lerdon, Baez, & Azocar, 2008). Season affects not only milk volume, but also milk quality; composition, fat, protein, and lactose content; and the herd’s reproductive performance. From an industry standpoint, seasonality influences the milk processing ability, the final product class, and even the monthly milk prices (Holmes et al., 2003). Consequently, there is an overall negative effect on the standardisation ability of the industry that begins with the heterogeneity of milk supply. In addition, seasonality is also a challenge with respect to scheduling and utilisation of plant infrastructure because the handling of the milk during the peak season requires an adequate processing capacity while plants are often idle during autumn and winter months (Holmes, 2003). This excess capacity adds substantial processing costs to the system, which are paid by all, dairy producers and processors.

Boehlje and Schiek (1998) suggest that complex matters like these need to be studied using a complete systems approach, placing emphasis on the entire value chain. Several strategies have been designed to cope with the issue of seasonality, directed to improve the non-seasonal yield of milk. In NZ, these strategies are generally based on a proportion of the herd calving in the autumn and bonus payment schemes for winter milk production (Holmes et al., 2003). In Chile, bonus payments for winter milk can be accompanied by penalties for spring milk (Lerdon et al., 2008). However, pursuing a more level production pattern is costly to farmers, and although fresh winter milk usually gets rewarded, marketing arrangements sometimes provide little incentive for such activities. In conclusion, seasonality of milk production is the most common pattern for pasture-based dairying and one of the biggest challenges for the milk industry as a whole.

2.1.1.2 Feeding strategies.

Maximising the grass utilisation and animal performance from grazed pasture has been cited as one of three key areas of innovation important for the sustainability of dairy farming (Dillon et al., 2008). The most typical and appealing characteristic about pastoral systems is that milk can be produced from inexpensive pasture at lower costs; as demonstrated by the data for nine countries, a higher proportion of pasture in the diet is negatively correlated with cost of production (Dillon et al., 2005). This finding has been supported by broader sample studies (IFCN, 2010; 2011; 2012). In addition, supplements integrated with the pasture supply add flexibility to the systems and may produce extra milk and extra profit. As a consequence, the optimum balance between pasture and supplements is often system-specific and has proven to be difficult to find.

There are different feeding strategies aimed at several objectives: exploiting the natural production peak after calving; increasing the milk fat or protein content; extending the lactation; or improving the body condition score over the dry period (Dairy NZ, 2011). The diet influences not only volume of production and every aspect of milk quality and composition, but also reproductive performance which, in turn, affects the whole system's physical and economic efficiencies. Feeding strategies concerned with both productive and reproductive performance have to deal with the negative association between milk yield and fertility (de Vries & Risco, 2005; Washburn, Silvia, Brown, McDaniel, & McAllister, 2002). This is, in part, explained by the antagonist correlation between milk yield and fertility, and in part, explicated by the energy partition and balance of the lactating cow (Hansen, 2000).

The theory and practice of grazing management and feeding supplementary feed sometimes conflict and add complexity to these matters. Feeding strategies for pasture-based dairy systems have been developed looking at both grazing management and supplementary feed research; however, grazing management research has proven to be difficult, resulting in slower progress in strategy development. Research in this area has partially removed subjectivity from grazing management, propagating the use of certain rules, such as target pasture mass at key times and optimum seasonal grazing management (MacDonald & Penno, 1998). Although these rules meet the dual objective of feeding the herd while maintaining healthy swards and quality, the persistent dualism has determined that grazing management stays sub-exploited and underdeveloped. Meanwhile, the use of a wide range of supplements continues to gain popularity across the most diverse dairy regions in the world. Milk production responses of grazing cows offered supplements reported in the literature vary between 30 and 150 g of milk solids per kg of dry matter intake, however, positive quadratic responses to increasing amounts of supplement have been observed for yield of milk (Auldist, Marett, Greenwood, Hannah, Jacobs, Wales, 2013).

2.1.1.3 Stocking rate.

Stocking rate, also known as stocking density, is the number of animals supported per hectare or other unit of area. Although the weaknesses of the simplest ratio, 'cows/ha', are widely recognised, it has persisted because of its simplicity rather than its accuracy. The stocking rate (SR) a farm may support is limited by the availability of pasture and the intensity of the use of supplements (Penno, McGrath, Macdonald, Coulter, & Lancaster, 1999). Potential for pasture production depends mostly on the quality of the land. In pastoral systems, the reliance on pasture production means that SR affects not only physical and economic performance, but also a farm's risk profile (Penno, 1999). Usually, most types of risk associated with farming are positively correlated with increasing SR. Recent work by Anderson and Ridler (2010) analysed the optimisation of resource allocation in dairy production systems in NZ and found that there is less financial risk when a farm is slightly under-stocked than when it is highly stocked.

Stocking rate is, therefore, an effective management tool since it can be manipulated to provide a wide variety of management options. SR adjustments throughout the seasons are common place for most farmers, and often the potential of the land is challenged by the available supplement cropped or purchased. In general terms, the milk production response for an incremental SR change is negative on a per cow basis, while a strong positive relationship exists to a point between SR and milk production per ha (McCarthy, Delaby, Pierce, Journot, & Horan, 2011; Penno, 1999). Also, a farm may be able to carry more cows (smaller) per hectare, in which case a financial disadvantage per head may be partly or completely offset by higher stock numbers and performance per hectare.

Physical resource constraints, such as soil type, have real and significant negative impacts on the probability of increasing SR because of their effects on pasture production (Penno, 2000). MacDonald, Penno, Lancaster, and Roche (2008), after conducting a three-year-study on a seasonal calving system, concluded that there is a tendency for most production variables to behave quadratically with increasing SR. They showed the need for a more robust measure than cows per hectare and introduced the concept of a comparative SR. Using this concept, the carrying capacity of the farm is defined by the live weight of the cows and the potential of the land to produce pasture. According to Macdonald, Penno, Nicholas, Lile, Coulter, and Lancaster

(2001), for NZ farming systems, the economically optimum comparative SR appears to lie between 80 and 90 kg of live weight (LW) per tonne of dry matter (DM) produced.

2.1.1.4 Calving systems.

A calving system is defined by time and pattern of calving, two key elements in the construction of any pastoral dairy farming system. The dairy cow can conceive, calve and lactate successfully at any time of year as long as enough energy can be provided when it is required (Garcia & Holmes, 1999). Therefore, the calving system can be used as a management tool. This offers complete flexibility in the selection of a calving system. However, such flexibility is partially offset by the seasonality of pasture production that implies greater restrictions in respect to the times at which economical feed can be provided in the required quantities. Hence, there is a considerable productive challenge in meeting feed supply with the increased demands of pregnancy and lactation considering the herd need to get in calf again soon after calving. The combination of management strategies, production, and fertility governs the pressure of animal demand on the grazing area, shapes the lactation curve, and regulates the animal performance, all of which affects farm's profit (Steinwidder et al., 2011).

A compact calving pattern at the appropriate time is the major reproductive target for the seasonal dairy farm (Holmes et al., 2003). Cost-focused dairy pastoral systems in NZ tend to implement a location-adjusted strategy which requires a labour efficient, concentrated spring calving that matches the animal demand with availability of forage resources (Adams, Clark, Klopfenstein, & Volesky, 1996). This strategy has been quoted as one of three key areas for the sustainable development of dairy farming (Dillon et al., 2008). According to Garcia and Holmes (1999), early spring calving ensures sufficient feed in early lactation and more days in milk than a later calving pattern.

Nonetheless, a variety of results suggest that for maximum profitability, no calving time is optimal in all environments. Alternative systems are autumn calving, a combination of both spring and autumn, and all year round calving. All three systems can be found in Chile, but the combined spring-autumn tends to predominate in pasture-based dairies (Lerdon, Baez & Azocar, 2008). In general, one or other of these may be particularly suitable if pasture growth is slower in summer than in winter; if affordable supplements can be fed at any time of the year; and if there is a price incentive for winter-milk (Hodgson & Chesnutt, 1999). Production results show that autumn calving systems can have very good annual milk yields, mainly sustained on longer milking periods, and higher yields in late lactation. A review of comparisons between autumn and spring calving systems showed that autumn-calved cows require more supplements during winter and usually have lower daily milk yields at peak lactation than spring-calved cows (Garcia & Holmes, 1999). According to Garcia, Cayzer, Holmes, and MacDonald, (1998), economic results are diverse and are mainly a function of the premium received for milk produced in winter and the prices paid for supplements.

2.1.1.5 Genotype.

The use of profitable high quality genetics to increase the herd's performance from grazed pasture has been mentioned as one of the three crucial areas of improvement important for the sustainability of milk production (Dillon et al., 2008). There are so many interactions that the choice of a suitable cow genotype for a particular farming system remains a large and continually evolving area of research. The value of certain breeds depends on the system's configuration and resources. However, the breed itself does not completely explain genetic merit as it does when strain is also taken into account.

The NZ breeding programme managed by the Livestock Improvement Corporation (LIC) has put emphasis on milk solids (MS) production and, therefore, has produced a strain of Holstein-Friesian (HF) cow which yields higher MS and increased protein:fat ratio than overseas' HF. McCarthy et al. (2007) compared the economic efficiency of three divergent strains of HF cows; high-production North American (HP), high-durability North American (HD), and New Zealand (NZ) across a variety of Irish pasture-based production systems. The economic performance of each strain and feed system was affected by different production scenarios, milk quotas, predicted future prices, costs, and potential land availability. The results showed that in a fixed milk quota scenario, the NZ strain returned the highest profitability while the HD strain proved to be the next most profitable. The HP animals were least profitable in all systems because the productivity gains achieved were outweighed by associated increases in reproductive costs. Typically, in a different environment to what cows were bred for, genetic selection solely for increased milk production may result in reduced farm profitability.

South American dairy production systems have been highly influenced by genotypes from North America whose strains are typically capable of very high milk yields with low MS produced by mobilising large amounts of body reserves. On pasture alone, this metabolic effect reduces lactation length and leads to reproductive issues (Harris & Kolver, 2001; Harris & Winkelman, 2000). Thomson, Turner, Lopez-Villalobos and Glassey (2005) evaluated the effect of genotype on milk composition, milk value, and dairy farm profitability by means of a trial including a low and a high merit strain from NZ, and another high merit strain from America. Their results clearly showed that, within the same breed and under the NZ payment system, the American strain resulted in high milk production but lower farm profitability than the NZ strain. Overall, the potential for improving the performance of different dairy systems through breed substitution and by identifying the more appropriate strains has been frequently examined (Piccand, Cutullic, Schori, Keckeis, Gazzarin, Wanner, & Thomet, 2011). Crossbreeding,

breeding and multi-factorial selection are increasingly valid options to include in any farming system's design. The results presented above reinforce the economic value of genetic improvement based on a selection index pertinent to the production environment.

2.1.1.6 Economics.

Empirical data has demonstrated that pasture-based dairy systems consistently have lower costs than other farming alternatives (IFCN, 2011). This organisation also indicated a mean world cost of milk production of US$40/100 kg milk in 2010[4] in a study which included all major producers and farming systems in the world. Long term experiments by White, Benson, Washburn, and Green (2002) on pasture-based systems showed what may be considered a regular pattern: lower milk production per cow, inferior feed and culling costs and lower labour, plant and equipment costs. This has been supported by other authors who claim that pastoral systems exhibit consistently higher net returns per cow than confinement systems (Rust, Sheaffer, Eidman, Moon, & Mathison, 1995). However, there is often controversy when undertaking these sorts of comparisons because the attributes to be measured and the appropriate metrics to be used are often system-specific. For instance, return on feed cost is less relevant if analysing a pasture-based system due to the inherent difficulty in estimating dry matter cost from long lived pasture (Barnard & Boehlje, 1998). In contrast, some financial indicators, including solvency and liquidity measures, have been regarded as mandatory (Barnard & Boehlje, 1998; Hanson et al., 1998). This is consistent with the inherent cash flow difficulty in all land-based industries (Oltmans, 2007).

Profitability, which is possibly the most important determinant of long term business performance, has several indicators which cannot be considered in isolation and which need to be contextualised adequately. There are several financial indicators, and depending on the indicator and the context where it is used, an empirical comparison might exhibit conflicting results. For instance, in the US where a vast range of dairy farming systems coexist, a pasture-based system may exhibit a higher gross margin than a confinement system (Parker, Muller & Buckmaster, 1992; Tozer, Bargo, & Muller, 2004). Yet, the confinement system can be found to have the highest profit measured as net income per cow when the milk:feed price ratio is favourable (Tozer, Bargo, & Muller, 2003). In NZ, the same pattern was found by Jensen, Clark, and Macdonald (2005) who analysed different levels of intensification within pasture-based systems. They found that increased input systems sustained greater SR and were able to duplicate the output, while the indicator return on assets revealed that profitability was governed by the relationship between milk payout:feed price. When the payout was low at NZ$3.50/kg MS, the low input system was competitive irrespective of land price ($18,000 or $37,000/ha) or

[4] Considering all cash and non-cash costs and including indoor and outdoor systems from 49 countries.

supplement cost (18c or 24c/kg DM). Conversely, at a higher payout of NZ$4.5/kg MS, the higher input systems showed higher profitability.

2.1.1.7 Diversification or specialisation strategy?

Milk production usually represents more than 85% of the total dairy farm's income, which originates from a multi-product system resulting from vertical diversification, which may include feed or stock sales (IFCN, 2011). Assuming that the rationale for portfolio diversification is to decrease non-systematic risk, this multiplicity of outputs can be seen as an advantage due to effective diversification (Rumelt, 1982). However, according to Ethier (1982), it can also be perceived as a disadvantage due to a lack of specialisation. In some cases, certain outputs are actually by-products, such as bobby calves[5] and cull cows, and not deliberate diversification. According to Rumelt (1982), true diversification occurs when a firm produces or sells a product which has zero or close to zero cross price-elasticity with each of the firm's other products. Different diversification strategies that exist in farming can be classified according to variations in their related or unrelated activities. The latter, also called primary diversification, is perhaps the most common practice for farmers all over the world, and usually involves those activities that share common skills or resources.

However, why would pasture-based dairy farmers choose specialisation instead of diversification? Many factors influence this decision, and the perceived risk and attitudes towards risk play a major role (Chatterjee & Wernerfelt, 1991). Risk averse farmers are more likely to increase portfolio diversification. Initial farm size and current levels of diversification are also likely to influence future diversification decisions: large farm size may be associated with greater diversification of unrelated farming activities. Chatterjee and Wernerfelt (1991) also demonstrated that the resource profile can partially explain the type of diversification strategy the firms engage. Therefore, some resources and core skills can be taken as competitive advantages (Porter, 1985) and also as key factors explaining diversification. A resource-based approach would consider three classes of resources: physical, financial, and intangibles. Typically, financial resources are more flexible than the other two. In contrast, physical resources usually have fixed capacity, and excess physical capacity will lead to related diversification. Similarly, the presence of intangible assets also leads to related diversification, and conversely, the availability of internal funds, equity capital or unused debt capacity, will favour unrelated diversification (Chatterjee & Wernerfelt, 1991).

2.1.2 The challenges.

Pastoral dairy farmers, regardless of their setting in the world, face several diverse challenges. These may be classified into at least three areas: productive, environmental, and consumers or

[5] In NZ, these are calves up to five days old.

general. Those challenges from the productive area are often addressed and researched. Challenges concerning to the environment and consumers areas are possibly even more complex than those related to production, and are probably among the most debated in modern agriculture. Both are closely connected because environmental issues are likely to influence preferences, public opinion, and consumer trends. The present section briefly addresses some of these challenges.

Among the production challenges, ensuring an adequate feed supply to high-yielding dairy cows in a highly variable environment would be the greatest challenge (Ferris, 2007). Feasible grazing systems require the use of high quality, high yielding pastures aimed at increasing either farm productivity, profitability, or both (Waghorn et al., 2007). In the future, land availability may limit the expansion of pasture-based dairy systems so that the maximisation of productivity per hectare could become critical (Shalloo, Dillon, O'Loughlin, Rath, & Wallace, 2004, cited in Patton, Shalloo, Pierce & Horan, 2012). A more general, and for some perhaps greater challenge, is how to get the most out of the existing competitive advantages by using a number of options spatially across the farm and temporally across the seasons (Lapple, et al., 2012). Plenty of alternatives have been designed to buffer the systems and cope with variability, mainly by spreading and increasing feed supply (Valentine & Kemp, 2007). Despite these alternatives existing, and variability being intrinsic to most pasture-based farming systems, not all farmers adjust their tactics and strategies to match heterogeneity and uncertainty.

Sustainable profitability is a challenge that combines the productive and environmental aspects. As Beale (2006) claimed in the Financial Times[6], contemporary businesses want not just large dividends, but also want them to be ethically driven, environmentally concerned and ecologically sustainable. Pasture-based dairy farming is required to be profitable on a sustainable basis; this means establishing high, lasting, and economic productivity and improving the quality of life without damaging the environment (Derpsch & Moriya, 1998; McGuckian, 1996). McGuckian (1996) also emphasised the enhancement of the natural resource base over time as a condition for sustainability. Therefore, farm sustainability is only achieved when all objectives, obligations and requirements associated with the farm system are fulfilled in a reconciliatory way (van Eijk, 1998). On-going financial and environmental problems related to agriculture prove that the reconciliation of all factors linked to farm sustainability is if not the greatest challenge, at least a difficult proposition.

Many common practices in farming have the potential to negatively impact on the atmosphere, water or land qualities. Among environmental challenges, agriculturally produced greenhouse

[6] The Financial Times is one of the world's leading business news and information organisations, publishing in several countries and languages worldwide.

gases stand out as a current concern (Surinder, Bolan, Bhandral, Hedley & Luo, 2004). Methane (CH_4) is a greenhouse gas over 20 times more effective in trapping heat in the atmosphere than carbon dioxide (CO_2), and is emitted from a variety of natural and human-influenced sources. However, 18% of total greenhouse emissions are produced by fermentative processes in the digestive system of ruminants (FAO, 2006). The quantification and management of these undesirable outputs is under study, as well as other interrelated bodies of research dedicated to understanding and generating mechanisms to cope with global warming and its consequences (Fischer, Shah, & van Velthuizen, 2002). In the meantime, environmental regulations threaten the image and competitiveness of pastoral farming systems.

Environmental impacts affecting land and water are more 'conventional' and longstanding, but not less challenging issues. Relatively recently, regulatory agencies, environmental groups, and concerned citizens have focused their attention on livestock operations potentially harmful to the environment. This is significant because, in any industry, the public perception influences present and future consumption and trends, sways the people willing to take part in the business, and contributes to the growing development of environmental standards and regulations (Hicks & Dietmar, 2007). For example, agriculture through historic over-application of phosphorous and nitrogen from commercial fertilizers and organic wastes, has contributed to many off-site impacts through surface runoff and subsurface transport. Consequently, wastewater and fertiliser-related pollution problems have regularly been reported as resulting from farm operations (Nahuelhual, Engler, Carrillo, Moreira, & Castro 2009). Dairy farms are particularly critical because of the high organic matter and nutrient levels contained in dairy effluent, which can have detrimental effects on drinking water, water supplies, fish resources, and recreation if not adequately managed (Rahelizatovo & Gillespie, 2004).

Finally, there are the challenges around the adoption or adaptation of technology to a changing world, markets and regulations. Griliches (1987) defined technology as the state of knowledge concerning ways of converting inputs or resources into outputs or product. Land-based industries, soils, climate, and landscape, in particular, are likely to affect efficiency and impose restrictions on the selection and type of technology used. Therefore, technology is not only limited but also shaped by the environment in which it is applied (Alston, 2002). According to Sumner and Wold (2002), land differences influence the amount and type of resources, the opportunity cost of land, and the level of scale economies. Pasture-based systems developed on superior land classes have the potential to produce more pasture and milk, outperforming other poorer-resourced systems. More importantly, well-managed and resource-rich pastoral farms could generate fewer adverse environmental impacts and, thus, would be socially more acceptable (Benson, 2008). Conversely, less well-managed farms or farms making use of more marginal, fragile land types could be easily damaged under pressure. Increased pressure on existing resources may only be tolerable if it is both profitable and sustainable in the long term. Consequently, if significant increases in milk production are to be made from higher productivity grasslands, this may require efficiency increases, technology adjustments, or even paradigm changes.

2.2 Farming Systems Approach

Farming systems are multi-factorial, complex entities that may not be able to be properly assessed unless their drivers are fully understood (Kristensen & Jakobsen, 2011). The systems based on pasture may exhibit additional intricacy, resulting from biotic and abiotic components, economic and genetic factors, and environmental and management functions. Many relationships explaining variation in dairy performance can be assessed through financial data analysis, but others may only be explained by contextual factors and managerial behaviours. According to Garcia and Holmes (1999), due to the large number of relationships and interactions present in pasture-based systems, meaningful research should only be approached by means of systems research.

The first premise of systems research is holism. Wilson and Morren (1990) proposed that the first step towards system thinking and practice is to develop the ability to explore experiences holistically, assuming that no matter how the individual parts are studied, the emergent properties within the whole cannot be understood, nor can the original complex situation be improved, unless it is studied in its entirety. A farming systems approach may contribute significantly not only to the data analysis, but also to the understanding of actual farming practices (Tripp, Anandajayasekeram, Byerleee, & Harrington, 1990). The use of hard, empirical data enables unbiased studies, while the systems approach may be needed to reach significant conclusions. These conclusions may in turn contribute to the continuous development and acquisition of relevant technology, since the processes related to technology mastering or advancement need to be grounded in a full knowledge of the specific farming system into which it is to be implemented (van Eijk, 1998). According to Ronan and Clearly (2000), a systems approach and appropriate participatory activities that include active farmers are central for any rural industry to be able to react proactively and appropriately to most challenges. This may be the case within the dairy sector, where these types of initiatives have been increasingly promoted at both national and international levels.

2.2.1 Values and goals.

Performance is a relative term and how to gauge it depends on the businesses' values and goals, along with other important factors such as its lifecycle stage and age. The complex nature of the interactions within a farming system and the significant influence that the farmer, the family and the values and goals involved have on the operation of the farming system must be recognised (Tripp, 1991). Gasson (1973) defined values as

> … a more permanent property of the individual, less liable to change with time and circumstances. A value is a conception of the desirable referring to any aspect of a situation, object or event that has a preferential implication of being good or bad, right or wrong. Values are felt to be justified by reason, moral or aesthetic judgements. …are ends in themselves, pursued for their own sake. They serve as standards influencing the selection from among available modes, means and ends of action. (p. 522)

So, why values and goals are so important in practice? Olsson (1988) affirmed that farmers with well-established values follow a structured decision-making process, which provides them with the greatest opportunity to succeed. Four major categories related to dominant values that are likely to be associated with farming were created by Gasson (1973). If i*nstrumental* values predominate, then farming is viewed as a means of obtaining income and security. Similarly, if prevailing values are *social* in nature, farming is undertaken for the sake of interpersonal relationships. However, the dominance of *expressive* values means that farming is used as a means of self-expression or personal fulfilment. Finally, if *intrinsic* values outweigh other values, then farming is valued as an activity in its own right. Later, Gasson and Errington (1993) stated that typical goals in farming were maximising profits, controlling a larger farm, reducing levels of debt, having a well-managed tidy farm and improving lifestyle. Nowadays, these goals might still be a sound representation of typical values for most farmers around the world. The vision and mission statements encouraged across many industries, including agriculture, are related to both values and goals, and act as long term expressions of the basic purposes and values of the business (Steiner, 1997).

2.2.1.1 Lifecycle stage and age of the business.

Lifecycle describes the development of the business over time. To assess a lifecycle’ stage, two aspects must be considered: the business’ age and the business operator’s age. According to Gale (1994), a factor that contributes to considerable variability in the farm sector is the interaction between the farm and the farmer life cycles, which may be related but are not necessarily in synchrony. Boehlje (1973; 1992) identified three stages that can apply to both the farm and the farmer: establishment, growth and survival, and disinvestment. Each stage can last for several years, may have particular characteristics including objectives and goals, and would require specific skills or management.

In most industries and particularly in farming, the age of the business is an important factor when understanding its goals and objectives, and for interpreting its results. Theoretical and empirical works have shown that a business’ growth’ rate usually declines with age (Evans, 1987; Jovanovic, 1982). Similarly, there is a well-established pattern which shows that failure rates also fall as businesses age (MacDonald, 2007). Moreover, well-established businesses have greater survival prospects than younger businesses (MacDonald, Korb, & Hoppe, 2007). The importance of a business' age holds, irrespective of the farm size, whereby large farms are more likely to succeed, but the effects of a business' age are generally even larger than the effects of farm size and can be similar to the implicit of business' operator's age. Apparently, know-how and business' networks seem to provide an important advantage to well-established firms, regardless of their size.

2.2.1.2 Business operator's age.

The operator's age has a profound impact on the firm's performance. Despite the existence of mixed results, a general consensus is that farms operated by middle-aged managers are more likely to survive and grow (Gale, 1994). Gale also partially explained this, suggesting that while older farmers generally lack the motivation for growth, new and young farmers encounter financial constraints that limit the size of the farm they operate. The farm's lifecycle hypothesis suggests that farms entering the industry should have younger operators than farms exiting the industry, which has been supported by Gale's results (1994). Experience continues to matter at a diminishing rate as farm managers' age. In addition, according to Perkin (1992), older farmers are more risk averse than younger ones, possibly due to previous negative experience and/or because they are close to retirement. Also, young farmers may need to take more risk to get higher returns and get ahead Perhaps 45-year old farmers and older also attach more importance to social goals and values (Gasson, 1973).

2.2.2 Structure.

In the context of this research, the business's structure refers to the configuration of a firm's internal resources, which are associated with production, ownership, and management factors. The business's structure is regarded as being pertinent because it may uncover those values and goals that are likely to be prevalent in a particular farm. According to Spulber (2004), whatever the structure, it has to enhance implementation of the firm's strategy; consequently, changes in the goals or strategic shifts have to be reflected in the business structure, sometimes favouring some business units to the detriment of others. In New Zealand farming systems, 'structure' describes the farm's ownership. According to Dairy NZ (2012) business in NZ are as follows:

Owner operator: The operator owns both cows and land or leases them from an external party; typically these are family businesses. This business structure may have a manager.

Owner with 50-50 sharemilker: The operator ownw the land but not the herd and contracts a sharemilker or equivalent. A variation is when the operator owns the herd but not the land and receives a variable milk income that generally fluctuates between 40 – 60%.

Owner with contract milker: The owner of the land and the cows and contracts either contracts a milker or a variable order sharemilker to milk the cows who receive a percentage of income.

Operator variable order sharemilker: The operator is a variable order sharemilker and gets approximately 22% of milk income. The owner owns the land and cows.

Other or Diverse: The operator can be in any other ownership type, typically with a combination of more than one role or activity. It could also relate to companies and equity partnerships that are either corporate or family-centred with a number of equity partners that own shares. Any of these may have a manager; otherwise one of the equity partners may operate the farm.

Some of these categories are NZ specific as these business structures are relatively unique to this country. Other structures, such as 'owner-operator' and 'diverse', are common to most countries. Whatever the case, it is generally accepted that ownership, and particularly land-ownership, causes noise when analysing the economics of essentially land-based businesses. Therefore, a proper separation from production activities is needed prior to any analysis (Gardner & Hargreaves, 1987; Oltmans, 2007). Land tenancy will be discussed further because of the importance of land, both as an input for production and as an asset for investment.

2.2.2.1 Land ownership.

For most agricultural activities, land is the single largest asset accounting for more than 40% of total assets in Oceania and most countries in South America, including Chile. In part because of this, there is an inherent cash flow difficulty in all land-based industries. Correspondingly, debt on real estate tends to dominate the liability side of the balance sheet in farming (Oltmans, 2007). In theory, a business should generate a return commensurate with the investment and the risk involved, as well as being able to meet all outgoings. In other words, the market price must maintain a strong relationship with the estimated price by capitalizing expected farm income at current prices (Decimavillaa, San Juanb, & Sperlichc, 2008). According to Schönhaut (1999 in ODEPA, 2009) land quality is just one factor affecting the dynamic price of the land; other factors are demand, location, potential land uses and versatility, size of the property, improvements incorporated to the property, public infrastructure in the area, among others. As a consequence, the relationship between income and value has not been traditionally that clear with farm land. Some of the factors just mentioned can be summarized in what has been called the lifestyle market effect. In NZ for example, the significantly higher market value of land in the Waikato region is influenced by the demand for dairy and for other purposes (IFCN, 2012). Land not only has 'productive' value but also a 'place value' that creates problems when analysing the pure farm business (Oltmans, 2007). Sometimes, the place value may exceed the productive value, and different tools have been put in place to overcome this undesirable effect.

Leasing is a process by which a firm can obtain the use of land or other fixed assets, for which it must pay a series of contractual, periodic, tax deductible payments called rent. The lessor is the owner of the asset, and the lessee is the one who benefits from the use of the assets under the lease contract. According to Gardner and Hargreaves (1987), the reasons for lease land from the lessee's standpoint are as follows:

- It is a step to farm ownership;
- It may improve capital utilisation through scale increase;
- It can provide flexibility, minimise risk, and increase profits; and
- It can allow for return on limited capital.

According to Gardner and Hargreaves (1987), farmers have traditionally preferred to own rather than lease farm land. However, the long term option in the buying or leasing decision depends upon the actual relationship between interest rates, rents and land values, and upon the expectations a farmer has about these variables in the future. The perceived uncertainties about each of these play a role, as does the risk involved in the expected variation in the return on investment (Gardner & Hargreaves, 1987).

Wealth generation, defined as the increase in equity is achieved in NZ farming through a number of land purchases and sales during the life cycle of a farm business (Gardner & Shadbolt, 2005). Therefore, it is evident that the related concepts of wealth, assets and equity have significant importance in NZ farming systems. In contrast, these concepts are expected to be less important in Chile where no reports on wealth creation related to farming have been found. In Chile, land often has a share of total assets greater than the 40% estimated by IFCN (2011). Survey information provided by Chilean dairy farmers showed that land was the main component of total assets (70%), followed by capital in cattle (16%), machinery (7%) and construction (7%) (Silva, 1997). Farming in Chile is characterised by far more stable farm ownership patterns with fewer opportunities to purchase land, since land is held by farming families for many generations.

2.2.3 Family businesses.

The family business model is the most commonly in use in New Zealand. A farm business may be classified as a family business if ownership is combined with managerial control; the household is identified with the work place; and/or the family provides a significant part of the labour requirements. According to Gasson and Errington (1993), this definition has changed over time because the labour criterion has become less relevant, as the principle switched from labour to capital. A family business is a partnership of people who are, in a social sense, already partners (Robbins & Wallace, 1992). If this is so, then, as noted by Gersick, Davis, McCollom, Hampton, and Lansberg (1997), a three dimensional model may be a sound conceptual representation of the family business. This multi-dimensional model comprises three independent subsystems: the family, the business itself, and the ownership on its own as an investment. As the subsystems coexist and overlap, they also generate subsequent combinations, totalling seven zones, including a multiple combination of the three subsystems. These special configurations, exemplify the complexity of this distinctive type of business. Such complexity needs to be acknowledged in order to understand or predict the drivers and the management process.

Family farm businesses exhibit clear advantages, such as flexibility in responding to the environment or a greater confidence in the family working team (Gasson & Errington, 1993). The degree of elasticity in task allocation may be a positive factor comparable to that related to the cash flow; reliance on family labour may signify that wages do not have to be paid rigidly. This also features positively from a liquidity point of view, especially during unfavourable periods provoked, for example, by depressed markets. Moreover, as the firm's goals and values, the business nature, and the operator and employees all build a business's level of performance, a higher level of commitment is expected from family members than for strangers which, in turn, may at least partially compensate any other disadvantage (Gersick et al., 1997).

However, although common identity, values, and language provide strength to the family business, at the same time they can work against the executive behaviour of the employed family. Furthermore, the family business also exhibits weaknesses, such as conflict of interests and lower rationality, than other types of businesses because the different demands are linked,and family and business responsibilities do not naturally mix (Robbins & Wallace, 1992), but tend to overlap and often to conflict. In addition, the family business is typically less rational than other firm's structures that often behave according to more objective, unemotional management. Another drawback of family employment is that in some cases it can result in a smaller range of skills being available than if human resources were supplied from the market. If the range of skills were broader than needed, sometimes the opportunity cost for family labour could also be neglected (Gasson & Errington, 1993).

2.2.4 Management in farm businesses.

The importance of management in farm businesses is such that sometimes a change can result in a lift in profitability greater than that expected from the adoption of new technology. From a management perspective, if the existing technology is used to its full potential through optimising technical efficiency, the savings achieved are translated into a farm's higher chance of surviving and prospering (Bravo-Ureta & Rieger, 1991). According to Bennett (1982), management research used to common in early farm economic research but it has gradually lost importance as research moved towards more quantitative theory and methodology. However, the human factor is a determinant of performance given certain technology or productive environment. Agriculture, being based on three major resources, land, labour, and capital, without the contribution of management farming would be random (Nuthall, 2006).

According to Spulberg (2004), the management strategy is defined as a broad plan of action to achieve the business goals, and includes the following five main components:

1. Business goals;
2. External environment;
3. The competitive advantages;
4. The competitive strategy; and
5. Business structure

In turn, management as a process, rather than as a strategy, is defined in a slightly different way. It is typically represented by effective knowledge, planning, and control. The management process has been shown to be able to be used to develop more successful farming systems than other approaches (van Eijk, 1998). According to Barry, Ellinger, Hopkin, and Baker (2000), the strategic management process can be organized into the following systematic set of six interconnected steps:

1. Developing the firm's mission;
2. Formulating its objectives;
3. Assessing the firm and its environment;
4. Building and implementing a strategy;
5. Evaluating its performance; and
6. Implementing any corrective action.

Impediments to the management process sometimes arise from the management style itself, or from limitations in observation skills and the ability to order, analyse, and process complex information (Barry et al., 2000). Decision-making is an input component in the complex management process. The farmer's decisions are influenced by many interconnected factors: values, financial and non-financial goals, knowledge, and previous experience are well-known factors providing strong guidance in successful decision-making. Willock et al. (1999) pointed out that attitudes towards stress, risk, technology, and nature, and also personality and other psychological characteristics, play an important role. Stress levels and control, innovativeness and intelligence have proven to be significant in determining a farmer's success in decision making (Willock et al., 1999).

Individual characteristics related to the manager's style and skills in the context of farm management have been the subject of different studies and types of taxonomy. In NZ, multiple management styles, ages and gender differences were identified by Fairweather and Keating (1990) through an empirical study of farmers. Dissimilarities were found not only in values and objectives, but also in preferences, likes, and dislikes. Three management styles were identified resulting from this variability. The *Dedicated Producer* is associated with young men who thrive on hard farm work, with achievement, and a high quality of production. Their means are full time work and care in planning and financial management. In contrast, the *Flexible Strategist* tends to be older and female. This style thrives on being conscious about nature, responding to the environment, reducing work load, and pursuing off-farm ventures. Its means are higher level understanding, effective marketing, and asset diversification. Thirdly, and lastly, *Lifestyler's* are oldest and comprise both males and females who allocate even higher value on nature, and thrive in working with family and sustaining or increasing lifestyle by several means.

Regardless of the world setting, variation in farm profitability is a consequence of interacting outputs, inputs and prices, but especially a result of business skills applied to available resources (Kay & Edwards, 1999; Wilson, 2011). The external environmental plays a major role as a determinant of success or failure in pastoral farming, but the variability of results within a particular environment has suggested that the role of farmers as general managers and their managerial abilities need to be observed (de Lauwere, 2005). According to Olson (2010), the functions farmers accomplish are many, diverse, and related to major areas such as production, marketing, finance and human resource management. Farmers need to be effective, and unlike managers in other sectors, versatile. Covey (1989) highlighted seven habits of highly effective people in general, that could also be applied to managers and operators in the farming sector:

1. To be proactive;
2. To be goal minded (principle centred);
3. To prioritise (put first things first);
4. To be positive;
5. To seek understanding first and then to be understood;
6. To synergise (seek interdependence and put value in team work); and
7. Sharpen the saw (cultivate observation skills).

The farm management literature states that a successful farm manager requires a broad set of skills as reported by Boehlje, Dobblins, and Miller (2001): strategic, procurement and selling, relationship, leadership, and risk management skills. Nuthall (2010) also identified that observation, keeping of records, and the use of a scoring system of facts were core skills in farm management. According to Barry et al. (2000), superior managers show a methodical approach to the strategic management process, strong analytical skills, decisiveness, and the capacity to admit the consequences and to review decisions as conditions warrant. From the skills listed above, some may be referred also to as contributors to a particular characteristic known as entrepreneurship.

2.2.4.1 The manager's entrepreneurial orientation.

Entrepreneurial orientation refers to behaviours, processes, or practices that lead to a sustainable competitive advantage, especially when this involves proactiveness, innovativeness, and financial risk taking. In economic theory, an entrepreneur is defined as a the person who makes judgement decisions about the management of scarce resources (Gasson & Errington, 1993). According to van Praag (1999), entrepreneurs are held responsible for economic development by introducing and implementing innovative ideas, including product, processesing, market and organisational innovations. Taken to the extreme, an entrepreneur may be that person who has a single objective of profit maximisation and always selects the appropriate means to attain this goal. As this is not prevalent in farming, the pure definition of entrepreneur is ignored while *entrepreneurial orientation* is discribed as another management style.

Entrepreneurial orientation influences performance and is an important factor enabling firms to create, modify, and apply their resources in more efficient ways. However, both the resource configuration and the environment may modify the impact of entrepreneurship. Recent research indicates that, despite many others characteristics being evaluated, only proactiveness has shown a significant positive contribution to business performance (Kraus, Rigtering, & Hughes, 2012). Although numerous forces drive the entrepreneurial orientation in agriculture, information and knowledge are important contributors. As in other industries characterised by negotiated or personal linkages, those individuals with unique and accurate information and knowledge have greater power and control. This would imply having greater capabilities to transfer risk to other less capable individuals (Boehlje & Schiek, 1998). According to de Lauwere (2005), performance in farming depends on many internal and external conditions, but the role of the agricultural entrepreneur is extremely critical in doing this. A study of Dutch farmers showed that the positive entrepreneurial characteristics were achievement-orientation, market-orientation, perseverance, creativity, leadership, initiative, self-criticism, and inspiration, which were highly correlated, as were the negative entrepreneurial characteristics, 'love of ease' and 'passivity'. In addition, the farmers who scored higher in the positive characteristics exhibited better performance measured as annual income and expectations achieved (de Lauwere, 2005).

2.3 Metrics Used for Success Appraisal in Pasture-Based Systems

Ensuring and enhancing farm performance requires effective management, and measurement of both financial and physical resources (Dairy NZ, 2011). The selection of the best measure of performance in farming can be controversial because the way success is gauged depends on the particular business and its goals. Parmenter (2010) distinguished between a key result indicator (KRI) and a key performance indicator (KPI): a KRI tells what has been done and can be either a financial or non-financial measure, while a KPI tells what can be done to increase performance dramatically and is always a non-financial measure. However, in this research KPI are quantitative measures that can be financial or non-financial, and serve as testimony of the past, reflect in some essential way the purpose of a firm, and can be used to encourage improvement (Hansen, Stokstad, Hegrenes, Sehested, & Larsen, 2005).

Despite being useful, KPIs have some intrinsic limitations (Bogetoft & Otto, 2011). A limitation of these indicators is that KPIs make assumptions about the relationship between inputs and outputs. For instance, when businesses of different sizes are compared, constant returns to scale (CRS) are assumed. A second limitation of the KPI approach is that it usually involves partial evaluations. Often, a substitution effect between inputs can be expected and this is why partial benchmarks can lead to misleading comparisons. To avoid these, the use of certain combinations of benchmarks may be required. A third limitation is known as the Fox's paradox, which suggests that even if one firm has higher values in all its partial benchmarks, it might have poorer overall results than other firms. This paradox highlights the importance of achieving the right combination of outputs so that to do well, a firm must make adequate use of those sub processes that have relatively higher productivity than others, and not just perform each process well. In this section, an approach to success appraisal in pasture-based dairy farming is proposed based on the review of relevant literature. This includes physical and financial key performance indicators particularly suited for pasture-based farming systems.

2.3.1 Physical Key Performance Indicators (KPIs).

Physical performance indicators, especially ratios, often assist financial indicators in providing a more holistic view of the business by showing how certain resources have been allocated (Rawlings, 1999). Physical indicators are valuable for tracking performance over time and help to identify strengths and areas for improvement. Measurements are often given in metric units and many have been defined by Fingleton (1995) for European farming systems. They may be set as targets to monitor and control in the short term, and also used retrospectively to make comparisons between seasons, farms, or competitors.

Production measures and indicators defining the system such as grazing area, pasture supply, use of supplements, or stocking rate, must be included in a basic set of physical KPIs as follows:

1. Dairy area (may or may not exclude dry stock): sometimes acres; usually hectares (ha);
2. Herd size: peak milked cows as in New Zealand or total cows as in Chile;
3. Labour input: total full time equivalent (FTE) (corresponding to 24,000 hours of work time); these can be paid FTEs, non-paid FTEs, or ratios such as cows/FTE or kgMS/FTE;
4. Production: total litres, kg MS, Energy Corrected Milk (ECM) (kg);
5. Production ratios: any of the previous measures on a per cow, area, or labour unit basis; such as Litres per cow (L/cow); Litres per hectare (L/ha) (Bywater, 2010); and
6. Stocking rate: cows/ha, Animal unit/ha, Livestock unit/ha, kg Live weight/ton grass grown.

Many of these indicators, such as area, herd size, or labour units, are self-explanatory inputs, and all are common, significant and well known as physical indicators. Outputs have more variation across countries, but commonly, production is expressed as litres (L) or kilogram (kg) of milk. Dairy systems analysed using a raw milk volume do not account for possible variation in milk constituents. In such cases, the resulting conclusions may be biased in favour of those producers with lower levels of milk solids. To overcome this, two standard measures of production have been proposed: kg MS (which ignores volume of milk), and energy corrected milk (ECM) which normalises different milk qualities to match a MS content of 4.0% fat and 3.3% protein (IFCN, 2011, 2012).

Production may be better expressed as annual litres of milk per cow or dairy area if the payment system rewards volume, for example, L/ha/year and L/cow/day. In Chile, production of milk (L) per year and per unit of area has been indicated as the most reliable indicator to measure dairy farm efficiency (Bywater, 2010; Department of Agricultural Economics at the Catholic University of Chile, 1991, cited in Silva, 1997). Bywater (2010) also recommended the use of litres per cow in Chile. Under European conditions where cows are housed, the ratio per cow has been indicated as significantly more important than the ratio per hectare (Hansen et al., 2005). A Brazilian study of a pastoral dairy system also found the indicator per cow to be more important in explaining variability in return on capital (Neto, Campos, de Olivera, & Gomes, 2012). Macdonald et al. (2008) went further, and proposed including cow size by expressing production relative to size or body weight (for example, kgMS/kg LW).

Estimates of how much pasture is available or eaten in terms of dry matter per unit of area (kg DM/ha), how much feed energy each hectare produces (Mega Joules of Metabolizable Energy/ha), and how many supplements the cows eat (kg DM/cow/year) are also valuable indicators. In pasture-based systems, these indicators, although valuable, are based on information that is usually unavailable or unreliable (Smit, Taweel, Tas, Tamminga, & Elgersma, 2005). Cases where indicators are accessible often depend on backwards' calculations, so their reliability needs to be addressed (Bywater, 2010; Mattiauda, Tamminga, Gibb, Soca, Bentancur, & Chilibroste, 2013).

2.3.2 Financial KPIs.

The observation and study of causes underlying differences in performance began in the early 1900s and marked the foundation of farm management and farm business analysis (Kay & Edward, 2012). A financial KPI is often a ratio of an output to an input and, although most industries have very specific KPIs, some financial indicators are used generically. These include Return on Assets (ROA), Gross margin, and Debt ratios (Bogetoft & Otto, 2011). The Farm Financial Standards Council (FFSC) (1997) developed and published recommendations for the preparation of farm financial performance measures which many organisations have adopted as a guide. Later a task force created by the American Agricultural Economics Association developed guidelines for the estimation of farm commodity costs and returns. In addition, groups in New Zealand and other countries have developed their own sets of KPIs to be applied within their particular farming systems.

Nowadays, differences in methodology, terminology, and definitions remain across countries, especially when farming systems vary. Furthermore, recent research has demonstrated that no single dominant measure describes a farming system’s performance over a reasonably long period. Hadrich and Olson (2011) suggested that a single indicator, such as ROA, may not capture enough variability, and multiple indicators should be used jointly to determine a farm’s performance.

2.3.2.1 Profitability.

In this section, a basic set of profitability indicators is presented and explained. Profitability may be the closest to an efficiency measure of all the financial indicators because it captures both inputs and outputs. Several measures of profitability have been recommended by specialised entities around the world. The FFSC (1997) recommended examining profitability based on four major indicators: the Net farm income (NFI) as an absolute measure; and three relative measures: Operating Profit Margin (OPM), ROA, and ROE. In New Zealand, Operating Profit (OP) per hectare, Farm Working Expenses (FWE) per kgMS, ROA, and ROE are important KPIs for dairy farming systems (DairyBase, 2009).

Net Farm Income (NFI) is one aspect of profitability, and encompasses Gross Farm Income (GFI) - (Total farm expenses + Depreciation). Depreciation is an imputed cost based on market values and a standard depreciation rate depending on the asset. NFI is an useful measure for comparing profitability year to year *within* a business, but is not suited for comparative analysis of firms of different size. NFI represents the returns to unpaid labour, management, and the owner's equity (Olson, 2010). It is the amount by which revenue exceeds expenses plus any ordinary gain or loss on the sale of capital assets (Kay & Edwards, 2012).

Other farm financial ratios can be derived from NFI, such as the relationship between operating expenses and gross farm income, also called the Revenue ratio. Kohl and Wilson (1997) indicated that a revenue ratio greater than 80% denotes a weak financial position; a ratio between 80 and 65% would be considered stable; and less than 65% indicates a strong position. These threshold values increase by five to ten per cent when assets are mostly leased rather than owned. From NFI, operating profit (OP) can be derived. OP can be summarised as:

OP = NFI – Livestock-Labour-Management-Feed Adjustments + Debt Interest + Other Farm Income. OP is the return after the livestock inventory change adjustment, non-paid labour, and management adjustments; supplementary feed inventory change; and depreciation, all of which are included in the calculation of operating expenses (DairyBase, 2009).

Although OP is a measure of business performance, it is not an indicator of operating efficiency (Shadbolt & Gardner, 2005). In New Zealand, owned run-off adjustment is also included in the OP calculation and the use of relative measures expressing OP per kilogram of milk solids, cow, or per hectare is encouraged. Operating profit margin (OPM) can be calculated from OP relative to gross farm revenue (GFR); it is the ratio OP/GFR, and thus, is an expression of the input/output ratio. When leasing costs are not deducted, OPM is an accurate indicator of the business's operating efficiency in producing profit from its revenue (Shadbolt, 2011). By definition, it is also an indicator of how well costs are controlled. Kohl and Wilson (1997) indicated the following reference values for OPM positions: strong, >25%; stable, 10-25%; and weak, <10%.

Anderson and Ridler (2010) studied resource allocation optimisation in dairy farming systems to determine the importance of assessing expenses as well as production and income to optimise profit through resource allocation. Farm cost measures and detailed expenditure contain valuable information whose value increases with intensification. In Norway, for example, the most important KPIs are both fixed and variable feed costs, and the difference between milk income and variable feed costs (Hansen et al., 2005). Relevant KPIs are Operating Expenses (OpEx), including both cash and non-cash expenditure, and Farm Working Expenses (FWE), which only includes cash expenditure (Shadbolt & Gardner, 2005). The distinction between cash costs and economic costs is particularly important when comparative analysis is undertaken and both need to be used when appropriate. According to Dillon et al. (2008) and Lobos, Soto, Zenteno, and Prizant (2001), total economic costs are considered to be the leading indicator of the sector's ability to compete, adapt, and expand. Total economic costs include all resource input costs, including family labour, equity capital, and owned resources, such as land. Based on this, operating expenses are *a priori* preferable over FWE. Both, OpEx and FWE can be expressed in absolute value ($), as a ratio using unit of output such as FWE/kgMS, or as a ratio using unit of input such as OpEx/ha. Thorne and Fingleton (2006), based on Fingleton (1995), proposed working under the format of expenses relative to kilograms of milk solids rather than area to examine the competitiveness of Irish milk production.

In Chile, production costs and direct costs of production are both important indicators measured in CLP$ per L of total milk produced (Lerdon et al., 2008). 'Direct costs' involve only costs directly related to the management of the herd, the milking facility or dairy shed, feed, taxes, rent and labour costs, including wages and social security. 'Production cost' includes several items as follows:

- wages,
- electricity,
- fuels and lubricants,
- contributions and rent,
- maintenance of machinery, buildings, milking facility, fences, roads, etc.,
- fertilizers, chemicals, seeds and forage conservation,
- concentrates and off-farm grazing,
- animal health and milk control,
- insemination,
- replacement and purchase of cows,
- depreciation,
- administration,
- general expenditure, including overheads, compensation manager, freight, and livestock sales fees.

Relative profitability indicators are widely used across many industries and types of businesses. ROA and ROE are the recommended indicators of the earning capacity of the asset or equity base (Doehring, 2001). ROA represents the average interest rate being earned on all investments in the business. If assets are valued at market value, ROA can be looked at as the opportunity cost of farming versus alternate investments (Olson, 2010). Its calculation is as follows:

ROA = (Net Farm Income + Debt Interest – Management/Unpaid labour reward + Other Farm Income) / Total Opening Farm Assets

ROA is the term used by the FFSC, but it can also be referred to as Return on Investment (ROI) or Operating Return on Dairy Assets and hence, it is the return on assets employed at the beginning of the year to generate the income. It is the dairy operating profit plus owned run-off adjustment less rent, divided by opening assets (DairyBase, 2009). In contrast, Kay and Edwards (2012) recommended the use of average assets, calculated as the average of the beginning and ending total assets at market valuation. In Chile, return on total assets, including land, is calculated by using average assets and market valuation (Lerdon et al., 2008).

Because the ROA shows profitability per dollar of assets, it can be used to compare businesses of different sizes and even belonging to different industries (Boehlje, 1994). As ROA is affected by opportunity costs (labour and/or management), care is needed in calculating it. According to Kohl and Wilson (1997), there are different critical values when benchmarking ROA, depending on the ownership of the assets. A strong position is indicated by ROA greater than 5% where assets are mostly owned, but higher than 12% if assets are mostly leased. Similarly, a weak position is indicated by 1 and 3%, respectively.

ROE is a measure of the return achieved by the owner’s equity; in other words, it is the interest rate earned on the farm’s net worth (Olson, 2001). ROE is calculated similarly to ROA and is defined as the dairy OP plus owned run-off adjustment, plus net off-farm income, less rent and interest, as a percentage of opening equity. A crucial relationship exists between ROA and ROE, which tells whether or not acquired assets are generating a return greater than the cost of borrowing (Doehring, 2001). If ROA is greater than the cost of debt, then ROE is greater than ROA; conversely, if ROA is less than the cost of debt, then ROE is less than ROA. ROE is very sensitive to the cyclical nature of agricultural production and, with both ROE and ROA, the absolute difference between the two values depends on the debt to equity ratio and the standing interest rate. Long term, the ROE should be higher than the ROA because it is assumed that the manager is using debt leverage advantageously. Therefore, there is a trade-off between a high return on equity and high risk as the two are positively correlated.

A downside to ROA and ROE is their reliance on asset valuations. A sound representation of asset valuation, such as government valuations must be used consistently to ensure a that meaningful interpretation is derived from these measures. Other indicators that may be largely affected by asset valuation are measures of financial efficiency, such as Asset Turnover Ratio (ATR). This is calculated as the relationship GFR/Average total farm assets. According to Kohl and Wilson (1997), there are no critical values for ATR defining strong, stable, or weak positions since these depend on the type of operation and whether assets are owned or leased.

2.3.2.2 Solvency, liquidity, and wealth.

Solvency is a financial performance indicator of ownership risk (Shadbolt & Gardner, 2005). A business is solvent if assets exceed liabilities and insolvent if vice versa. Ratios in the area of solvency are designed to measure the long-term solvency of a farm and are concerned with the levels of equity and debt. According to Kay and Edwards (2012), solvency measures the liabilities of an operation relative to the amount of the owner's equity invested in the business. It also provides an indication of the ability to pay off all the business's financial obligations. The most commonly used measure of financial risk is the leverage ratio, from which other indicators can be derived. Therefore, both solvency ratios, Debt:Assets and Equity:Assets, are strongly related. The Debt:Asset ratio can be defined as:

Debt:Asset Ratio = Total Farm Liabilities / Total Farm Assets.

Trading in an insolvency situation is illegal since this is a high-risk situation for any lender. According to Barry et al. (2000), the desirable value for the Debt:Assets ratio should be lower than 0.5, and the optimum leverage ratio may vary but increases with farm size and leased land. The critical value for this ratio relates to the firm's ability to meet all the expenses and service the debt with an acceptable margin of safety. If a farm business is efficient and has a high return on assets, then it would be desirable to have a certain level of debt in order to 'lever up' return on equity. Kohl and Wilson (1997) stated that there is nothing inherently wrong with high levels of debt, provided the operation is able to service that debt. Therefore, a Debt:Assets ratio of zero is not necessarily desirable, but can represent a lower financial risk. If debt payments get first claim on profits and equity is a residual return, Debt:Assets will need a relatively higher return to compensate for higher risk.

According to Shadbolt and Gardner (2005), while profitability could be considered an opinion, cash is a fact and therefore, liquidity is very important. They also claimed that lack of liquidity is the most common reason for farm business failure. Chatterjee and Wernerfelt (1991) stated that all the standard measures of liquidity can be used as proxy for availability of unused internal capital. Four liquidity indicators are commonly used in farming: Working capital, Current ratio, Operating cash, and Disposable income. The available Working capital and the Current ratio are measures of liquidity that show the ability of a business to meet financial commitments. Both are relatively easy to understand and are straightforward calculations:

Working Capital = Total Current Farm Assets - Total Current Farm Liabilities;

Current Ratio = Total Current Farm Assets/Total Current Farm Liabilities.

A positive value for working capital is desirable, but too high a value may indicate that too many lazy assets are being held (Kohl &Wilson, 1997). The Current ratio shows the number of times the current assets cover the cost of the current liabilities; hence, a ratio below one could indicate a potential developing cash flow problem. A very high value may not be desirable either because it may indicate that too many assets are tied up in conservative investments that have lower rates of return. Both the absolute measure of Working capital, and the ratio, are relevant because they show whether or not an operation can cash in its current assets without compromising its operational status. These indicators express the business's health; if fixed assets have to be sold to cover current liabilities then the operation is affected in undesirable ways. Bankruptcy occurs when a business is unable to cover its commitments without liquidating fixed assets (Barry et al., 1995). These measures are usually snapshots at the end of the year, which do not tell the story of seasonal fluctuations, and therefore, their usefulness for farm seasonal dairy businesses is limited.

In farm businesses where indebtedness is high, Debt servicing capacity has proven to be another useful liquidity indicator (Shadbolt & Gardner, 2005). There are various methods for calculating Debt servicing capacity, being the following the most comprehensive:

Debt servicing capacity = (Interest + Principal paid + Rent) /Gross farm revenue

Financial attributes may affect operational efficiency, both on a daily and on a long term basis. Nasr, Barry, and Ellinger (1998) explained the different theories about the relationships between financial structure and technical efficiency. They noted that the Agency Cost hypothesis implies a negative relationship between debt and efficiency. Similarly, the Free Cash Flow theory implies that excess cash flow results in more relaxed management, and thus lower efficiency. The Credit Evaluation theory postulated that more efficient farms are expected to require investment, and hence, are likely to have higher debt levels. Chavas and Aliber (1993) earlier suggested the Embodied Capital hypothesis, which implies that indebted farmers are more focused and tend to have higher efficiency levels. Bierlen and Featherstone (1998) investigated the effects of financial constraints in farm investment and concluded that a trade-off between financial stability and efficiency may exist. Supporting this, Handley et al. (2001) found a negative relationship between indebtedness and technical efficiency. Lopez, Featherstone, Langemeier, and Grunewald (2006) found that mean technical efficiency was lower when farms faced financial constraints, whereas allocative efficiency was found to be greater for financially constrained farms. They additionally noted that farm size influences these relationships. Hallam and Machado (1996) reported that larger farms tend to be more efficient. Weersink, Turvey, and Godah (1990) found that efficiency was positively associated with size but at a decreasing rate.

Operating farm cash surplus or deficit, and discretionary income are also regarded as relevant liquidity indicators in New Zealand. Farm cash operating surplus is calculated as a farm's total cash income from sales, minus the sum of purchases and cash expenses (FWE) generated through the year. Makeham and Malcom (1993) suggested that cash surplus/deficit is the best liquidity measure for a seasonal business. An alternative to discretionary income is known as Discretionary Cash (Martin, 2009). In New Zealand, Discretionary cash is considered to be an important KPI, representing the cash available to meet capital purchases, debt repayments, drawings, and extraordinary expenses. Discretionary cash t can be defined thus:

Discretionary cash = Cash operating surplus – (Rent + Interest + Tax) + (Net non-dairy cash income + Income equalisation + Net off-farm income)

This calculation excludes interest, rent, and taxes, which, in contrast, are included in the definition of discretionary Income. Hence, farm cash surplus can be calculated by subtracting net debt paid, drawings, and net capital investments from the disposable income on adding in existing off-farm income. This is the indicator of cash available to meet debt repayment, personal or family requirements, and to invest after having paid imputable taxes, leasing, and debt obligations (Shadbolt & Gardner, 2009).

The relative importance of wealth and wealth creation in farming is different in NZ and Chile. However, the standard measure of absolute wealth, equity, is international. Wealth creation may be represented by a positive change in equity, which is commonly taken as a measure in New Zealand (Shadbolt & Gardner, 2009). Growth in equity can be calculated as the change in owner's equity over the year as a percentage of opening equity. A positive change can be the result of an appreciation in value or the retention of increased earnings. Conversely, a negative change in wealth may be the result of depreciation of the value of the assets or negative returns.

2.3.2.3 Resilience measures.

Resilience may be defined as a system's capability to absorb shocks, avoid crossing a threshold, and reorganise after an adverse effect (Resilience Alliance, 2009). The concept emerged to conceptualise human-environment systems in sustainability science, and was originally used in relation to the robustness of populations and ecosystems (Folke, 2006). Earlier, Walker, Hollin, Carpenter, and Kinzig (2004) defined resilience as the on-going capacity of a system to cope with whatever the future may bring without experiencing undesirable changes. Resilience applied to farming systems in the area of farm management is a relatively novel concept that has been defined as the capability to adapt to alterations in the environment and to take advantage of opportunities created by them, while maintaining productive capacity despite potential variability in financial, market, and production related factors (Shadbolt, Rutsito, & Gray, 2011). Maintaining farm viability in the long run depends on the ability of the system to adjust to change in a way that still generates a profit without compromising land integrity and environmental quality. Overall, resilience is a desirable attribute of farming systems and relates to what ecology and biology have defined as robustness, plasticity, and rusticity (Sauvant & Perez, 2010). Aven (2011) pointed out that a key difference between robustness and resilience is that the first relates to a fixed threat, whereas resilience applies to any type of potential event and associated uncertainties in a given environment.

Rodriguez, deVoil, Power, Cox, Crimp, and Meinke (2011) claimed that flexible farming systems are more resilient than more rigid systems. Research suggests that flexibility is an important attribute for farming systems, just as phenotypic plasticity is a key element in the functioning of organisms (DeWitt & Schneider, 2004). Rodriguez et al. (2011) explained that where farm management is highly contingent on, for instance, environmental conditions, farm managers often vary crops and inputs based on the availability of limited and variable resources (land, water, finances, labour, machinery) and signals from the operating environment (rainfall, markets), with the objective of achieving a number of often competing objectives such as reduced risk or increased profits. According to this, the ability to respond quickly to changes from the external environment is critical in maintaining profit margins and extracting profits from variability. Dairy NZ (2009) has noted that:

> The need to compete against low cost producers in a volatile international market means that dairy farmers must remain focused on resilient farming systems with relatively low fixed costs (p. 6).

This means that businesses with a higher proportion of variable costs may be more responsive to changing market conditions. Conversely, firms with higher proportions of fixed, structural costs may not be able to adjust to change. Information management and quick recognition of volatility, followed by appropriate adjustments and corrections, are vital, and resilience studies may help farmers to identify strong and weak areas (Rodriguez et al., 2011). However, there are two key issues around resilience studies on farming systems. First, the observation of resilience in the farm management discipline is a difficult task since it requires empirical data for a minimum period which depends upon the variability of the environment; it cannot rely on snapshots as resilience implies behaviour, which needs to be observed over time. To overcome this, alternative methodologies, including the use of modelling, have been proposed. Second, indicators or surrogate variables able to offer an appropriate empirical measure of resilience are needed (Bennett, Cumming, & Peterson, 2005). Walker et al. (2004) postulated that latitude, resistance, and precariousness are three major attributes of a system’s resilience. Latitude may be defined as the amount of stretch that a system may support without losing the ability to recover its original form; in other words, its flexibility. Resistance may be defined as the ease required to create a change in the system. Precariousness is the closeness of the system to the point that leads to permanent change. Shadbolt et al., (2011) proposed that these attributes can be estimated through surrogates commonly found among key performance indicators in regular use in farming: liquidity can be assimilated to latitude; efficiency to resistance; and solvency can express the degree of precariousness (Shadbolt et al., 2011). Resilient farms are expected to be efficient overall, have increased liquidity, vary according to market conditions, and have a low Debt:Assets ratio under unfavourable market conditions. Along with this, Scholz, Blumer, and Brand (2012) pointed out that resilience is linked to risk and vulnerability; it incorporates the capability of a system to cope with the adverse effects or risks that a system has been exposed to.

2.4 Macro-environment

Farm businesses are an integral part of the food and fibre industries and sit within the wider national and international macro-environment (Nell & Napier, 2005). The IFCN (2011) noted that the viability of dairy farms internationally rest on their ability to cope with the risk to which they are exposed. There are several types of risks, from productive to political risk, from technical to financial risk, and from personal to market risk. Robinson and Barry (1987) defined a risk as that situation whose outcome is not known with certainty and which alters the decision-maker's well-being. The EPEST approach has been recommended for the macro-environment assessment in farming because farming systems are naturally exposed to many risks. This approach, alternatively and systematically, looks at economic factors (E), the political and legal environment (P), ecological and climate factors (E), social-cultural and consumer aspects (S), and technological issues (T). Farming systems often depend on the external environment and, therefore, need to be highly responsive to it. To enhance this responsive ability, it is advisable to understand the external environment dynamics and to monitor emerging or potential strategic opportunities and threats. This section presents the country background using the EPEST approach, with an emphasis on the New Zealand and Chilean dairy farming systems and industries, and also focusing on some relevant empirical research in both countries.

2.4.1 Economic factors.

Different social realities exist in New Zealand and Chile, beside peculiar economies, currencies, and farming systems. Social realities have been shaped by particular cultures, histories, and contemporary characteristics. As a consequence, the New Zealand and Chilean dairy industries differ in their development and importance to their economies (Challies, & Murray, 2006), despite having many similarities, such as shared geographical characteristics, climatic features, production patterns, and ideological convergence around free trade. Table 2 provides a comparative description of the two countries.

Table 2

Basic Comparative Figures

Country	New Zealand	Chile
Land area (1000 km2)	268	744
Population (million)	4	17
Population density (person/km2)	16	23
Labour force occupied in Agriculture	7%	13.2%
*Agriculture contribution to GDP (%)	16	15
*Self-sufficiency in milk supply (%)	>1000	115

Source: CIA (2012); *Robobank (2012)

New Zealand has a land area just over one third that of Chile, with a population density of 16 people per square kilometre compared to 23 in Chile, and an agricultural labour force occupied approximately half that of the Chilean one. Directly, agriculture contributed to 4.6% of the New Zealand Gross Domestic Product (GDP) (Statistics NZ, 2012) and 5.1% of Chile's (INDEX Mundi, 2012). Table 2 shows that the dairy sector directly and indirectly throughout dairy-related activities contributed to 16% and 15% of the New Zealand and Chilean economies. However, farming, and particularly dairy, has always been of far greater importance to New Zealand than to Chile (Painter, 2007). Table 3 shows the contrasting macroeconomic indicators of the target countries.

Table 3

Economic Indicators of Selected Countries

Country	New Zealand	Chile
Per capita GDP (US$)	27,900	16,100
Average wage rate (US$/hr)	11	3
Inflation rate (%)	4.5	3.3

Source: CIA (2011)

Table 3 presents figures in US$ because there is no exchange rate between New Zealand and Chile and some type of standardisation is needed to compare the two countries. GDP per head and average wages have typically been much higher in New Zealand, but the inflation rate fluctuates in both countries under inflation targeting regimes. Both countries are important commodity exporters, having a similar degree of trade openness in their economies. The promotion of free trade has been a longstanding policy that enjoys wide support in both countries, based on the belief that every country has a comparative advantage which must be used to develop a trade pattern for its own benefit and that of its trading partners (OECD, 2011). Figure 1 presents the NZ$ to US$ exchange rate, which shows a clear increasing trend for the same period (1999 to 2012).

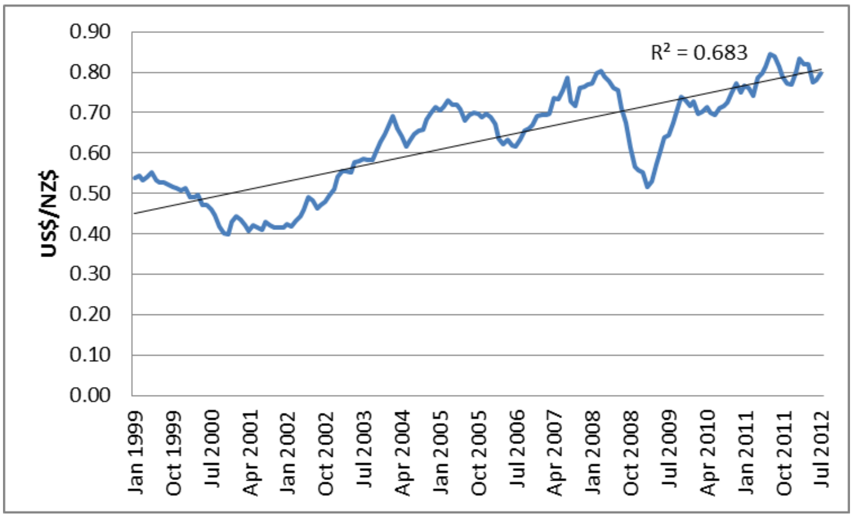

Figure 1. NZ$ versus US$ exchange rate.

Adapted from Robobank (2012).

The NZ$ has appreciated against the US$ since 1998, reaching its historical maximum value in 2011. Sharples (1990) warned that, especially when making international comparisons, the exchange rate used may affect the conclusions. The author clarified that volatile exchange rates may show very high or low competitiveness relative to other countries, and therefore advises the use of averages over a certain length of time when comparing measures of competitiveness. Harrison and Kennedy (1997) noted that exchange rates may influence competitiveness measurements in the way that devaluation of the domestic currency results in a decrease in the price of domestically-produced goods sold on the world market, and thus, an increase in domestic firms' profits and market shares. This is also stressed by Krugman (1994), who points out that a nation's competitiveness may be falsely created by devaluing the domestic currency, thus increasing the value of exports, whereas the nation's standard of living may actually decline if the purchasing power is not favourable. Brinkman (1987) explained that when the demand for the currency of a competitive country is high, this actually strengthens its exchange rate. Chile has traditionally shown higher level of international trade openness than New Zealand, with the greatest absolute difference being greater than 20% in 2008. Thereafter, the continually declined, reaching very similar stable levels by 2010 (OECD, 2011). Interestingly, almost all credits and deposits are denominated in local currency: the NZ dollar (NZ$) and the Chilean peso (CLP$). Figure 2 shows the Chilean exchange rate to US$ from 1999 to 2012.

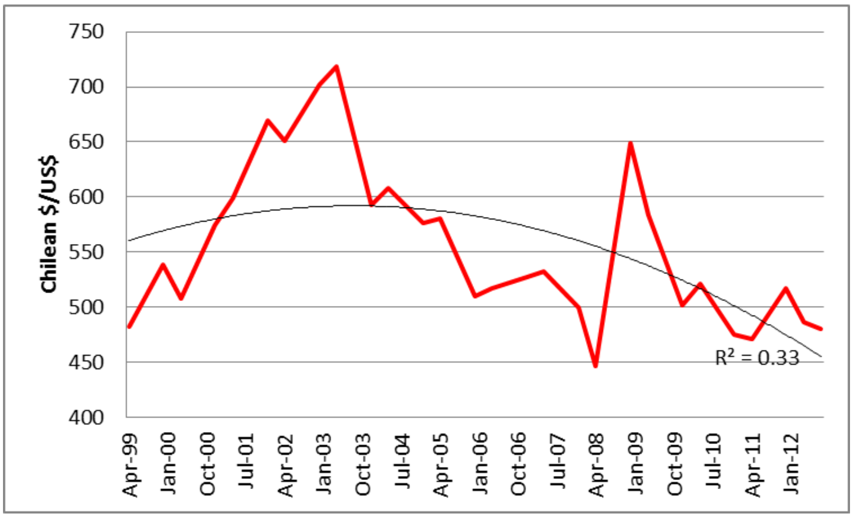

Figure 2. Chilean $ versus US$ exchange rate.

Adapted from: Central Bank of Chile, (2012).

The exchange rate between the CLP$ and the US$ has had an erratic trend, sharply devaluing from 1998 to 2003, appreciating thereafter until 2008, when again the exchange rate abruptly reached CLP$650. This level of variability and volatility makes converting local currency into US$ for analytical purposes problematic. Bureau, Butault, and Hoque, (1992) pointed out that comparing production costs between countries is also made difficult by the variation in exchange rates across time periods.

2.4.2 Political and legal factors.

Political and legal factors in New Zealand and Chile are similar. The deregulation of the New Zealand economy in the 1980s generated the conditions for restructuring the agricultural sector and for changing farming practices towards higher efficiency. This is recognised as an important turning point that affected the relative profitability of agricultural industries, forced successful farmers to become internationally more competitive and pushed less successful farmers out of the business (Frangley & Engelbrecht, 1998). Illustrating this, Figure 3 shows the evolution for the last 30 seasons in number of dairy herds and their average size.

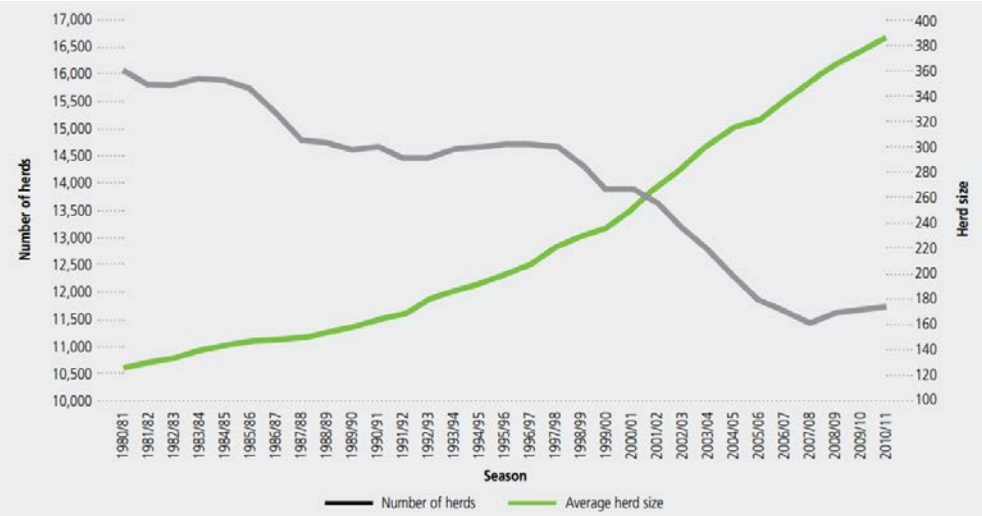

Figure 3. New Zealand trend in the average herd size and number of herds.

Source: NZ dairy statistics 2010/11, LIC & Dairy NZ (2011)

In New Zealand over the last 30 years, the number of herds has decreased from 16,000 to less than 12,000; conversely, the average herd size has increased from just over 120 cows to more than 380 cows. Amalgamations for bigger scale were common across the country, resulting in these trends (Journeaux, 2002). Jaforullah and Devlin (1996) pointed out that the average herd size also increased because land holdings and herds owned by corporate farms increased, especially in the South Island. This process of amalgamation was not in isolation from other phenomena of similar relevance associated to the pattern of land use and the manufacturing industry. Conversions from sheep and beef farms to dairy units following the changes in relative profitability of these agricultural activities provoked a clear change in land use (Jaforullah & Devlin, 1996; Johnston & Frengley, 1994). Johnston and Frengley (1994) indicated that following deregulation, sheep and beef farming was displaced by dairying or forestry. The manufacturing industry also suffered dramatic changes after a series of mergers and acquisitions took place. The number of manufacturing cooperatives decreased from 30 in 1980, to 16 in 1996, and four at beginning of the 21st Century (Holmes, 2003). According to the Fonterra

Cooperative Group’s Annual Report 2002, economies of scale, efficiency of transport, and the retention or gain associated with market share were major reasons for the amalgamations.

Similar changes were occurring in Chile and worldwide. Zwanenberg (2001) stated that in the 1990s a worldwide dairy industry consolidation took place and highlighted the key drivers for this as being milk demand growing faster than supply, and increasingly powerful customers having more requirements. A similar dairy expansion accompanied by conversions happened in Chile, but the turning point occurred later, in 1994. According to Escobar, Mladinic, Sanhueza, and Diaz (2006), the beginning of the change for the dairy sector occurred when it was announced that Chile would join the MERCOSUR. Before that, the Chilean dairy industry showed a sustained rate of slow growth, a result of a stable macroeconomic policy and appropriate sectorial policies, including specific tariffs on imports, implementation of standards, sanitary rules, and technology transference programmes. However, since 1995, the dairy sector has grown significantly, particularly in the Central–Southern territory as a consequence of the modifications to the strategy after joining the MERCOSUR.

2.4. 3 Ecological and climate factors.

New Zealand and Chile share a number of ecological and climatic factors, including latitudes, mountainous landscapes, soils originating from volcanic ash, and similar lithology, climate, and isolation (Challies & Murray, 2006). Geographic location and associated features mean that both countries benefit from a complete set of natural barriers. While New Zealand is a group of islands in Oceania in the South Pacific Ocean, Chile is located in Southwest South America, with the Pacific Ocean coastline stretching more than 4,300 kilometres long to the west; the Andes[7] to the east; the Atacama which is the world’s most arid desert to the North; and the Antarctic to the south. Due to the geographic isolation, strict border controls, and similar farming practices, both countries are free from a range of diseases that are endemic in the rest of the world.

The variability in the New Zealand climate is due to its turbulent mid-latitude location, which is influenced by many features from the Tropics to the sub-Antarctic (National Institute for Water and Atmospheric Research [NIWA], 2010). Much of the variability in the New Zealand climate originates from the interactions of global air circulation and orography being the west to east gradient in rainfall the most notable effect. Evenly distributed, frequent damaging events can include floods, droughts, wind storms, and heat waves (NIWA, 2010).

[7] The Andes is the longest continental mountain range in the world, being a continuous range of highlands along the western coast of South America. This range is about 7,000 km long, about 200 km to 700 km wide, with an average height of about 4,000 metres.

Chile extends between 22 and 55 degrees of latitude South, with strong climatic influences form the sea and the Andes. A large area has a mountain climate with perpetual snow and glaciers. However, a large percentage of the population lives where agriculture thrives in the lowlands of Central and Southern Chile. This part of Chile tends to be wet all year round, with changeable weather (Escobar et al., 2006). Annual precipitation can be as high as 5,000 mm (200"), much of which falls as snow farther south and on the higher mountains. On the coast, winters are rarely extremely cold, but summers are cool and cloudy. Figure 4 shows the countries, their latitudes, with their key dairy farming regions highlighted in darker shading.

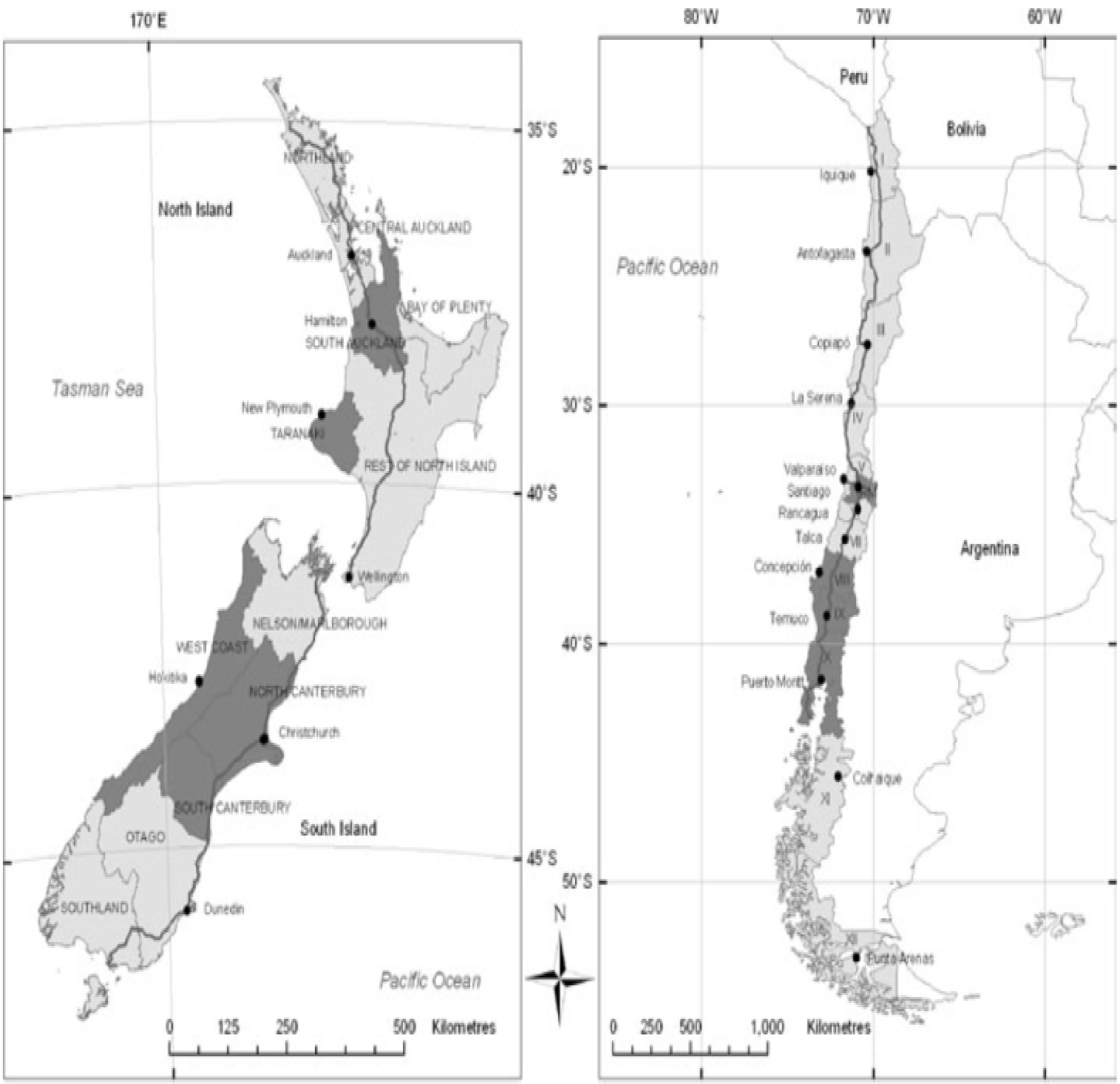

Figure 4. New Zealand and Chile dairy regions and latitudes.

Adapted from: Challies & Murray (2006)

In New Zealand, grassland occupies approximately 45% of the country's area and can be grown and intensively grazed all year round (McCall & Clark, 1999). However, NZ grasslands still show large variation in land characteristics, winter temperatures, and summer soil moisture (Hodgson, 1999; Holmes, 2003). In the majority of the New Zealand's non-mountainous territory the climate is temperate. Mean daily temperatures range from 8°C in July to 17°C in January, but summer temperatures can reach over 30°C in many places (NIWA, 2011). The average rainfall ranges widely from less than 400 mm in the Central South Island (Otago) to around 1,000mm in most regions (Gaul & Hughes, 1996). For the majority of the North Island and northern South Island, the driest season is summer (December–February), but for much of the South Island, winter (June–August) is the driest season.

Over the period 2006 to 2011, NIWA reported that there were several extreme events. The 2006/07 was a good climatic year, but the 2007/08 summer was the driest in a century in parts of the North Island, particularly in the Waikato region and the eastern South Island (Dairy NZ, 2009). Pasture growth, pasture covers, milk production, and stock body condition were severely affected by the drought. Dairy NZ (2010) indicated that the 2008/09 season was fairly typical climatically in most regions, but dry weather was again a factor in some major dairying regions, such as the Waikato and Bay of Plenty, and also in the Auckland region, Northland, central North Island, and the north and east of the South Island. In contrast, it was a wet year in Gisborne, Manawatu, and parts of Westland. A Dairy NZ economic survey (2011), reported that 2009/10 was a difficult climatic year for most regions, mainly due to a late summer/autumn drought affecting most of the upper North Island and some parts of the South Island. These widespread autumn droughts resulted in early drying-off of dairy herds in many regions, although the effects of the drought were less severe in the South Island as many Canterbury farms irrigated their pastures and parts of Otago–Southland had 42% more rainfall than average in early 2010.

The Chilean southern plains and their temperate grasslands extend south from 38º Latitude S up to approximately 44º S. Mean monthly temperatures range between 5 ºC in the winter months and 12-15 ºC in summer (Vera, 1996). Rainfall increases in the north to south direction from about 1,400 mm to over 2,000 mm, with 70% of the rain concentrated from early autumn to early spring (Balocchi & Lopez, 2001). Summer rainfall represents between 10 to 17% of this total in the north and south, respectively. This wheather pattern creates a brief water deficit during peak summer in the northern part of the region, which does not exist at the southern end. Over the period 2007 to 2011, according to the Dirección Meteorologica of Chile (2007, 2008, 2009, 2010 and 2011), rainfall patterns were varied. In 2007, key dairying regions such as Valdivia and Osorno were drier than normal (about 1,200 mm of rain in Valdivia and just less than 900 mm in Osorno). In 2008, rainfall was 1,995 mm and 1,028 mm respectively, while in 2009, Valdivia had 1,950 mm and Osorno a maximum of 1,345 mm. In 2010, Valdivia had an annual rainfall closer to average of 1,491 mm and Osorno also totalled 1,041 mm, similar to those observed in 2011: 1,618 mm and 995 mm respectively.

2.4.4 Socio-cultural and consumer factors.

The New Zealand and Chilean dairy industries have been through similar economic transitions. However, the development of the industry, the government paradigm shifts, and the trade and production strategies have been very different. New Zealand dairying has always been principally an export-oriented activity, while the Chilean dairy sector emerged to supply the domestic market. The basic dichotomy that brought about the two contrasting dairy industries in New Zealand and Chile remains in force today and is reflected in the information summary presented in Table 4.

Table 4

Dairy Industry Facts

Country	New Zealand		Chile	
Profile	2009	2010	2009	2010
Dairy farms		11691		15903
Cows (000)	4253	4397	466	423
Average herd size		376		27
Protein (%)		3.7		3.36
Fat (%)		4.91		3.74
Milk solids (%)		8.61		7.1
Milk yield (t/cow)	4.36	4.36	4.91	5.72
Land (USD/ha)		22315	11000	

Source: IFCN (2011)

Chile has many more, considerably smaller dairy farms than New Zealand. The number of milking cows in Chile is approximately one tenth of those in New Zealand. The Chilean industry is made up of mostly heterogeneous and small-scale farms, close to market, representing around 80% of producers and 40% of the dairy herd. In New Zealand, given the external market focus, location close to domestic markets is not imperative, farm structure is relatively similar, and herds are markedly larger. New Zealand produces not only more milk than Chile but a different type of milk that yields higher milk solids (MS) and is more suited to industrial processes. Recently, milk solids content has become part of the Chilean development strategy, which states that the country needs to produce milk higher in MS, with a view to more efficient industrial processing into milk powder (Consorcio Lechero, 2012). The goal is to increase MS from the current value of 7.1% to 7.6% at a rate of 0.05% per year. Although it is clear that industry guidance is needed, how to achieve the goals remains unclear. Several variables, such as season and time of calving, breed, and diet, are being evaluated since these are major factors which can affect milk composition.

According to Winkler (1999), both countries have some disadvantages and many benefits in dairying as shown in Table 5.

Table 5

Advantages and Disadvantages of Respective Dairy Industries

Country	Advantages	Disadvantages
New Zealand	Labour productivity	Cost of capital
	Industry vertically integrated	Public concerns about dairy farming
	Dairy specialization	
Chile	Cost of labour	Industry structure
	Cost of capital	Politic-Economic environment

In Chile, the advantages are clearly lower wages and capital costs due to cheaper land than New Zealand. A major advantage in New Zealand is that virtually all processing is dominated by a farmer-owned cooperative (Painter, 2007; Willis, 2004), Fonterra, which became the largest dairy exporter in the world after the New Zealand Dairy Board, the New Zealand Dairy Group, and Kiwi Cooperatives merged to create a single entity (Fonterra Cooperative Group, 2002). According to the same source, this consolidation has resulted in greater efficiency in operating scale, transport, and labour management, while securing milk supply, access to capital, market share and power, and ensuring New Zealanders and not foreigners receive the potential benefits. This means that there is great capacity and limited industry competition within NZ, with Fonterra having a 89% share of the market, down from 98% in 2010 (Fonterra, 2012).

Chile has two major companies, Nestlé and Soprole, which account for approximately half of the total milk processing, and many more, smaller competing processors (ODEPA, 2012). There is strong competition between companies that engage in vertical and horizontal integration to control the oligopolistic market (Amtmann & Blanco, 2003). According to Consorcio Lechero (2012), production and seasonality have increased steadily. The industry structure has also changed, with the number of companies decreasing from 25 to 14, and processing plants from 38 to 25. In the period 1977-2011, the fluid milk production increased by 2.8 times, mainly in the form of sterilised milk; milk powder production has increased 2.4 times, and whey powder has also had a significant increase.

In 2011, the total processing capacity of the industry for fluid milk reached 12.5 million litres (L) per day, and milk powder, fluid milk, and cheese, reached 6, 4.7 and 1.95 million L a day, respectively. The regional distribution shows that the processing capacity in the South (X, XIV regions) is 78% of full capacity, at 98% of milk powder production, 88% of cheese production capacity, and 35% for processing fluid milk. The Central zone is at 65% capacity for fluid milk processing. To maintain current growth conditions and seasonality, the processing capacity would be adequate until 2020 for powdered milk and fluid milk, but is at limited capacity for cheese making, which could be saturated by 2016. However, as plant capacity may be sensitive to increases in volume and seasonality, this potential scenario may occur up to three years earlier (Consorcio Lechero, 2012).

New Zealand and Chile are partners and competitors in more than one market and have signed numerous and varied treaties in the search for promotion of longer-term synergies and cooperation (Barton et al., 2007). The two dairy industries have been in direct competition since 2006 when the Trans Pacific Strategic Partnership came into force, whereby international tariffs are expected to be fully suppressed by 2017. Trade liberalisation between the countries is expected to promote efficiency, cooperation, and mutual technological advancement across a broad range of sectors. These strategic cooperation and competition have been seen as a benefit, but also as an issue, by some Chilean dairy farmers (Challies, & Murray, 2006). Other interactions also exist, particularly in the form of New Zealand investment in Chile (Escobar et al., 2006). Neither New Zealand nor Chile is of major significance to the other in terms of trade. Until 2005, bilateral trade between the countries had been minor (Challies, & Murray, 2006). As cooperation and competition occur at the country level and extend to the individual farms within and between countries, an approach to generic competitive strategies becomes relevant and is addressed later in this chapter.

2.4.5 Technological factors.

Technology is defined as the systematic knowledge and set of features that provide context to actual farming practices, while technique refers to skills and performance in a more mechanical context (Villano, Boshrabadi, & Fleming, 2010). The estimation of technical efficiency determines the scope for improving farm performance through better farming practices, but is subject to existing technological constraints. Any comparison across countries acknowledges that the underlying technology is different since it is shaped by such issues as ecological and climatic factors, industry, logistics, policies, and human resources.

2.4.5.1 New Zealand dairy farming systems.

This section addresses New Zealand's export-oriented dairy industry and the key technological aspects of New Zealand dairy farming systems. As discussed before, the dairy industry has expanded rapidly over the last few decades, with the national herd doubling between 1980 and 2009. Traditionally, dairy farming was restricted to summer-safe, flat to rolling land with mean annual rainfall over 2,000 mm a year. However, the expansion has moved into regions that receive 600-1,000 mm rainfall, and which are highly reliant on access to irrigation in summer months or are subject to high drought risk. New Zealand dairy farming systems are based on a seasonal operation, a compact spring calving pattern of eight to 12 weeks, and a completely dry milking herd for at least eight weeks a year (Holmes, 2003). The distance and associated costs of transport between New Zealand and its main export markets, combined with an environment suitable for pastoral production, has resulted in a focus on efficient dairy production systems (Moot, Mills, Lucas & Scott, 2010). The principles of this system are pasture feeding, a 12-month calving interval, and owner–operated low labour units (LIC & DairyNZ, 2011). However, increasing use of imported feed has been observed, which has allowed for higher stocking rates, leading to an escalation in the production per hectare and in the use of the fixed assets. Figure 5 presents the milk solids production ratios, per cow, and per effective hectare, since 1992/93.

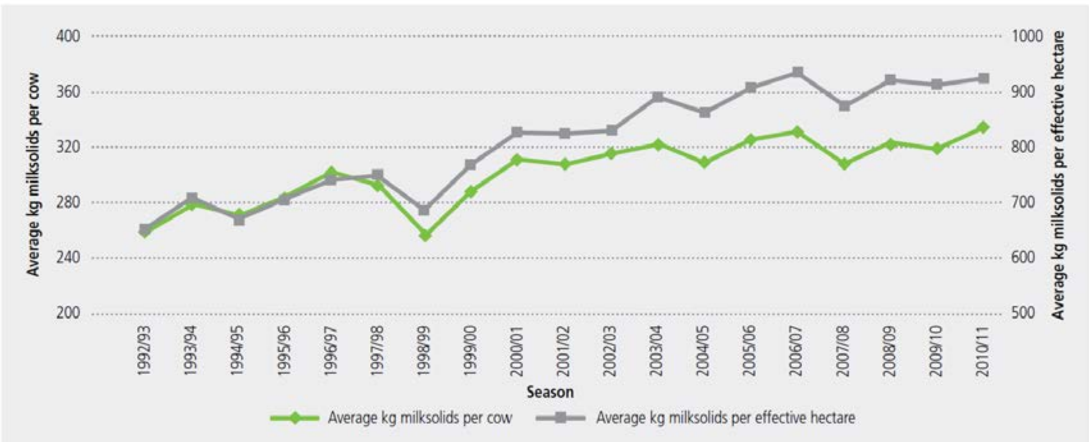

Figure 5. Evolution in MS production per cow and per effective area since 1992/93.

Source: LIC & Dairy NZ,(2010)

The increasing trend, the seasonal variation in production in response to climate and rainfall, and the increased gap between production per cow and per hectare since 2003/04 are worth noting. Using ‘herd’ as the sample unit, the average annual increase in MS production since 2001/02 has been 4,721 kilograms. According to LIC & Dairy NZ (2011), this annual growth rate of 4.5% from 2001/02 to 2010/11 has several contributing factors:

- More hectares dedicated to dairy-annual growth in milking area of 3.8 ha (+3.1% per year);
- Larger herds – annual growth of 12.8 cows per herd (+3.9% per year);
- Higher stocking rate – annual growth of 0.02 cows per ha (+0.8% per year);
- More MS per cow – annual growth of 1.7 kg (+0.5% per year); and
- More MS per hectare – annual growth of 11.8 kg (+1.4% per year).

The annual growth in cows per farm has been slightly faster than the growth in milking hectares per farm, and therefore stocking rate has increased slightly over the last 10 years. This increase in stocking rate, coupled with the small growth in MS per cow, has resulted in a greater annual increase in MS per milking hectare. These continuing increases in production, and the New Zealand approach to pastoralism, have generated interest from farmers all around the world. Since the beginning, the New Zealand dairy industry has had a strong export focus, easily supplying the limited domestic market demand, which today sits around 5% of total NZ production (Dairy NZ, 2009). Most dairy production is sold at international market prices, resulting in milk prices that closely track the prices of commodities on the world market. Exports are directed to a variety of countries in approximately 200 different product forms. New Zealand is the largest butter exporter in the world (Indexmundi, 2012) and also an important exporter of whole and skim milk powders, contributing 44%, 38%, and 27% respectively to world trade (FAO, 2010).

New Zealand’s primary producers have a strong cost leadership focus shaped by low milk prices at the farm gate (Holmes, 2003). Low-cost milk production is supported by the availability of pasture all year round, direct grazing, and a the match between maximum herd feed demand and peak pasture production in spring. As a consequence, New Zealand dairy farmers have become world cost leaders and diversified along the value chain into the processing and marketing of dairy products through a farmer-owned industrial sector (Painter, 2007). Developments in New Zealand’s dairy farming have included: a focus on productivity and labour saving technologies; the use of nitrogen fertiliser and supplements; on-going adaptation to new technologies; and larger farm sizes (Emerson & Rowarth, 2009). Some other factors have also been branded as critical to the New Zealand dairy sector: international market access; effective national and international political support; effective adaptability of industry structure; maintaining a disease–free status; and the farmers themselves (Conforte, Garnevska, Kilgour, Locke, & Scrimgeour, 2008).

The New Zealand dairy farmers' engagement, not only in their managerial role, but also in the farm operation, makes them invaluable human capital for the country. The farmers' commitment is well complemented by other characteristics such as people on farm being energetic, technically skilful, and optimistic (Holmes, 2003). It is debatable whether or not human capability is a limiting factor in New Zealand already but it is undebatable that labour is increasingly becoming an issue (LIC, 2011). Herringbone milking structures are common, and rotary sheds are incrasingly being adopted to increase labour productivity. These innovations have been regarded as cost efficient, competitive, simple, and profitable (Dobson, 1996), and assumed to be the consequence of particularly well-honed management skills resulting from world market exposure (Painter, 2007). Table 6 presents a summary of the regional and national statistics showing the operating structure of dairy farms in NZ.

Table 6

Operating Structure of Dairy Farms in Both Islands and at the National Level

Business structure	North Island		South Island		NZ	
Owner Operator	5,830	76%	1,847	24%	7,677	65%
Share milker 50/50	1,815	81%	434	19%	2,249	19.2%
Others	1,302	72%	507	28%	1,809	15%
Total	8,949		2,788		11,735	
Total	76%		24%		100%	

Source: Adapted from LIC & Dairy NZ Statistics 2010/11 (2011)

The majority of NZ dairy farms have traditionally been family owned and operated (Sankaran & Luxton, 2003). According to the LIC and Dairy NZ statistics (2011), in 2010/11, 65% of dairy farms functioned under an owner-operator structure. Another 35% of all herds were operated by sharemilkers or under other structures. Interestingly, the same source reports that, on average, sharemilkers on less than 20% agreements have the larger farms, the highest production per herd and per effective hectare.

A noticeable characteristic is that New Zealand farmers typically challenge the status quo: they like seeking growth in profit and efficiency by using different strategies and by being innovative (Williams, 2006). One of these strategies is the separation of actual milk production from breeding, production of replacement heifers, and feed production (Robertson, 2010). This specialisation phenomenon occurs through contracting arrangements: a dairy operator may own the milking facilities but contract out part of the feed production and replacement heifer growing phases. Some advantages of this separation are human and capital resource specialisation, economies of scale, and increased overall efficiency (Purdy, Langemeier, & Featherstone, 1997). A further dimension of this separation can be observed in the ownership and operation of the resources, which is also relevant for sharemilking agreements. Although the specialisation in resource use decreases flexibility, the participation in only one stage may increase the options for negotiating with partners. According to Boehlje and Schiek (1998), the specialisation strategy allows farmers to leverage volume by investing funds in only part of the needed total fixed assets, while maintaining a certain degree of control of the other phases through contract specification.

2.4.5.1.1 *The pasture resource and feeding systems.*

The grassland resources, which occupy approximately 45% of the country's area and can be grown and intensively grazed all year round, play a major role in New Zealand's farming success (McCall & Clark, 1999). However, these grasslands show large variation in pasture production mainly determined by land characteristics, winter temperatures, and summer soil moisture (Hodgson, 1999; Holmes, 2003). The profile of pasture production for most regions typically peaks in spring and, to a lesser extent, in early autumn (Robinson, 1999). Furthermore, pasture growth patterns are location-specific. For instance, Gaul and Hughes (1996) noted that pasture growth in Canterbury and North Otago more closely matched this seasonal pattern of production than other regions of New Zealand. This production pattern and the widespread use of irrigation have made dairy farming viable in the Canterbury region.

New Zealand pastures have traditionally been sown in perennial ryegrass (*Lolium perenne)* and white clover (*Trifolium repens)* (Robertson, 2010) that allow an annual productivity ranging from nine to 18 tonnes of dry matter per hectare (tonDM/ha) (Valentine & Kemp, 2007). Nationally, and at a commercial level, mean annual pasture has been reported as 12 tonnes DM/ha/yr, while top quality production may range from 10-16 ton DM/ha/yr (Holmes, 2003). New Zealand feeding systems have predominantly been reliant on direct grazing of pasture, or crops, such as oats, brassicas, swedes, chicory, and fodder beet, along with variable contributions of hay, maize silage, palm kernel, meals, or other supplements (Harris et al., 1998; Penno et al., 1999). According to Holmes (1998), conventional farms in the past were self-contained for feed, but by 1998, most farms were using some kind of imported feed, including grazing off-farm. More recently, DairyNZ[8] classified New Zealand dairy feeding systems according to the use of imported feed and/or off farm cow grazing as follows:

- System 1: Self-contained – no imported feed: All stock on the dairy platform and all supplement harvested off the milking area.
- System 2: 4-14% of total feed imported or grazing off farm: generally for dry stock and replacements with large variation in quantity depending on the region. This system overlaps in part with system three and must be identified by the objectives and the pattern in the use of supplements.
- System 3: 10-20% of total feed imported with imported feed used to extend lactation in autumn or to winter the herd.
- System 4: 20-30% of total feed imported and used during both early and late lactation.
- System 5: More than 30% of total feed imported and used at all times of the year, including lactation and dry period.

2.4.5.1.2 New Zealand dairy calving systems.

In New Zealand, 90% of dairy farming systems are based on spring–calving herds supported by seasonal-supply, pasture-based feeding systems (Garcia & Holmes, 1999; Holmes, 2003). Spring-calving herds offer many advantages to management, such as synchrony between pasture growth and feed demand, and a simple work schedule, although it requires a higher seasonal, concentrated labour input. Other advantages are concerned with animal welfare and animal health (Holmes, 1986). The seasonal calving system allows for calf rearing in groups instead of the individual rearing of calves. First calving usually takes place at 24 months and the calving interval is 364 days ± 31 days (Macmillan & Moller, 1977). Calving dates differ between regions with a clear gradient from a median calving date in the first week of August in the north, to a median calving date 30 days later in the south (Holmes, 2003). In some areas where very dry summer conditions are common, split calving has been adopted to smooth feed demand (Robinson, 1999). However, research at the farm and commercial levels has shown that a range of autumn and spring calving systems (from 100% of cows in autumn through to 100% of cows in spring) can be operated successfully in New Zealand, depending on local climate and resources (Holmes, Brookes, Garrick, Mackenzie, Parkinson & Wilson, 2003).

[8] DairyNZ is the dairy industry organisation representing farmers and is funded by a levy on milk solids and through government investment. Its purpose is to enhance the profitability, sustainability, and competitiveness of New Zealand dairy farming (DairyNZ, 2012).

2.4.5.1.3 New Zealand breeds.

The prevalence and main characteristics of New Zealand dairy breeds have changed over time. Nowadays, the New Zealand Holstein–Friesian (HF) is predominant, making up 42% of total dairy cows, followed by 36% Holstein–Friesian and Jersey crossbred cows, and 13% Jersey (Dairy NZ, 2011). The remaining 9% is made up of other breeds, including 0.8% Ayrshire. According to Porter (1991), the Holstein–Friesian originated in North America (NA) from imported Dutch black and white cows through selection as specialist milk producers in confinement systems. This resulted in a larger, single purpose dairy cow which can produce a very high volume of milk low in MS content. The New Zealand Friesian differs from the NA Friesian, being a smaller biotype and producing milk with a higher MS content. The third breed of importance, the Jersey, is a dairy biotype that originated in the British Islands of the English Channel. It has the notable ability to adapt to diverse climates, phenotypically a good dairy conformation, moderate milk yields of very high MS content and it is less suited to meat production than other breeds (Porter, 1991). Finally, Ayrshire is a dairy breed native to Scotland that typically provides good milk and meat on low-cost forage, has an excellent udder, and can adapt to a wide range of climates (Porter, 1991).

The shifts in breed use and crossbreeding[9] feature strongly in the history of New Zealand dairying (Holmes, 2001). By the early 1970s, the dominant breed had changed from Jersey, to Friesians that had been bred under local conditions from animals imported from the USA before 1925 (Harris & Kolver, 2001). Since the 1960s, northern hemisphere Holstein-Friesian genetics were introduced again with an expectation that traits for very high milk production would be expressed in New Zealand conditions. However, this breed did not yield expected results and crossbreeding was later adopted to reduce the impacts of 'Holsteinisation' (Harris & Kolver, 2001), which included shorter lactations and reproductive issues (Lucy, 2001). Farmers have focused on breeding cows more suited to pasture–based systems (Montgomerie, 2004) including crossbreeding to take advantage of heterosis effects comprising improved fertility (Harris, 2005). More recently, semen from elite Jersey–Friesian crossbred sires ('KiwiCross') has been commercially available, not just in New Zealand, but also around the world.

According to LIC and Dairy NZ (2011), in the 2010/11 season, Holstein–Friesian and crossbreed cows exhibited the highest MS production (kg), while the HF cows produced more protein. Jerseys produced the highest percentages of milk fat and protein and lowest absolute milk volume as shown by the average per cow statistics for each region. North Canterbury had a larger proportion of Holstein and HF than the rest of the country, and recorded the highest per cow milk volume (4,916 litres), milk fat (221 kg), and protein (186 kg). In turn, Taranaki, with a

[9] A crossbreed is defined as having, at most, 13/16 of any one breed (LIC & DairyNZ, 2011)

larger proportion of Jersey cows, recorded the highest percentage for milk fat (5.07%) and milk solids (8.95%).

2.4.5.2 Chilean dairy farming systems.

Dairy farming is among the most important agriculture sectors in Chile, being particularly significant in the Southern regions (Escobar et al., 2006; Lobos et al., 2001). The dairy farming systems in Chile vary by region, tending towards smaller, more intensive operations in the Northern regions and larger, export-oriented and more seasonal operations in the South (Challies & Murray, 2006). At the country level, Chilean dairy farming systems can be grouped into three or more classes, ranging broadly from confinement to pasture–based systems. The pastoral systems may also house the cows over the winter period, and all three classes rely to some extent on the use of supplements all year round (Smith, Moreira, & Latrille, 2002). Evidence suggests that most farm businesses can be classified as System 4 or 5 according to the DairyNZ classification system.

The Northern farming systems are often confined or semi-confined dairies, where animals are fed on concentrates, irrigated lucerne, and maize or grass silage (Challies & Murray, 2006; Smith et al., 2002). These operations are domestic market-oriented with all year round production supplying Santiago de Chile, the capital city, and its six million citizens. The proximity to the metropolitan region allows relatively small-scale, intensive, and niche production to occur, and as such, the price paid to producers is often higher than the national average (Challies & Murray, 2006). Domestic market-oriented producers supply the raw milk for a range of high value-added products, such as yoghurts and flavoured milks (Barton, et al., 2007). In this context, dairy producers are usually classified as small (up to 50 L per day), medium (100 to 700 L per day), or large (more than 700 L per day), according to the volume of milk delivered (Salas, 1995).

The southern central regions of Bio-Bio, also called VIII, La Araucania (or IX), Los Lagos (X), and Los Rios (XIV) have the potential to establish successful pasture based dairy systems. In these regions, land values are lower and more extensive dairying occurs almost naturally (Bravo-Ureta & Fuentes, 2003 and Troncoso & Tobar, 2005, cited in ODEPA, 2009). The distance from the major market means that less perishable items, such as cheeses and milk powder, are more likely to be produced (Barton, et al., 2007).

The pasture-based dairy farm in Chile is usually family owned, but frequently not owner-operated, mostly because of absentee landlords (Anrique & Latrille, 1999). Even owners who have completed agricultural studies tend to focus on professional or advisory careers rather than on-farm management (Smith et al., 2002). At the operational level, human capability is often a limiting factor because of lack of skills and education, the poor social status of contract milkers, and sub-standard working conditions on farms (Vargas, 2001). Frequently, workers and farmers have little, if any, training in currently accepted management techniques. In terms of infrastructure, herringbone milking sheds are the most common, and twice a day milking is common (Carrillo, Moreira, & González, 2011).

Heterogeneity characterises Chilean dairy farming systems, and this heterogeneity is not just limited to variation across regions, but also intra-regionally (Carrillo et al., 2011). In the southern regions, low-technology dairies co-exist with technologically sophisticated enterprises across all systems. According to Smith et al., (2002), the greatest variability is found among the medium-sized farms. As a result of this heterogeneity, the costs of milk production are extremely variable, depending on the area, the intensification level, the technology used, and the management skills of farmers (Salas, 1995). According to Escobar et al. (2006), technological changes represent the most important development within the dairy sector in the last few years, and only the producers that have successfully incorporated hard and soft technologies have been able to remain competitive. In contrast, those farmers who were unable to change exited the industry, or converted to sheep and beef farming.

Chilean dairy farms are often not specialised, and usually allocate land to a variety of agricultural activities, such as beef or cropping, which generally occupy more than 50% of the total land area (Anrique et al., 2004; Lerdon, Munoz, & Moreira, 2010). In particular, the beef and dairy markets are closely related, mutually influencing the decision-making process. For most specialised farming systems, any change from dairy to beef is a long-term decision; however, for Chilean dairy systems which tend to be not specialised, it can be either a long- or a short-term decision (Winkler, 1999). However, what can be advantageous for the farmer can also be a serious disadvantage for the industry as a whole, mainly because this type of diversification policy increases both price and volume instability. This policy may have contributed to limiting the necessary specialisation for export production. However, the current situation minimises the risk, with a portfolio of products instead of one product marketed into a portfolio of importing countries. However, according to Escobar et al. (2006), medium and large producers tend to specialise and to incorporate technology to pursue higher standards of milk quality (hygiene and milk solids content). Recently, foreign investment that originated in New Zealand has come to dominate Chilean dairy product processing, triggering an export-orientation, and more seasonal operations have increased in number as a result (Escobar et al., 2006).

2.4.5.2.1 The pasture resource and feeding systems.

Pasture–based Chilean dairy systems are characterised by grazing herds with a variable percentage of the diet being supplements of various classes (Smith et al., 2002). These systems utilise 'natural' [10] and sown pastures year round, forage or pasture hay and silage, and different types of concentrates (Schnettler, Lopez, & Barchiesi, 2002). Very wet winters and short-term soil water deficits during peak summer are the major restrictions to pasture growth and grazing all year round in most southern-central regions. The pasture depending upon soil characteristics and management may comprise spontaneous clovers (*Trifolium sp.*), *Lotus sp.*, and fine grasses (Balocchi & Lopez, 2001). Typical sown pastures rely on some naturalised species, such as *Trifolium repens, Bromus catharticus*, and *Dactylis glomerata*, but most frequently include *Lolium perenne*, and sometimes *Festuca arundinacea*. Short-lived pastures, such as annual ryegrass and red clover pastures, are also common. Pastures in central-south Chile may yield between 12 and 18 tonnes DM/ha.year (Teuber, 1996). Well-managed natural pastures can provide similar yields and equivalent nutritional quality (Balocchi & Lopez, 2001).

In Chile and other parts of the world, supplements are a way to improve milk yields, both per cow and per hectare, and at the same time, reduce climatic risk associated with pasture–based systems (Edwards & Parker, 1994). Moreover, under grazing conditions, dry matter intake is frequently insufficient to meet dairy cows' high genetic potential and supplements are needed (Kolver & Muller, 1998). However, supplements increase the cost of production, and the profitability of their use depends on the milk:feed prices ratio and the response in milk production per gram or kilogram of feed fed to the cows. Milk production responses of grazing cows offered supplements reported in the literature vary between 30 and 150 g of milk solids per kilogram of dry matter intake, but positive quadratic responses to increasing amounts of supplement have been observed for yield of milk, energy-corrected milk (ECM), and fat and protein (Auldist et al., 2013).

2.4.5.2.2 Chilean dairy calving systems and breeds.

Dairy calving systems in Chile are diverse, from all year round calving to concentrated spring, autumn or both (Smith et al., 2002; Winkler, 1999). First calving usually takes place at 26 to 32 months, and the calving interval is 365 to 400 days. Artificial insemination is widespread (Ferreira, Mujica, Uribe, Lanuza, Quinteros, & Concha, 2010; Winkler, 1999**)**. An important feature of the Chilean farming systems is that there is no veal market, which means that male and female calves have to be raised (Winkler, 1999). This affects the selection of the type of breed; there is a tradeoff between milk and meat production which is consistent with the multi-product system and the diversification strategy explained earlier.

[10] 'Natural pasture' means that pasture species are spontaneous or naturalised but not necessarily native.

Traditionally, Chilean dairy farming systems have used predominantly dual purpose breeds, such as British Friesian and German Red, although these breeds becoming less important due to their lower milk production potential. Currently, herds are largely based on Holstein cattle, with a smaller proportion of European type dual purpose breeds and crosses. The main Chilean breed is now the American Holstein and North American farm management principles are predominant with Litres per cow (L/cow) being the industry standard benchmark for efficiency (Ferreira et al., 2010). However, increasingly "the health of the herd tied up with the genetic improvement is very much linked to the search of higher solid content of the milk" (Escobar et al., 2006, p.45). This means that crossbreeding and the use of other breeds is increasingly being considered due to the industry objective of increasing MS content before 2020 (Consorcio Lechero, 2010).

2.4.5.3 Milk payment systems.

This section describes the different milk payment systems in New Zealand and Chile. If strong industry guidance is required for dairy farming systems to succeed, there is no clearer signal from the market than that coming from the milk payment system. According to Draaiyer et al. (2009), understanding the reasons for different payment systems can be gained through consideration of the following factors:

- Stage of development of milk collection in the country or region;
- Level of trust in the relationship between producers and the industry;
- Educational level of farmers;
- Readiness of farmers to accept payment systems;
- Present dairy legislation;
- The hygienic quality of the milk available;
- Existing adulteration practices;
- Obtainable products from the raw milk; and
- Available testing methods.

Ideally, a payment system must be accepted and understood by the producers and all parties need to be convinced that the payment system introduced is the most appropriate. Moreover, dairy legislation is something to carefully consider before introducing a payment system, and national and local regulations might dictate what a payment system can or cannot do. A payment system must address the strengths and weaknesses of the surrounding productive environment; for instance, if hygienic conditions at milk collection are low, a payment system based on hygienic quality is a priority and, conversely, if these conditions are high, testing and paying for hygienic quality might not be the highest priority. Similarly, if adulteration practices are known, then testing and payment systems should be adjusted accordingly.

Accordingly, farmers must consider the final market for the products made from the milk they produce and consider this market in their decisions (Boehlje & Schiek, 1998). In the future, milk producers may be increasingly called upon to produce milk of varying composition for specific food uses. As milk solids content determines the yield of milk in dairy products, if the market for these is greater than the market for fluid milk, the industry might have a payment system based on individual components or total MS. However, in many countries, a difficulty in developing such a system is the ability to measure the components in the milk coming off the farm (Draaiyer et al., 2009). Therefore, any payment system should be based on raw milk testing methods that are available, trusted, and economical.

New Zealand has a small domestic market compared to its export markets, and therefore, far greater demand for dairy products than fluid milk. Consequently, the New Zealand system rewards dairy farmers for producing milk solids and penalises water content. Milk containing higher MS results in reduced processing costs for a given level of production, and therefore, increased profitability within the dairy industry as a whole (Bates, 1998). In addition, very high hygiene requirements at collection means farmers and processing firms have a strong focus on testing and information availability which is vital for meeting quality standards and avoiding commercial issues and penalties. Whenever possible the processing companies send information back to producers (even on a daily basis), allowing farmers to make changes in management to favour the production of one component or another.

For most New Zealand dairy farmers, milk income is derived from two sources of income as a result of a dominant, fully vertical, integrated cooperative with farmer owning shares in the processing company, matching kilograms of milk solid produced in a 1:1 ratio with shares. Thus, the typical milk pay-out for the farmer-owned cooperative, Fonterra, has two components: firstly, that due to the individual farm output and, secondly, that due to the company's performance in the international market. Nevertheless, it is worth noting that milk price is completely separate from dividends. A farmer's monthly income reflects the estimates of milk price for the season, while the share dividend is received in February and November each year and reflects the added value component of the product generated by the company performance in the previous season (exports). The milk component of the price is paid partially in advance by the monthly estimates, with a final payment at the end of a 15-month period (Fonterra, 2012). The minority of the processing industry is made up of an investor-owned company, which reward producers just for the amount of MS delivered.

Overall, two clearly different payment systems in New Zealand and Chile have promoted the production of dissimilar types of milk and have contributed shaping the different farming systems. In Chile, the milk is currently paid on volume and composition. Between 1997 and

2007, the Chilean Agricultural Census showed an increase in the volume of milk produced and a reduction in the size of the national dairy herd; this is consistent with the way producers are rewarded. Farmers have responded by increasing the individual cow productivity to the detriment of herd size and MS content (Ferreira et al., 2010). However, there is no single raw milk payment system in Chile; milk is paid for under several arrangements according to the company, and there are also differences between producers within a company. Milk is paid on a volume basis (L), using a base price and several other factors to make up the final price. Annually, each farmer negotiates the base price per L, and the final price includes bonuses and penalties according to:

- Somatic Cells Count < 3 million cells/ml;
- Colony forming units < 90.000 /ml;
- Volume supplied (L);
- Winter milk bonus;
- Protein > 3.0%;
- Fat > 3.0%; and
- Presence/absence of a cooling tank (Prolesur, 2011).

The base price relates to the litres of milk produced, with 3.0% fat and 3.0% of protein. The final price is only known after the bonuses and penalties have been applied. The 3.0% milk fat and 3.0 % milk protein have a built in bonus, resulting in a fixed amount paid per Kg of fat protein above 3.0%. Analyses to determine MS content are undertaken fortnightly, not daily. The value of protein is almost four times higher than the value of fat (Prolesur, 2011); this is also true for NZ and other countries. Other bonuses relate to the hygienic quality of the farm and the milk itself.

2.4.5.4 Recent empirical research on pasture-based farming systems.

Empirical research requires direct and indirect experience or observation (Hand, Mannila, & Smith, 2001). Empirical evidence has shown that pasture-based dairy farming systems in temperate regions have lower production costs per unit of output through lower feed and labour expenses (IFCN, 2010). These attributes are fully expressed where:

- pasture production potential is high;
- variability in seasonal pasture supply and quality is low;
- milk production itself accounts for a large proportion of total production; and
- large areas of land are readily available at relatively low cost.

This last attribute is particularly true in Chile where the cost of pasture land is approximately half that for similar quality land in New Zealand (CIA, 2012). Other relevant costs, such as wages and supplementary feed, are much higher in New Zealand than in Chile, triggering correspondingly higher labour efficiency (IFCN, 2011; Winkler, 1999). However, both pasture-based farming systems allow higher labour efficiencies than other more intensively capitalised systems. Research on resilience has suggested that this should add greater global sustainability in a scenario of increased supply and possibly lower prices. Pasture–based systems are expected to not only be more sustainable, but also have increased product quality and improved animal welfare (Benson, 2008; Dillon, et al., 2005).

Acknowledging the value of empirical data, *DairyBase*[11] was established in 2003 by Dairy NZ and has been addressing issues existing in the New Zealand dairy industry, such as the lack of robust information, terminology inconsistencies, and different approaches to the calculation of key performance indicators (Shadbolt, 2009). *DairyBase* collects and stores large amounts of data functional to the levy paying New Zeland dairy farmers and the industry as a whole. Statistics New Zealand is another source of hard data from a more random selection of NZ dairy farmers of national coverage. Every year, information from both *DairyBase* and Statistics New Zealand is used in different studies.

Dairy NZ is also a routine user of both the *DairyBase* and Statistics New Zealand datasets. A recent study has showed that milk production has consistently increased over the last decade, but at the same time, the average annual total factor productivity has declined by 0.5% (Dairy NZ, 2012). This apparent contradiction is explained by the fact that the extra production averaged 5.6% per year as a result from a 6.1% annual increase in inputs, such as farm working inputs, land, and cows. Over the same period, labour productivity, measured as additional cows per full time equivalent (FTE) per year, has increased at a rate of 3.1%. Therefore, farm working inputs other than labour that resulted in decreased total factor productivity need to be identified from the inputs.

Recent research based on the Dairy NZ farm systems classification using the amount of imported feed, investigated the drivers of financial success for each of the different systems. The study concluded that the cost leadership strategy was pursued by all the five systems in New Zealand through effective cost control over the period of analysis, and that the most important measure of profit was ROE (Shadbolt, 2011). Higher input systems also consistently produced more milk per hectare, but were less able to cope with deteriorating market conditions exhibiting inferior performance under depressed milk price scenarios. The author concluded

[11] DairyBase is supported by the New Zealand Institute of Chartered Accountants and the NZ Institute of Primary Industry Management.

that, regardless of the adopted feeding system, better performers are those that have both high capital and superior operating efficiencies.

Rouse, Harrison, and Chen (2010) applied a non-parametric efficiency analysis to a case study of New Zealand dairy farms data for 2004/05. They found that farms within the Waikato region were more efficient than Taranaki farms, and concluded that the differences were mostly explained by herd size. Their results revealed that around 300 cows was optimum herd size, and farms associated with higher soil quality combined with less hilly contours were more efficient.

Econometric studies have also played a role in analysing *DairyBase* information (many actually analysing its precursor, ProfitWatch). According to Laca-Viña (2010), empirical evidence suggests that a variety of farming systems have emerged as a result of dairy farming geographical expansion in New Zealand. Encouraged by this evidence, Laca-Viña tested for differences in technology between regions of New Zealand and studied the robustness of the different stochastic production functions responding to input/output selection (Laca-Viña, 2010). The author reported that sample farms from *Farm Monitoring* data located in the South Island of New Zealand were, on average, more productive than those farms in the Waikato–Taranaki region. Given the differences in technology and scale, it was not clear from his results which factor influenced his conclusions the most. The author also claimed that the high levels of technical efficiency of farms in both regions suggests that the industry could not expect to achieve major productivity gains through efficiency improvements; rather, these efficiency gains may only be achieved through technical progress or technology gains that increase both labour and capital productivity. The robustness of farm technical efficiency estimates to the input/outputs chosen was addressed by comparing farm level estimates obtained by the different models using the Pearson and Spearman correlation coefficients. Evidence suggested that efficiency estimates were not very sensitive to the choice of input/output set.

Motivated by the proposed Emissions Trading Scheme and its effects on dairy farming, Jiang (2011) looked at the regional efficiency performance of dairy farming in New Zealand using the stochastic frontier framework for the period 1998/99 to 2006/07. It was found that, given the different climate, soil, and farming history, the North and South Islands do not share the same technology. The subsamples in both islands did exhibit similarities, like decreasing returns to scale, but dairy farming technologies are markedly different. For example, labour and electricity were relatively more important for dairying in the North Island, while farming systems in the South Island relied more heavily on capital and fertiliser. Interestingly, when evaluated against their own regional frontiers, the North Island farming systems had higher technical efficiencies than those in the South Island. However, a direct comparison between North and South Islands showed that farming technology was more advanced in the South Island. Jiang concluded that efficiency encouragement in the South Island should focus on lifting individual technical performance, while a technological change is required in the North Island to lift the whole region's efficiency frontier.

Empirical data shows that Chilean dairy farming systems have traditionally shown greater variability in efficiency, profitability, and other variables' results. A study conducted in the Central area estimated a range between 3.3 and 13.6% of return on invested capital for dairies with varying levels of technology (Aichele, 1979). Similarly, in the Central area, Campos et al. (1995) determined that the average return on capital investment for the production of milk ranged between 5 and 14.9%. Another study by Silva (1997) surveyed 28 dairy producers in the VII Region and reported that return on assets for the larger producers fluctuated between 10 and 12%, but both variability and profitability observed with the medium producers were higher, ranging from 10 to 17% ROA. Diaz and Williamson (1998) looked at profitability, infrastructure, and management of pasture-based dairy farms in Southern Central Chile during 1995 and 1996, and observed a 3% ROA for producers with medium sized dairies and 8% for large producers. They concluded that the effect of scale on farm profitability was significant. They also found that size was positively correlated with management improvements and infrastructure.

According to several studies cited in Lobos et al. (2001), the most important factors determining the economic performance of a dairy farm are feed, genetics, reproductive results, animal health, scale, production per cow, pasture grown per hectare, cost control, and investment. In Chile, the evidence suggests that a series of management factors directly controlled by the farmer determine efficiency (Lerdon, Muñoz, & Moreira, 2010). This study revealed that costs of production, stocking rate, and quality of the milk were the key factors determining the productive success of the farm. Moreira and Bravo-Ureta (2003) measured technical efficiency and technological change using a highly unbalanced panel of 48 Chilean dairy farms from 1996/97 to 2001/02. They found that mean technological efficiency varied from 69% to 77%. Over the same period, but using a different methodology, stochastic metafrontier analysis, the same authors evaluated technical efficiency and the technological gap of dairy farms in Uruguay, Argentina, and Chile (Moreira & Bravo-Ureta, 2010). They found an even lower mean technical efficiency of 66% in Chile, which was the lowest in the region.

2.5 Benchmarking Farming Systems

This section addresses the motivation behind comparative analysis as well as relevant definitions and applications of benchmarking found in the management and efficiency literature.

2.5.1 Why benchmark?

Recording information and benchmarking are of particular importance in agriculture, and both have developed to varying degrees, depending on the country and the industry (Whitehead, 2008). According to recent studies, the smaller the scale of the farms, the greater the industry guidance in the form of technical and economic recommendations is needed (Bernard, Le Gal, Triomphe, Hostiou, & Moulin, 2011). This form of leadership from the industry has included benchmarking, monitoring, process control, and other extension activities have been included (van Eijk, 1998). Similarly, information, analysis, and evaluation are necessary for the enhanced design and management of viable and robust farming systems (NRC, 2011). This implies the acknowledgement of others doing well at something, the necessity for shared information, and the drive for excellence through continuous learning and improvement. The practice of benchmarking has had broad application in various contexts, including problem solving, planning, goal and strategy setting, process improvement, and innovation.

2.5.2 Benchmarking and benchmarks.

Benchmarking is the exercise or process of searching for best practices that lead to superior performance (Camp, 1989). Accordingly, it is defined as an on-going process that involves learning and benefitting from others' experience, leading to superior performance (Bogan & English, 1994). McGuckian (1996) is supportive of these definitions and also stated that a firm can develop methods to improve its own by looking at the performance of other businesses. Anderson and McAdam (2007) pointed out that many definitions are valid for benchmarking and argued that they essentially share the same common ideas. According to Jack and Boone (2009), a comprehensive definition of benchmarking should include information sharing, trust, collaboration, learning, and adoption of best practices to improve performance. However, to undertake these activities, a comprehensive benchmarking system, including a range of benchmarks, is needed.

Benchmarks are metrics that may be used as operating statistics to identify performance gaps and the competitive position of a particular business (Martin, Zwart, Gardner, & Parker, 2005). According to Benson (2008), necessary physical and financial performance benchmarks for pasture–based farming systems include ratios per cow, per unit of milk sold, and per unit of land area. The stated objective of benchmarking studies is to get insight through comparative evaluation; relative performance is assessed for firms which transform the same type of resources (inputs) into the same type of products (outputs) (Bogetoft & Otto, 2011). Benchmarking can be used to make longitudinal panel comparisons, where the performance of firms in different time periods is compared. Other stated objectives and uses of this practice may include decision making, coordination, control, and motivation (Bogetoft & Otto, 2011).

2.5.2.1 Benchmarking forms and types.

Martin et al. (2005) stated that benchmarking activities may be classified according to objectives in or four recognised forms as follows:

Industry group benchmarking: Comparative analysis where various benchmarks from a business operation are contrasted to similar measures in other businesses belonging to the same industry group.

Best practice benchmarking: "A particular systematic approach in which a business evaluates its own operations and procedures through a detailed comparison with those of another business, in order to establish best practice and to improve performance" p. 60 (Jack & Boone, 2009).

Competitive benchmarking: This is the study of a competitor without their cooperation, for the purposes of product or process quality improvement. This form is unlikely to reveal practices for improving performance.

Cooperative benchmarking: This is the study of production functions aimed at improving performance. It is done between benchmarking partners. This form has the potential to reveal innovative practices.

Similarly, Martin et al. (2005) suggested three distinctive types of benchmarking:

Process benchmarking: This type focus on acquiring the know how to achieve operating practices of excellence. In agriculture, this tends to focus on technical issues.

Performance benchmarking: This type concentrates at the tactical level on results that are consistently being achieved, and seeks to identify the practices that deliver such results.

Strategic benchmarking: This type concentrates on longer term, strategic decisions that have been made in a business, involving the triggers and the positive outcomes that resulted from the change. It is usually long-term focused and rarely industry-specific.

The most common use of benchmarks for diagnostic purposes and performance analysis in what is also called 'comparative analysis' (Jack & Boone, 2009) or industry group benchmarking (Martin et al., 2005). Watson (1993) identified four key components to benchmarking: the planning stage; conducting the research; analysing the data; and adapting, improving, and implementing the findings. The process of benchmarking involves a definition in the scope of the study and the selection of a benchmarking partner; determination of the relevant indicators or benchmarks; data collection; analysis focusing on strengths and weaknesses; discussion of results and implications; and seeking new benchmarks.

2.5.2.2 Benchmarking as a farm management tool.

Benchmarking has been a longstanding and widespread practice. Discussion groups and monitor farms, started in France in the 1940s and in New Zealand in the 1980s, respectively, are considered early examples of benchmarking to inform, transfer technology, and motivate learning and action (Campbell, 2008). According to the Food Chain Centre (FCC, 2007), farmers value benchmarking because for: cost understanding, working practices improvement, understanding business drivers, increasing returns, and improving quality of products and processes. Benchmarking has been reported as a common exercise among top performing dairy farmers (Wilson, 2011). Verissimo and Woodford (2005) stated that top farmers are generally information-rich and use many strategies to acquire and filter relevant information, including benchmarking. Benchmarking as a farm management method can help identify the necessary changes to improve financial position and is also useful for strategic planning.

However, while benchmarking is widely used, its adoption does not appear to influence profitability (Gloy & LaDue, 2003). Benchmark data are powerful diagnostic and research tools which enable the assessment of the prevailing farm management performance, as well as a monitoring the trends and changes in farming (Jack & Boone, 2009). Benchmarking, and the search for competitive advantage, can address whether differences in performance are due to random events or to managerial ability (Langemeier, 2010). Langemeier (2010) also indicated that it is hard to perform well consistently, and concluded that benchmarking over several seasons is essential for determining competitive advantages. In addition, according to Benson (2008), judgements about relative performance of one or more particular farming systems should be based on a large sample from different regions and various practices.

Benchmarking can be used to assess an individual farm business's performance, and to examine the relative competitiveness of different farming systems. However, Makeham and Malcom (1993) criticised benchmarking, pointing out that the emphasis on accounting and recording leaves out the critical technical and human aspects of management, and it also has a past, not a future orientation (Anderson & McAdam, 2004). Barnard and Nix (1979) cited in Fleming, Farrel, Villano, and Fleming (2006) noted five key problems with comparative analysis benchmarking identified in the academic literature:

1. It was not a holistic approach;
2. It failed to incorporate some key economic principles;
3. It failed to establish causal relations between farming practices and performance;
4. It had limited scope for action; and
5. It neglected the effect of risks and uncertainty in farm decision–making.

According to Fleming et al. (2006), failure to identify causal relationships between performance and factors such as input-output prices or rainfall often led analysts into interpretative errors. Therefore, a holistic approach is needed to adequately contextualise benchmarks. Possibly the most damaging criticism of comparative analysis was that it neglected economic principles. Malcom (2004) postulated that economics is the core discipline of farm management, and without its contribution results from comparative analysis have little prescriptive value. Benchmarking businesses to identify differences and similarities in financial and productive farm performance may not be enough to comprehensively assess a farming system (Anderson & Ridler, 2010). A farming systems approach interpreting the outcomes of the comparative analysis may overcome these faults. However, according to Fleming et al. (2006), benchmarking partial performance measures means that benchmarks may only convey partial information on the farm's performance. A more comprehensive measure is then needed to get an accurate picture of the whole farm performance.

2.5.2.3 Data envelopment analysis (DEA): a method for benchmarking.

The literature reviewed has shown that most performance measures are system-specific and that there is no consensus on the best set of benchmarks to concisely describe a dairy farming system. However, efficiency can fulfil the role of being a simple, comprehensive, and versatile indicator that naturally stands out as a benchmark because it is always a relative measure. Efficiency measures the ability of a certain business to use the existing technology or set of resources in the best possible way. Using an output-oriented perspective, it is the observed output of a particular farm compared to the maximum attainable output that can be produced under the current production frontier or technology set (Farrel, 1957). Villano et al. (2010) defined efficiency as the ratio of the observed output to the corresponding technological frontier or benchmarking peer, conditional on the level of inputs used. Although it is debatable whether technical efficiency is the ultimate measure of performance as claimed by Diewert and Lawrence (1999), it is undoubtedly important because if a firm does not attain technical efficiency, it means that resources are being wasted.

It is important to distinguish between efficiency and productivity. Jiang (2011) highlighted the differences and similarities between both terms, and claimed that these were not interchangeable since productivity is an absolute measure. DairyNZ (2012) defined productivity as the ratio, aggregated inputs to aggregated outputs. However, Bravo-Ureta (1986) warned that the aggregation of inputs and outputs is subjective and can affect the conclusions. Despite differences in methodology, warnings, and acknowledged limitations, modern benchmarking analyses increasingly use best practice or frontier analysis methods. Table 7 presents a taxonomy of frontier methods adapted from Bogetoft and Otto (2011).

Table 7

Frontier Methods Taxonomy

	Deterministic	Stochastic
Parametric	Corrected Ordinary Least Squares (COLS)	Stochastic Frontier Analysis (SFA)
	Aigner and Chu (1968), Lovell (1993), Greene (1990, 2008)	Agner et al. (1977), Battese and Coelli (1992), Coelli et al (1998a)
Non-parametric	Data Envelopment Analysis (DEA)	Stochastic Data Envelopment Analysis (SDEA)
	Charnes et al. (1978), Deprins et al (1984)	Land et al. (1993), Olesen and Petersen (1995), Fethi et al. (2001)

In the choice of deterministic or stochastic methods, the key question is whether the analysis requires flexibility in the mean structure or precision in the noise separation. Data Envelopment Analysis (DEA) is a deterministic, non-parametric method that responds to flexibility, without the need to know the underlying production functions or to have price information. Gattoufi, Oral, and Reisman (2002) reported that top DEA article journals include the *European Journal of Operations Research*, *Management Science*, *Journal of Productivity Analysis*, *Applied Economics*, *Journal of Econometrics*, and *Journal of Banking and Finance*. In the last decade, DEA has increasingly gained popularity among more diverse areas of research because of its simplicity, versatility, and relevance.

Farrell (1957) first envisioned the use of the production frontier in terms of efficiency, observing that there existed an efficient function from which all the observed points deviate randomly but in the same direction. Later, Charnes, Cooper and Rhodes (1978) introduced DEA as a technique based on mathematical optimisation, which had the ability to evaluate relative efficiency and to set individual firm efficiency targets. More recently, Coelli (1997) pointed out that a firm was only efficient if it operated on the frontier, and further, if all associated 'input excesses' were zero. A distinct advantage of DEA is that it provides explicit, real peer units for benchmarking. Rouse et al. (2010) described DEA as a formal method, either for efficiency measurement, benchmarking, or both.

DEA owes its name to the way the frontier envelops observations, which are typically represented by a performance score that ranges between zero and one and an expected skewed to the right distribution for the efficiency scores with most scores falling above 0.5 (Cooper, Seiford, & Tone, 2006). The production frontier has several important properties, such as non-negativity, non-decreasing values, concavity, and weak essentiality. The first to third conditions are obvious in their meanings, while the weak essentiality property means that the production of positive output is impossible without the use of at least one input (Coelli, Prasada Rao, O'Donnell, & Battese, 2005).

DEA models separate the data variables into input or output types such that input variables are causal factors to the outputs. The proper treatment of inputs and outputs in efficiency studies has been regarded as being very important; the variables have to be consistent with the phenomena they are supposed to capture. According to Coelli et al. (2005), inputs may be classified into five categories: capital (K); labour (L); energy (E); material inputs (M); and services (S). Often E, M and S categories are aggregated into a single category 'EMS'. Capital, unlike the other variables which are consumed in the production process, is a durable input which may be measured from the various assets of a particular Decision Making Unit (DMU) or farm. In farming, K is typically composed of land, livestock, buildings, and plant. Labour constitutes another primary input, normally measured using a single variable which aggregates paid and unpaid labour and management. It may be expressed in physical full-time-equivalent units, hours of work, or in monetary terms. None of these measures take into account the composition and quality of the labour force such as skills, age, gender, and education levels (Coelli et al., 2005).

Moreover, the number of efficient DMUs relies on the number of inputs plus outputs (Cinca & Molinero, 2004). The greater the dimensionality of the production function the more constraints the model has and the less discerning the analysis (Jenkins & Anderson, 2003). The analysis ought only to include inputs and outputs that are definitely relevant to the proposed study. According to Rouse et al (2010) there are some other rules about their proportion:

1. The number of farms (firms or decision-making units) must exceed a minimum of three times the number of inputs plus outputs; or
2. The number of farms must be higher than the product of inputs and outputs.

One important point to note is that inputs need to represent a production function or technology set such that the proposed output is achievable (Coelli et al., 2005). Another rule is that input variables should be controllable variables. The transformation of multiple inputs into outputs is affected by controllable and non-controllable variables, as well as observable and non-observable managerial characteristics. Therefore, there is a lack of information about the true underlying technology that needs to be acknowledged. This, in turn, leads to an efficiency estimate that is always higher than the real value of efficiency. The efficient DMUs (peers) resulting from a DEA provide concrete evidence of performance improvement targets for both inputs and outputs. As peer units are usually interpreted as those demonstrating how a firm can improve, it is relevant that changes are actually feasible, which is only possible if inputs are fully controllable. The analysis of the DEA peers is out of the scope of this study; exploring the explicit, real peer units would be a field for further research.

Economic or ‘overall’ efficiency (EE) is one of the major factors explaining differences in firm survival and growth (Olson & Vu, 2009). It has two components: price or ‘Allocative’ Efficiency (AE) and technical efficiency (E), such that

EE = E x AE (Farrel, 1957; Olson & Vu, 2009).

AE reflects the ability of a business to use inputs and produce outputs in optimal proportions to maximise profit, given their respective prices (Farrell, 1957). In turn, E is a measure of how a business transforms inputs into physical outputs and includes two components: pure technical efficiency (TE) and scale efficiency (SE) (Moreira & Bravo-Ureta, 2010). According to Barnard and Boehlje (1998), economic efficiency is determined to a large extent by pure technical efficiency because it reflects managerial ability especially in smaller firms. Allocative, scale, and pure technical efficiencies all impact profit, but the first is always related to changes in input and/or output prices, neither of which are controlled by farmers. In contrast, technical efficiency refers only to discretionary variables or those variables that can be influenced by someone’s discretion, judgement, or preference (Harrison, Rouse & Amstrong, 2012). According to Latruffe (2010), in most circumstances an improvement in technical efficiency can result from a more competent use of the existing technology: that is by producing the same output by using less inputs or more output with the same level of inputs. A second way to improve efficiency is through economies of scale. Figure 6 shows a graphical representation of both constant (CRS) and variable returns to scale (VRS) DEA envelopes for one output and one input condition.

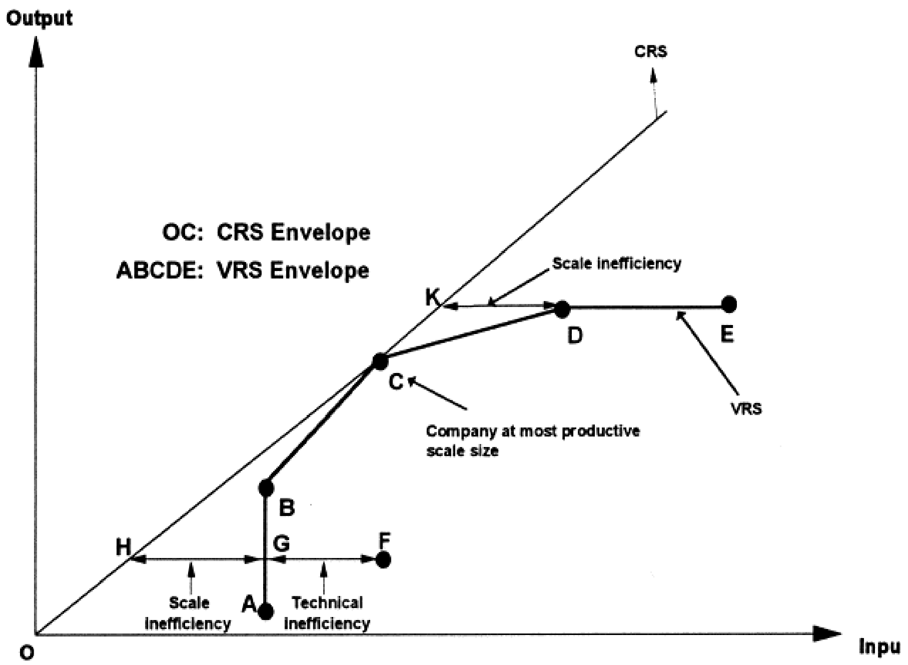

Figure 6. CRS and VRS DEA envelopes.

Adapted from: Coelli (1997)

Scale refers to a firm's size; scale efficient firms have a scale elasticity of one and work under Constant Returns to Scale (CRS), while scale inefficient firms could exploit either scale economies or diseconomies, which imply Variable Returns to Scale (VRS), including both decreasing (DRS) and increasing returns to scale (IRS) (Coelli, 1997). DRS takes place when a proportionate increase in all inputs results in a less than proportional increase in output; the latter conversely happens when increased inputs lead to a more than proportionate increase in output. 'Scale' interacts with technical efficiency in predictable ways: in larger scale operations, managerial input can be spread too widely and this might generate inefficiencies, while excessively small scale operations can result in high costs, because the fixed investment is spread over relatively low output levels (Barnard & Boehlje, 1998). TE, when measured under the assumption of CRS, only represents the true technical efficiency if the firm has an optimal scale of operation (Rouse, Harrison, & Chen, 2010). Otherwise, the pure TE component, which refers solely to management practices rather than the firm's operating scale, must be calculated under the VRS assumption. SE may also be of interest, and can be calculated as the ratio CRS:VRS. Different DEA assumptions define diverse DEA methods that differ in the ex-ante assumptions involved. A major DEA assumption is that data is measured without error, and thus, differences in efficiency scores are due to inefficient transformation of input into outputs, not allowing for noise or error. The free disposability assumption stipulates that unnecessary inputs and unwanted outputs can be freely discarded.

2.5.2.4 Regression or Recursive Partitioning Tree.

Regression partitioning tree is a data mining method that recursively partitions data into sets, each of which is simply modelled using regression methods (Witten & Frank, 2000). RPT is a non-parametric statistical technique used to classify observations into homogeneous groups (Godfrey, 2011). DEA efficiency scores can be used as the response variable in a second stage approach, to find the best summary set of benchmarks that explains a dairy system's performance. Since often the databases provided many more variables than those required to build such a summary set, an effective reduction of the multidimensionality of the datasets is in most cases desirable. RPT can regress discretionary and non-discretionary inputs on its analysis. This approach not only generated a ranking of variables, but also revealed the interaction between independent variables, which it is not possible to do with other forms of multivariate analysis (Curran et al., 1993). RPT approach can identify the relationships between different variables of interest as reported by Hansen et al. (2005). Rossi et al. (2005) also pointed out that RPT provides a variable ranking that is more stable than stepwise variable selection.

2.5.3 Generic competitive strategies.

Competitiveness is defined as the ability to profitably produce and provide value at an equal or lower cost than that of other sellers in a specific market (Harrison & Kennedy, 1997). Since a competitive advantage is not in itself a guarantee of achievement, in order to be successful, a firm needs to define the position and the competitive strategy that it is pursuing. By defining these position and strategy, firms get closer to the best way to succeed in a particular industry. Similarly, by executing a generic competitive strategy, the business is able to put its competitive advantage into practice. The competitive advantage of a firm is the extra value it creates and this is the difference between the value created by the firm and the potential value created by its competitors (Spulber, 2004).

Prosperous farm businesses are increasingly utilising and embracing well-known concepts and principles to improve their competitive position, efficiency, and productivity. However, the traditional techniques for being efficient, which are reducing cost and increasing margins, are not always sufficient to ensure successful agricultural production (Boehlje & Schiek, 1998). Three positive ways to achieve the best possible strategy, differentiation, focus, and overall cost leadership, are determined by the firm's competitive advantages (Porter, 1980). The first step towards defining the best strategy is to scan the external business environment and assess the business's internal resources and capabilities. According to Gray and Boehlje (2004), once the activities upon which a business may build a competitive advantage have been identified, the strategic position from the three options above can be defined.

2.5.3.1 Differentiation.

The transition of agriculture from a commodity industry to one of differentiated products indicates a dramatic paradigm shift in the industry (Boehlje & Schiek, 1998). The main aim of the differentiation strategy is to be perceived as unique industry-wide. Differentiation can be gained by selecting one or more attributes that clients perceive as important and trying to position the firm in such a way that the attributes of its products are considered by the consumer to be different from the rest of the industry's products. Some of the most common attributes that consumers perceive as different are the firm's delivery service and marketing approach (Porter, 1985). Differentiation takes many forms including design or brand image, special features, customer services, and technology. Differentiated firms have a low level of competition and rivalry as consumers have a lower sensitivity to price due to brand loyalty.

2.5.3.2 Focus.

Boehlje and Schiek (1998) stated that differentiation in the commodity industry has been particularly noteworthy when combined with a focus on the consumer and manufacturing approach to production. Focus strategy is based on choosing a market segment or group of segments in the industry by product line or geographic market. Once the market segment is chosen, the firm's efforts should be focused to serve that segment to the exclusion of others. The focus approach can achieve low-cost or differentiation for that market segment, but not for the whole market (Porter, 1985).

2.5.3.3 Overall cost leadership.

This strategy has a broad scope and is used in agriculture and many other industries and industry segments. A business has a cost advantage if cost efficiencies allow it to consistently outperform competitors and earn greater economic profits (Porter, 1980). In order to achieve and maintain a cost leadership position, an aggressive construction of efficient scale processes and on-going cost minimisation through innovation is required (Spulber, 2004). More specifically, Barney and Hesterly (2006) indicated that there are six main sources of cost advantages for firms that successfully adopt cost leadership as described below:

1. Size differences and economies of scale;
2. Size differences and diseconomies of scale;
3. Experience differences and learning-curve economies;
4. Differential low-cost access to productive inputs;
5. Technological advantages independent of scale; and
6. Policy choices.

Further, the authors explain that the ability of a valuable cost leadership strategy to create a sustainable competitive advantage is conditional upon the strategy being difficult and costly to imitate. At the farm level, cost structures are explained by fixed and variable costs. According to economic theory and empirical research, the cost explanatory variables are U shaped, meaning that costs of production decrease to a minimum point where economies of scale are achieved. Subsequently, diseconomies of scale occur and costs increase *(*Smyth, Butler, & Hennessy, 2008).

Agricultural systems' cost advantages are seen in those countries or regions where the particular climate, soil conditions, or labour supply advantages allow more efficient farming than in other regions (Kay, Edwards, & Duffy, 2012). The competitive strategy that best represents pasture–based dairy farming systems is cost leadership due to typically low feeding costs, since feed is the highest single cost component for these farming systems (IFCN, 2011). Low variable costs, and particularly low feed costs, have been reported as being important underlying causes of efficiency at the farm level which are responsible for achieving a high gross margin (Flaten & Giaever, 1998, cited in Hansen et al., 2005).

The New Zealand dairy industry has historically adopted a strategy of "broadly-targeted cost leadership" (Akoorie & Scott-Kennel, 1999, p.12). This strategy has been used throughout the New Zealand dairy industry to compete against other players in the global marketplace. Under the cost-leadership strategy farmers decide on the combination of inputs they wish to use and they make these decisions in order to minimise costs. In other words, if the input market is in perfect competition and under a cost-leadership strategy, the best technically feasible input-output combination is that which minimise production costs. These assumptions are considered to be appropriate for countries where farmers cannot accurately predict the volume of output, take input market prices as given and do not have any control over milk pay-out such as NZ and Chile.

Shapiro (1985) discussed the nature of the 'fit' between a firm's logistics system and its overall strategic focus. He considered three possible foci (product innovation, differentiation through customer service, and cost-leadership) that were broadly related to Porter's (1998) typology of strategies. For each focus, Shapiro clarified the nature of the task that logistics needed to accomplish. Thus, under a strategy of cost leadership, the logistics function should seek to minimise costs while keeping service at an acceptable level. Further, the ways suggested to control costs include, but are not limited to: exploitation of economies of scale; centralisation of inventories to the extent possible; lowest cost routing; and automation of materials handling and order processing. The need for a strategic fit between a firm's competitive strategy and its supply chain strategy was also espoused by Chopra and Meindl (2001).

2.5.3.4 Competitiveness within groups.

The competitiveness of a particular firm or a group of firms can be defined as the ability to face competition and to be successful when doing so. According to Latruffe (2010), competitiveness may be the capability to sell products that meet demand requirement, such as price, quality, and quantity. In addition, this capability must result in profits over time and enable the firm to prosper. Competitiveness is a relative measure, and a broad concept with many definitions and disagreements about how to measure it precisely. However, there is consensus that in order to evaluate the competitiveness of a given farm or farming systems, it is necessary to have data from peers that allow benchmarking to occur.

Data envelopment analysis (DEA) has proven to be an effective tool for analysing productive efficiency, and benchmarking the competitiveness of agricultural units and farming systems (Coelli, 1995). A wide range of benchmarking approaches and frameworks are described in the literature, which are often based on non-parametric methods, such as DEA (Bogetoft & Otto, 2011). This method allows the estimation of individual farm technical efficiency (TE) relative to the maximum feasible production possibilities, given certain technology availability to a particular group.

2.5.3.5 Competitiveness across groups.

Benchmarking across groups that have different production opportunities can still be achieved using DEA, although it needs to be taken further using a metafrontier approach. O'Donnell et al. (2008) used this extended methodology to compare the TE of firms that could be classified into different groups. They used data drawn from FAO Statistics, containing observations from 97 countries classified into four groups (Africa, America, Asia, and Europe) from 1986 to 1990. The data set comprised observations on just one output variable, representing the aggregation of 185 commodities, and five input variables related to agricultural production. This study showed that African and European countries produced agricultural outputs under conditions that were more restrictive than in other regions of the world with an average metatechnology ratio that indicated they could at best produce only 89% of the output that could be produced using the unrestricted metatechnology. America could produce 91% at best, and Asia (including Australia and New Zealand) could produce 93% of the output that could be produced using the unrestricted metatechnology.

Likewise, Moreira and Bravo-Ureta, (2010) used a single–output, multi–input approach and found different TE and metatechnology ratios for dairy farms in Chile, Argentina, and Uruguay. They also suggested that technical efficiency can be interpreted as a relative measure of managerial ability given certain technologies or productive environments. The findings from this study were that technology was indeed different for each country and that the average metafrontier efficiencies were 79.6%, 83.8%, and 91.4%, for Chile, Argentina, and Uruguay respectively. However, metatechnology ratios were much closer with 65.8%, 72.8%, and 73.4%, respectively. One attribute of the whole pooled sample was that farms were all operating at a sub-optimal size.

2.5.4 The International Farm Comparison Network.

The International Farm Comparison Network (IFCN) is an organisation that benchmarks farms across the world. In 2010, 90 countries that accounts for 98% of the world's total milk production were benchmarked (IFCN, 2011). The IFCN vision is to be "…the leading, global knowledge organization in milk production" (p. 8), while the mission advocates for the creation of "…a better understanding of milk production worldwide" (p. 8). The IFCN has been defined as a global network of dairy researchers from companies and other stakeholders in the dairy supply chain with a focus on milk production. The IFCN particularly addresses the dairy chain's resources and costs, emissions created, and the political challenges that come from producing milk itself.

In 2010, the typical farms' analysis comprised 157 dairy farms from 60 regions and 49 countries, which accounted for 87% of total milk production. Typical farms under the IFCN method represent those that produce the highest share of milk within their region. Table 8 shows a comparison of selected measures for both Typical New Zealand and Chilean dairy farms. Note that these figures are from actual farms representing each country's distinct dairy farming system and are not national averaged values.

Table 8

Comparison of Representative Dairy Systems

Country	NZ	Chile
Location	Waikato	Region X
Herd size (cows)	348	421
Stocking rate	3.3	1.0
Labour units	2.3	7.1
Kg MS/cow	394	685
Kg MS/ha	945	753
Total assets (US$/100 kg)	126	48
Total Capital cost (US$/100 kg)	2.4	0.5
Equity	70	100
Milk price (US$/100 kg)	34	35
Cost of Production (US$/100 kg)	34	27
Average wages on farm (US$/hr)	18	6
Cost of labour (US$/100 kg)	6	6
Labour productivity (kg/hr)	290	100

ECM kg = Milk kg corrected to 8.5% MS; Stocking rate: 1 Livestock unit = 650 kg LW
Source: IFCN (2011)

The IFCN has specific methods for the calculation of major KPIs. Net farm income (NFI) is obtained by deducting total expenses from total cash income and then making the necessary non-cash adjustments. Milk price is calculated by dividing the milk returns by the total kilograms of ECM sold. The costs calculation for the dairy enterprise consists of the following costs: milk production, raising replacement heifers, and home grown feed production cost and/or cost of feed purchased for dairy cows and replacements. Total costs are composed of expenses included in the profit cash and non-cash costs, including depreciation and opportunity costs for factors of production such as family labour, own land, and own capital. Both returns and total costs are expressed in US$ and per hundred kilograms of Energy Corrected Milk (ECM). Cost of production includes farm working expenses, wages, and debt servicing, but excludes management wages and depreciation. The cost of labour (US$/100 kg milk) is similar in both countries despite the number of labour units being more than three times higher in Chile than in New Zealand. This is explained by labour productivity which is almost three times higher in NZ. These considerable differences in labour units could be afforded in Chile because the average wage was US$ 6 per hour while in NZ this was US$ 18 per hour.

The entrepreneur's profit measures the financial sustainability of the typical farm and shows the total profitability of the dairy enterprise. It is calculated by subtracting the opportunity costs for factors of production as above from the NFI. The return to labour, in turn, indicates how much profit an employee or farmer generates per hour of farm work. It is calculated by adding wages for hired labour and the opportunity costs of family labour to the entrepreneur's profit, and dividing this partial result by the total hours of labour used for the dairy enterprise. It is driven by the wage level of the country, the labour input on the farm, and the economic performance of the farm. Average wages on the farm include the gross salary plus any social costs the employer has to cover. For hired labour, the cash labour costs effectively incurred are used, and for unpaid family labour, the average wage rate which a hired worker would be paid to perform a similar task in the same region is used.

The IFCN also studies the sustainability of dairy farming worldwide. Seven areas, where economic, social and environmental sustainability stand out, are considered. Table 9 presents the areas of importance, their indicators and their sustainability scale numbers (IFCN, 2011).

Table 9

Sustainability Areas and Indicators for Dairy Farms Worldwide

AREA	INDICATOR	UNIT	GOOD	BAD
ECONOMIC	Entrepreneur's profit	US$/100 kg milk ECM	> 1	< -1
RISK	Operating profit margin	%	> 15%	< 12%
COMPETITIVENESS	Return to labour	%	> 110%	< 90%
EMISSIONS	Carbon footprint	g CO2/100 kg milk ECM	0 - 130	> 140
RESOURCE USE	Water footprint	L/kg milk ECM	0 - 1800	> 2000
INTENSIFICATION	Stocking rate	LU/ha	< 1	> 1.2
JOB CREATION	Employees /100 ton of milk	Labour units	>1.1	<0.9

Considering the indicators in Table 9 and the data available in Table 8 the typical NZ farm is in a more risky situation than the Chilean farm. This is mainly due to a lower entrepreneur's profit and higher intensification. Also of interest is noting that among the benchmarks chosen to measure sustainability, many of them are commonly used and of easy quantification.

3. Method.

Farming systems and their available technology are shaped by natural resources; the physical, economic, and social environment; policies; the characteristics of the labour force; and the existing market for potential outputs. Hence, it is expected that farmers in different regions or countries face different production opportunities and make choices from different sets of feasible input-output combinations. This chapter presents the research method used in this study which was in accordance with these concepts that is framed by a systems approach but makes use of predominantly quantitative methods.

3.1 Research Strategy

To answer the research questions posed in this research, a variety of methods were used after reviewing the literature which provided the background to better understand the three dairy databases used in this research. The first part of the study was straightforward and compared two dairy farms from NZ and Chile. The second part of the study required grouping and classifying observations from the country-specific dairy bases. Country-specific classifications for production systems in NZ and Chile were developed on an annual basis for NZ (June-May) and Chile (January-December). After the existing observations were classified into the most appropriate ‘system’ based on the review of supplementary feed and regional information, a comprehensive measure of performance was found for individual observations by applying an efficiency analysis separately to each class. Corresponding efficiency scores were then associated with the DMU in the original data set and a regression method was applied to determine the relative importance of independent variables in determining efficiency in each dataset. Finally, an overall measure of efficiency combining both datasets was calculated for each observation to give the metafrontier for the final comparative analysis.

3.2 Materials and Data Analysis Methods

This section introduces the sources of data and the methods applied to the present study. The International Farm Comparison Network (IFCN) provided data for the farm to farm comparison from its world-wide dataset for 2011. Data was analysed using specific features within the TIPI-CAL 5.3 spread sheet. The country-specific datasets were “*DairyBase*” from NZ and “*TodoagroBase*” from Chile. R statistical software was used to analyse data from these two datasets. Computerised statistical packages such as R are time savers for both quantitative and qualitative research (Patton, 2002). R software was used for the core part of this research, to calculate the efficiency scores and to run the regression that identified the key performance indicators. The R statistical software system for Windows was used because of its versatility and flexibility in undertaking a range of tasks with large datasets, including both statistical and non-statistical analyses. The R codes[12] used rpart and lpSolve packages. The data analysis combined input oriented Data Envelopment Analysis (DEA), followed by Recursive or Regression Partitioning Trees (RPTs), descriptive statistics, and a metafrontier approach, which together provided the means for extracting relevant conclusions from the data available.

3.2.1 *DairyBase* and *TodoagroBase* overview.

Databases typically record historical information through systematic collection and, if required, conversion of quantitative and qualitative observations into numbers or codes. *DairyBase* and *TodoagroBase* are independent data collections of dairy farm data, annually produced at the end of each season or year. These datasets created by industry-owned and private agricultural advisory services in NZ and Chile respectively, were used in this research as secondary data sources. Each year, farm businesses are included on a voluntary basis; therefore, the cooperating units are self-selected rather than a random sample. The information, validated at the time of entering, has been made available for research purposes. Each database contained unbalanced panel data as the total number of participants varied throughout the seasons, years, farming systems, regions, and countries.

DairyBase included information for five consecutive years: 2006/07, 2007/08, 2008/09, 2009/2010, and 2010/11, while *TodoagroBase* comprised information for five consecutive production years: 2007, 2008, 2009, 2010, and 2011. Participants represented diverse locations across NZ’s North and South Islands, and Central-South Chile. The datasets only shared a few common variables but most of those were expressed in different units (for example, milk output was expressed as kilograms of milk solids for *DairyBase* and as litres of milk for *TodoagroBase*). Financial variables and most ratios were often exclusive to one or the other dataset. Shared and unshared variables acquired relevance at the final stage of this study, particularly in the cross-country comparison. For most analyses, the datasets were analysed separately and the original data were preferred; data conversions were only made when necessary.

3.2.1.1 Data quality and limitations.

Data quality and appropriateness are just as important as the analytical techniques themselves because regardless of how powerful a technique may be, it cannot overcome problems that fundamentally reside in the data (Coelli et al., 2005). Inaccuracy of production data, a chronic problem to be aware of, may or may not be evident to the analyst. *A priori*, the quality of the available data was considered high because farmers volunteer their data to the databases, and therefore, have a vested interest in both the collection and the use of accurate data.

[12] The R codes written by Lecturer and PhD in Statistics, Jonathan Godfrey (Statistics and bioinformatics group Massey University) can be found in Appendix 3

DairyBase supplied New Zealand farm-level data consisting of information on more than 200 variables and ratios (Appendix 1). Each observation consists of a set of records; the database originally contained 2,616 sets of financial records and 657 sets of physical observations records throughout the period. A balanced panel would have included the same 523 farms each year and totalled 2,615 observations. However, the dataset was unbalanced, with only 39 farms consistently surveyed every year across the whole period. A similar situation was found among Chilean observations, and although the lack of balance in both databases was acknowledged and managed accordingly, the small proportion of farms present each year was a limitation in this research. This posed the question of how much of the inter-annual variation found was attributable to the relative 'weight' of different farms present each year. Non-random, missing data on *DairyBase* was not a concern because the sets of observations were complete for the variables of interest.

TodoagroBase supplied Chilean farm-level data consisting of information on more than 90 variables and ratios (refer to Appendix 2). The database originally contained 1082 sets of combined financial, economic and physical records for a range of farming systems, from exclusively pasture-based farms to supplement intensive systems feeding up to 4,734 kilograms of supplement per cow per year. After reviewing the literature, a cut-off value of 2,700 kg/cow/year fed was used to define a pasture-based system; this resulted in 1,028 pasture-based cases being available for further study (95% of the original sample). Missing data was a concern when it involved important variables for the dairy enterprise. Missing data was an issue, and included observations on depreciation, and remuneration among others. This was important in calculating ratios or as part of operating expenses. The value of assets was calculated backwards using the original profitability value but this resulted in another issue which was incoherent data. This issue was a concern when involved variables used for the efficiency analysis because implied a lower confidence in the data. Case deletion was applied in a few cases. However, the most drastic measure was complete variable exclusion with the assets, whose calculated value was not used in the main DEA analyses.

In summary, there were a few concerns which prevented the research from reaching fully generalizable conclusions regarding a respective class or farming system. There were two major issues: unbalance and non-randomness in the two datasets. Due to non-random sampling it was uncertain whether the samples were fully representative of the NZ and Chilean pastoral dairy farms populations. The second concern was that presumably, in both NZ and Chile, the samples comprised above-average-managed dairy farms. In NZ, available information showed that the *DairyBase* sample had been above average in indicators of interest. According to Jiang (2012), differences in production have traditionally existed between *DairyBase* farms, and the national statistics. While *DairyBase* samples have traditionally consisted of farms with management and performance above the average, there has not been a big difference in the direction and magnitude of the bias between regions. Therefore, since a large sample does not necessarily prevent bias (Hawley, 2010) efficiency estimates and other outcomes should be interpreted with care as they may not reflect the true situation in the respective farming systems.

3.2.2 Review of methods.

Quantitative research permits the diagnosis of historical and current situations, and developing trends (Taylor, 2005). In order to achieve the objectives of this research, this study used a combination of predominantly quantitative methods, both parametric (descriptive statistics) and non-parametric, enabling valid, objective descriptions and conclusions. This section describes the data envelopment analysis models, the recursive partitioning technique, and the metafrontier approach in the order in which they were applied.

3.2.2.1 DEA models.

DEA owes its name to the way the frontier envelops observations, which are typically represented by a performance score that ranges between zero and one (Cooper, Seiford, & Tone, 2006). In DEA terminology, all observations are so-called decision making units or DMUs. The envelopment identifies those efficient DMUs (those with a score=1) and locates them on the frontier; in that way they serve as benchmarks to rank all the inefficient DMUs. The term 'frontier' is used to emphasise the fact that the function gives the maximum output that is technologically feasible. The maximum value of one means that the DMU has achieved maximum output with minimum expendable inputs or resources; in contrast, a minimum of zero means nothing is achieved by using certain inputs (which is hard to find in practice). DEA uses mathematical optimisation or linear programming (LP) to calculate efficiency scores, based on one or more outputs and commonly utilises multiple inputs.

DEA can operate on either input or output orientation, but both models estimate the same frontier, identifying exactly the same set of DMU's as being efficient (Farrel, 1957). In contrast, the efficiency scores associated with inefficient DMU's may differ between the two methods (Coelli, 1997). The frontier may also be determined assuming a transformation of inputs into outputs under constant returns to scale (CRS) proposed by Charnes et al. (1978), or variable returns to scale (VRS) reported and explained by Banker, Charnes and Cooper (1984) and later by Fare, Grosskopf, and Lovell, (1994). Under the latter assumption, decreasing (DRS) and increasing returns to scale (IRS) may occur. DRS takes place when an increase in inputs results in a less than proportional increase in output; conversely, IRS happens when increased inputs lead to a greater than proportional increase in output. In this research, DEA models were set up to use VRS and an input-oriented approach. The use of VRS is customary in agriculture and commonly preferred in related studies. The input orientation was used in this study since a manager has greater control over inputs than over outputs, which are influenced by external factors such as climate and prices.

The selection of Regression Partitioning Tree as the best possible method to use in a second stage DEA was the end result of an iterative process that started looking at linear models. After reviewing the literature, linear models were chosen as it was necessary to incorporate multiple predictors to predict efficiency and the Gauss-Malcom theory behind them is robust and well understood (Hazelton, pers. com.). The multi-dimensionality in the dataset required a method capable of handling several parameters; therefore, multiple linear regression (MLR) was tested to regress efficiency scores attached to the original sets of observations previously cleaned of trivial variables. The NZ dataset was used to test the parametric model (MLR) behaviour, which was set up to capture main effects and also interactions which were considered unavoidable. After a primary cleaning of trivial variables, the number of variables was still large (81) and hence MLR failed to achieve the expectations. According to Strobl, Malley, and Tutz (2009), standard regression methods commonly fail in these conditions and recursive partitioning trees are an alternative approach.

3.2.2.2 Regression or Recursive partitioning tree.

Regression partitioning is a technique that produces either classification or regression trees, depending on whether the dependent variable is categorical or numeric, respectively (Strobl et al., 2009). In this study DEA efficiency scores were used as the response variable in a second stage approach, to find the best summary set of indicators that explains a dairy system's performance. Since the databases provided many more variables than were required to build such a set, and following the principle of parsimony, an effective reduction of the multidimensionality of the datasets was pursued. In a second stage RPT, DEA scores from the first stage were regressed on discretionary and non-discretionary inputs in a country-specific but common-to-all-groups analysis. This approach not only generated a ranking of variables, but also revealed the interaction between independent variables, which it was not possible to do with other forms of multivariate analysis (Curran et al., 1993).

RPT generates a flow-chart structure or tree which has a root node, secondary and tertiary nodes and so on, and finally terminal nodes called leaves. Trees reveal the variables' ranking of importance with the root node representing the top level indicator. Each node provided information on the splitting criteria (variable's name) and the threshold value above or below which a class is defined. Each leaf presents the class's mean efficiency, and the number of DMUs included (n). To reach a leaf node, the pathway starts at the root node. From each non-leaf node the procedure splits the data to the left, or to the right, based on the condition and value of a certain variable, whose index is stored in the observed node. If the observed value satisfies the condition, the procedure goes to the left, otherwise, to the right.

The partition is created such that observations with similar efficiency values are grouped by a set of rules. Once a rule is selected and splits a node into two, the same process is applied to each "child" node which is why RPT is called a recursive procedure (Witten & Frank, 2000). In general, splitting and stopping follow the principle of impurity reduction, whereby each split results in a child node which is more pure than the parent node. In each node, the variable that is most strongly associated with the response variable (*y)* is selected for the next split (Strobl et al., 2009). Finally, a response class is predicted in each terminal node of the tree (leaf or class). Splitting stops when the software detects that no further gain can be made, or some pre-set stopping rules are met. In this research at each node the recursive procedure stopped splitting the node further in any of the following cases:

1. The number of observations in the node was less than the specified value (n = 50);
2. All the samples in the node belonged to the same class (or, in the case of regression, the variation was too small), because it was not statistically possible to split the node further; or
3. The best split found did not give any noticeable improvement compared to a random choice.

The pathway to any particular leaf showed the main effects and the interactions between variables. The RPT operates as a reduction, classification, and prediction tool for observations meeting certain set of rules. A key property of this technique is that it is possible to compute the importance or relative decisive power of each participating variable (Strobl et al., 2009). A variable may be present more than once, and this only reinforces its importance. To avoid the analytical or the prediction procedure getting stuck in a certain node, the technique also provides so-called surrogate splits, in addition to the best 'primary' split (Strobl et al., 2009). These surrogate splits can be used for observations with incomplete records and yield nearly the same results as the primary splits. If a farm fulfils all the node or partitioning conditions on a particular pathway, then it is likely with 95% of confidence that its efficiency will be mean efficiency at leaf +/- deviance.

In summary, RPTs were expected to identify important benchmarks or indicators defining efficiency classes and also to present a number of pivotal values to expose the pathway or combination of conditions useful to predict technical efficiency. These pivotal values were the thresholds indicating a single feature, which may split the dataset such that the variance of subsamples in each partition is less than their variance in the whole dataset. The pathway from the root to a leaf node was a sequence of decision-making steps, and the leaf node function was evaluated to provide a numerical prediction of the averaged value of efficiency for each leaf.

3.2.2.3 Metafrontier envelope.

The measurement of efficiency across groups is only possible if efficiency is measured relative to a common metafrontier which is the boundary of a metatechnology or unrestricted technology that envelops the restricted group frontiers (Battese & Prasada Rao, 2002; O'Donnell et al. 2008). This study used a metafrontier to compare dairy farm efficiencies in NZ and Chile. By definition, a metafrontier envelops all farms and all group frontiers. In this research, the main reason for using a metafrontier envelope was to provide comparable efficiency scores for businesses operating in different environments existing either across seasons, regions and countries. The metafrontier also enabled the technology gaps to be estimated for firms under different technologies, relative to the potential technology available to the industry as a whole (Battese, Prasada Rao & O'Donnell, 2004). *A priori*, the mean technical efficiencies relative to the metafrontier are always expected to be smaller than those calculated from the group frontiers. The difference between the group scores (*E1*) and the metafrontier scores (*E2*) represented the restrictive nature of the particular environment. There is a gap between a farm and the group frontier, which represents the differences in performance between the efficient farms (TE = 1) and the particular DMU, and is called 'd'. Then, there is another gap 'e' between this DMU and the metafrontier. Both indicators may be used to calculate the metatechnology ratio as the relationship d/e (Battese & Prasada Rao, 2002; O'Donnell et al. 2008). This ratio is of considerable interest because it measures the potential improvement in performance resulting from changes in the production environment.

3.2.3 Procedure: the data analysis.

The data analysis comprised five key stages including sampling, grouping, efficiency analysis, RPT, metafrontier, and benchmarking. The procedure in more detail is presented in chronological order as follows:

1. Analysing IFCN data relevant to the countries of interest, NZ and Chile;
2. Developing a classification system for each country's data which yielded 27 NZ and 10 Chilean classes using a combination of season/year, region and supplements use;
3. Running the DEA (VRS) separately for each class which created a DEA score for each observation so that the multiple effects of season/year, region and system were minimised in the complete data set for that country;
4. Obtaining DEA scores (0-1) for each observation within each class and adding these scores to the original databases;

5. Testing stepwise MLR using DEA scores as response variables with all non-trivial variables contained in the datasets as predictors;
6. Looking for alternatives to MLR, which was discarded due to the high dimensionality of the dataset plus multi-collinearity[13] and missing data issues;
7. Substituting MLR with RPT in the second stage, using efficiency scores as the response and input variables as predictors;
8. Identifying country-specific sets of major KPIs for NZ and Chile based on RPT outputs;
9. Describing the samples using descriptive statistics on the identified KPIs;
10. Standardising the output and input variables to be used on the metafrontier envelop to a common currency when necessary; then running the VRS DEA code in R on the combined NZ-Chilean data using these variables.
11. Summarising the differences between farming systems, within, and between countries, using selected variables with the highest explanatory power, and the metafrontier scores.

3.2.3.1 Sampling.

Since the research is based on existing datasets, this section actually refers to the original and final configuration of the samples after cleaning the data. The samples in the databases consisted of dairy farms across the countries over five agricultural years, where the sampling unit was the dairying enterprise. The original number of observations contained in the NZ and Chilean datasets for each season is shown in Table 10.

[13] This is a term commonly applied to the statistical phenomenon in which two or more predictor variables are highly correlated. In this situation the coefficient estimates may change erratically in response to small changes in the model or the data (Adler & Golany, 2001).

Table 10

Original NZ and Chilean Samples

Season	DairyBase	TodoagroBase
2006/07	625	259
2007/08	628	245
2008/09	497	237
2009/10	567	205
2010/11	297	135
Period	2614	1081

The NZ data were allocated to eight NZ regions based on the *DairyBase* clustering criterion. The number of observations for the period 2006-11 is shown in brackets for each region from the top of the North Island to the bottom of the South Island as follows: Northland (268), Waikato (864), Bay of plenty (215), Taranaki (292), Lower North Island (182), West Coast-Tasman (226), Marlborough-Canterbury (324), and Otago-Southland (243). Waikato farms represented 33% of the original sample, which shows the importance of this region to the NZ dairy industry. Similarly, the southern central dairy territory in Chile consisted of five agro-ecological zones: Llano Central Sur (404), Ribera de Los Lagos (308), Litoral Sur (82), IX Sur and XIV Norte (221), and Los Angeles-Angol (66). The first two regions comprised more than 66% of the total data, thus demonstrating their significance to the Chilean dairy industry.

Observations were excluded from the raw data for the following reasons:

- Business structure other than owner operators (NZ data only);
- Extreme outlier data;
- Important missing data that could not be inferred or interpolated;
- Incoherent data (Chilean data only); and
- Systems other than pasture-based, that is using above 2700[14] kg supplement per cow per year (Chilean data only).

Only data for owner operators were analysed in the NZ data to attain a homogeneous possible sample which was representative of this type of business which is the most prevalent business

[14] Equivalent to 45% of the diet based on supplements (year round).

structure in NZ. Table 11 shows the number of observations included in the analysis at the end of this cleaning process.

Table 11

Number of DMUs Included in the Analysis per Year and Country

Season	DairyBase	TodoagroBase
2006/07	619	245
2007/08	614	231
2008/09	496	231
2009/10	564	197
2010/11	295	125
Period	2588	1029

3.2.3.2 Variable correction and creation.

For the purpose of this study, it was appropriate to adjust the variables for inflation that occurred throughout the period even though inflation rates for the period were negligible in both countries. Since *TodoagroBase* provided Consumer Price Index (CPI) corrected values for the year 2011, variable correction was only needed for the NZ dataset and it was carried out using the same criterion to be equivalent to the Chilean index[15] and an appropriate CPI coefficient for each year published by Statistics New Zealand (2012). The general CPI for the 'all groups' index was selected. The available price deflators were as follows: 20060/07 (1.119); 2007/08 (1.067); 2008/09 (1.065); 2009/10 (1.055); and 2010/11 (1).

The next step was to check *TodoagroBase* and to decide which variables in the NZ data should, and could, be created based on the available information. The following set of variables was created:

- Farm Working Expenses (FWE) and ratios (FWE/cow; FWE/ha);

- Operating Expenses (OpEx) and ratios (OpEx/cow; OpEx/ha);

- Operating Profit (OpProfit) and ratios (OpProfit/cow; OpProfit/ha);

[15] A more correct adjustment would have been to use the dairy Producers Price Index as the adjuster which shows that on-farm inflation on dairy farms over the period was generally higher than measured by the CPI, and hence using the CPI under-deflated the figures.

- Milk price:Feed price ratio;

- Operating Profit margin (OPM);

- Cash Operating surplus;

- Discretionary Cash + Tax;

- Total Assets; and

- Asset Turnover ratio.

3.2.3.3 The NZ classification system.

Battese et al. (2004) pointed out that farms operating in different regions or under different technologies are not strictly comparable unless a special methodology is used to analyse the data. However, in such cases, the observations can be grouped according to similarities and differences in technology, and other conditions among the nominated periods or regions (Haghiri, Nolan, & Tran, 2004). For instance, the seasons 2007/08 and 2010/11 both had exceptionally high milk prices as shown in Table 12.

Table 12

Estimated Seasonal Prices for Output (MS)

	Estimated price (NZ$)	
Season	Milk ($/kgMS)	% Average
2006/07	4.15	0.69
2007/08	7.36	1.22
2008/09	5.22	0.86
2009/10	6.16	1.02
2010/11	7.36	1.22
Period	6.05	1.00

The physical information contained in *DairyBase* also suggested that farmers responded to price information by feeding more supplements to the herd in higher milk price years, which led to farming systems shifting towards greater use of imported feed. Physical input was also used to improve the understanding about dairy farming systems in the different regions. The most feed-intensive region in NZ, measured as supplement imported per hectare, was found to be Canterbury, followed by the Lower North Island and Waikato regions. The least intensive region was Tasman-West Coast, closely followed by Northland and Taranaki, which are the regions with the highest rainfall averages. The Dairy NZ Farming systems (reviewed in Chapter II) in the NZ dataset had a mean of 2.9 and a median of 3, with the most representative regions being Bay of Plenty and Southland. The use of imported feed was positively associated with stocking rate, measured as both Cows/ha and LWT/ha. The correlation was significant at the 1% Pearson coefficient, so is moderately high in both cases (0.629 and 0.642 respectively). In the period under study (June 2006 to May 2011), farming systems were characterized by quite distinctive indicators, as presented in Table 13.

Table 13

Averaged Indicators Showing the Relevance of Grouping into Farming System

	Farming system				
Indicator	1	2	3	4	5
Rainfall (mm)	1764	1766	1301	1346	1187
Nitrogen (kg/ha)	70	116	202	169	169
Hay (%)	20	17	13	11	7
Supplement (ton/ha)	0.23	0.71	1.45	3.19	5.44
Pasture&Crop (ton/ha)	10.69	11.31	12.1	12.79	13.61
MS/FTE	45811	48670	53997	60045	62570

The clear rainfall gradient shows that the volume of rain is negatively associated with the use of imported feed, and hence, the farming system in place. In contrast, the farming system is associated positively with the use of nitrogen (kg/ha) and feed grown (ton/ha), as well as with production of milk solids per unit of labour (kgMS/FTE). These findings supported the need to recognise the year and region effects, as well as their interactions with use of imported feed. Therefore, the samples were grouped by year and then classified into several sub-samples representing location and farming system, ensuring as much homogeneity of exogenous conditions as possible within sample group.

There was an iterative process that guided the classification systems in both countries. In order to decide on the best categorization system for existing differences in technology across NZ, the three approaches to nesting were evaluated: *Regional* consisting of regions (8) across five years and five DairyNZ farming systems; *Seasonal* consisting of years across region and systems; and *Farming systems* regardless of year or region. Three intensification levels (IL) were made by re-coding DairyNZ farming systems so that farming systems 1 and 2 composed LOW, 3 represented MEDIUM, while 4 and 5 composed HIGH intensification levels. After the evaluation process, observations contained in *DairyBase* were classified according to year of record, region and intensification level. The classification process is partially explained in this chapter and complemented by information contained in Appendix 4. Finally, the NZ classification system consisted of 27 classes (Table 14), with half of them being a combination of year, region, and farming system, and the other half, a combination of year and region. The latter can be observed for those classes where the number of observations did not allow for a further split at the intensification level criterion. The NZ classification system is presented in Table 14.

A priori, concerns regarding all the mentioned classification systems were identified. One concern when categorising by year was whether or not the underlying technology changes over time in a relatively short period. It was found that some particularly responsive variables showed both intra- and inter-annual variation. These variables included: input and output prices, pasture growth, use of imported feed, and rainfall, which were highly variable between seasons. A second concern was that the dataset was unbalanced with only 39 firms present across all seasons, which prevented a fully meaningful comparison between seasons. Similarly, issues around categorisation by Dairy NZ farming systems were recognised. Previous empirical work had shown little or non-significant differences between systems in efficiency, which were explained by greater variation in intra- than in inter-feeding systems. In addition, other factors were prone to affect the farming system, meaning that a variety of technologies could be represented by the same feeding system. Also, there were difficulties when categorising by region alone because of large intra-region variability.

Table 14

NZ Classification System

Season	Class (code)	Regions	Farming Systems
2006-07	67 16	Northland-TasmanWestCoast	All
	67 78	Canterbury-Otago	All
	67 2345LOW	Bay of Plenty, Waikato, Taranaki, Lower NI	1 and 2
	67 2345MEDIUM	Bay of Plenty, Waikato, Taranaki, Lower NI	3
	67 2345HIGH	Bay of Plenty, Waikato, Taranaki, Lower NI	4 and 5
2007-08	78 16	Northland-TasmanWestCoast	All
	78 7	Canterbury	All
	78 8	Otago	All
	78 2345 LOW	Bay of Plenty, Waikato, Taranaki, Lower NI	1 and 2
	78 2345MEDIUM	Bay of Plenty, Waikato, Taranaki, Lower NI	3
	78 2345HIGH	Bay of Plenty, Waikato, Taranaki, Lower NI	4 and 5
2008-09	89 16	Northland-TasmanWestCoast	All
	89 78	Canterbury-Otago	All
	89 2345 LOW	Bay of Plenty, Waikato, Taranaki, Lower NI	1 and 2
	89 2345 MEDIUM	Bay of Plenty, Waikato, Taranaki, Lower NI	3
	89 2345 HIGH	Bay of Plenty, Waikato, Taranaki, Lower NI	4 and 5
2009-10	910 16	Northland-TasmanWestCoast	All
	910 7	Canterbury	All
	910 8	Otago	All
	910 2345LOW	Bay of Plenty, Waikato, Taranaki, Lower NI	1 and 2
	910 2345MEDIUM	Bay of Plenty, Waikato, Taranaki, Lower NI	3
	910 2345HIGH	Bay of Plenty, Waikato, Taranaki, Lower NI	4 and 5
2010-11	1011 16	Northland-TasmanWestCoast	All
	1011 78	Canterbury-Otago	All
	1011 2345LOW	Bay of Plenty, Waikato, Taranaki, Lower NI	1 and 2
	1011 2345MEDIUM	Bay of Plenty, Waikato, Taranaki, Lower NI	3
	1011 2345HIGH	Bay of Plenty, Waikato, Taranaki, Lower NI	4 and 5

The final combined classification approach was useful in overcoming the heterogeneity faults in the dataset as shown in Figure 7 for total operating expenses (NZ$ thousands).

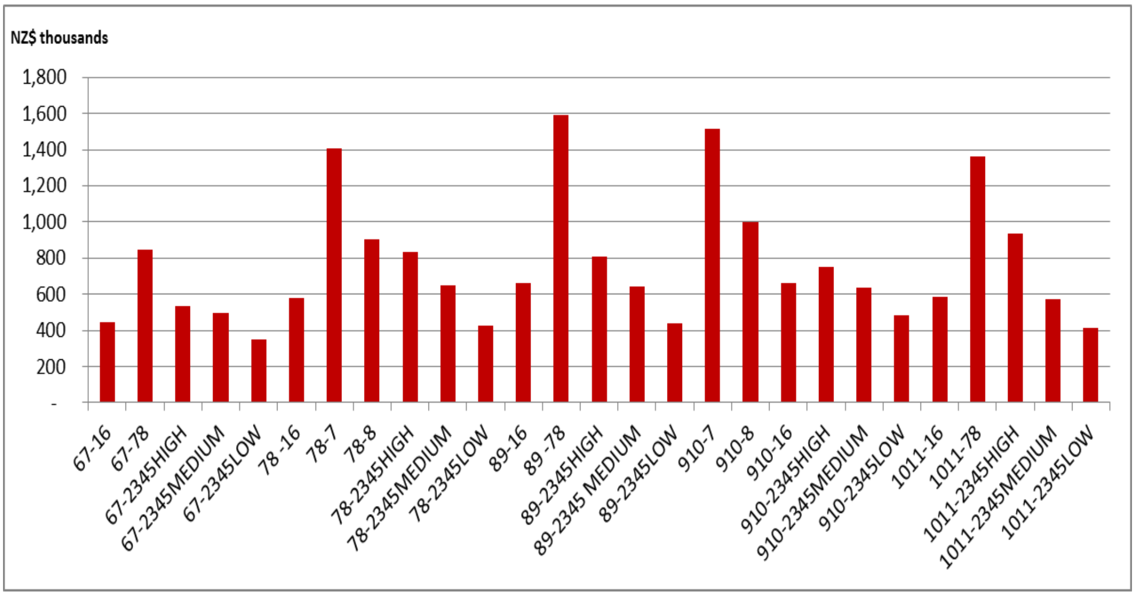

Figure 7: Averaged farm operating expenses within NZ classes.

As Figure 7 shows there was huge variability across classes. The greatest variability was found when comparing across regions, especially when Canterbury (region 7) and Southland (region 8) are taken into account. The year effect was also evident with operating expenses increasing steadily from 2006/07 to 2008/09, then stabilising in 2009/10 and decreasing slightly in 2010/11. The classification system normalised these and other effects, such as asset value and land quality (refer to Appendix 4). However, it was still complex, comprising 27 combinations of year, region, and intensification level. By performing DEA for each of these combinations separately, this study recognised differences in the environment (year effect), and farm specific characteristics related to region and intensification level. This provides more relevant efficiency estimators as farms are scored only with respect to their peers.

3.2.3.4 The Chilean classification system.

A similar approach categorizing by year and farming systems to give a comparable classification system was used for the Chilean grouping criteria. Observations contained in *TodoagroBase* were grouped into a classification system based on a combination of year and use of supplement per cow. This combined approach was similar to that used for NZ but was restricted by sample size, and thus, could not discriminate by regions. However, it was considered appropriate and sufficient for the Chilean dataset. Two intensification levels (MEDIUM and HIGH) were drawn by grouping according to the use of supplements looking at the variable ‘Supplement kg/Cow’. The critical value for MEDIUM was below 2000 kg/cow/year fed which was arbitrarily selected to generate classes of similar size. The final classification system is presented in Table 15.

Table 15

Chilean Classification system

Year	Class (code)	Regions	Farming Systems
2007	2007 MEDIUM	All	3 and 4
	2007 HIGH	All	5 or more
2008	2008 MEDIUM	All	3 and 4
	2008 HIGH	All	5 or more
2009	2009 MEDIUM	All	3 and 4
	2009 HIGH	All	5 or more
2010	2010 MEDIUM	All	3 and 4
	2010 HIGH	All	5 or more
2011	2011 MEDIUM	All	3 and 4
	2011 HIGH	All	5 or more

3.2.3.5 Class-specific input oriented DEA.

After developing these classification systems, each country-specific class was analysed to calculate efficiencies using input oriented DEA. All input and output variables were read by a DEA code in R software**.** This code allowed for CRS, VRS, or both models to be run and efficiency scores to be calculated in any of the mentioned model orientations. However, in this study, only VRS was used. The first step to set up for DEA is to classify variables as inputs or outputs, such that input variables are causal factors to the outputs. DEA assumes precise knowledge regarding which variables are outputs and inputs. The output selection were straightforward: the milk physical production indicators, expressed as kilograms of milk solids in NZ or litres of milk in Chile, and the financial indicator gross farm revenue were used separately in a single-output approach. These outputs were user-defined and were used so that each of them captured different effects.

Input variables were classified into controllable and non-controllable variables. The selection of inputs used is very important in efficiency studies and therefore, variables were selected with care. First, DEA input variables were selected from the sub-set of controllable variables and, second, they were consistent with the phenomena they were supposed to capture, for example milk production in the physical analyses (using either milksolids or litres depending on the country). Several inputs were meaningful from a productive standpoint, but some were omitted following the principle of parsimony and to avoid multi-collinearity[16]. The first principle, also called simplicity, states that large numbers of variables in DEA may lead to over-estimation of relative efficiency (Adler & Golany, 2001). In this study, the ratio between numbers of DMUs and total inputs plus outputs was kept much higher than 3:1 which, according to Bowlin (1998) and Rouse et al. (2010), ensures reliability of the results. Golany and Roll (1989) state that the number of DMUs should be at least twice the number of inputs and outputs considered and Dyson et al. (2001) recommend a total of two times the product of the number of input and output variables. These conditions were met in this study and all finally selected inputs were standard production factors including capital, labour, operating costs and cows as presented in Tables 16.

Table 16

Inputs Included in the Output DEA Models by Country

NEW ZEALAND	CHILE
Cows (peak number of cows milked)	Cows (mass cow; all cows on farm)
Labour (FTE*)	Supplement (kg/cow)
Operating Expenses (NZ$)	Wages paid (CLP $)
Opening Equity (NZ$)	Operating Expenses (CLP $)
Opening Liabilities (NZ$)	

*Full time paid and unpaid labour Equivalents: 1=2,400 hours of work a year

The variables presented in Table 16 were selected because they represent different aspects of the farming systems. Capital is a standard candidate variable in farming that typically includes land, livestock, buildings and plant. It may be represented by equity plus liabilities, as was done for NZ, or by the sum of various assets, as could have been done for Chile if data was more

[16] Inputs that correlate highly with one another were eliminated based on correlation analysis.

reliable. However, incoherent data made impossible the inclusion of assets as a DEA input in the Chilean model. Labour was another primary input included in both country's analyses, but expressed differently in NZ and Chile. In NZ, it was a single physical variable which aggregated paid and non-paid labour and management in full time equivalents (FTE). In Chile, it was expressed in monetary terms due to the lack of a physical indicator, and only accounted for paid labour; therefore, unpaid labour and management were not reflected on this measure. Both, the labour and the supplement variables did not reflect quality of the input in any way because de databases did not contain information on these regards.

3.2.3.5 Recursive Partitioning Trees fitting and KPI selection.

Both the milk and revenue efficiency scores obtained in the DEA stage were subsequently used in a series of country-specific RP Trees as the response variable *y*. The same procedure was followed separately with both, the *DairyBase* and the *TodoagroBase* datasets. First, a milk efficiency *y1* and a revenue efficiency *y2* were attached to the original datasets. All the variables available in the respective datasets were used as predictor variables. The first and second RPTs used DEA scores based on the physical output milk (kg of milk solids or litres depending on the country). Tree one regressed DEA estimates on all existing variables, including discretionary and non-discretionary inputs and ratios, in a common-to-all-groups second stage which involved all DMUs. Tree two was subsequently carried out after all milk-related ratios were removed (for example MS/cow, MS/FTE, MS/ha; Milk fat/cow, Protein/cow, Milk L/cow, L/ha). The third and fourth trees used DEA scores based on the economic output GFR. Tree three included all the dataset's existing variables, while tree four used all the same variables but was carried out after all efficient farms (DEA score = 1) were removed from the dataset. The reason for this was to increase the discriminant power in the analysis and uncover potentially new variables that had not been revealed by tree number three.

Two more trees, one per each country are presented in the respective sections and called 'the fifth tree'. These were used to fullfill different requeriments in both countries. The fifth NZ tree included all existing variables in *DairyBase* and used return on assets as the response variable to show what could be done without DEA by using a major variable instead of efficiency as *y*. The fifth Chilean tree included backward calculated assets to evaluate what could have been done and found with better quality information in *TodoagroBase*.

3.2.3.6 Benchmarks sets.

After running the R codes, a series of trees were available for interpretation and they revealed those benchmarks used for further analysis in this study. Only the roots, plus the second and third level splits in the multiple trees provided enough benchmarks, which were grouped in two sets: NZ-specific KPIs and Chile-specific KPIs. No common KPIs were primarily identified.

The sets included well known KPIs for each country and were used for intra-country comparisons.

The benchmark sets were expected to provide answers to the research questions and were used to analyse each database, provided that they were selected as the best possible measures of performance for dairy farming systems in each country. Instead of analysing the pooled samples, the datasets were split based on the efficiency scores gained in the first stage of DEA. All efficient farms (DEA scores = 1) overlapping in both milk and revenue efficiency analyses, were set apart. The NZ group consisted of 644 DMUs while doubly efficient DMUs in Chile were 276. In both countries these figures were roughly equivalent to one quarter of the analysed total observations. In addition two other groups were of interest. A second class was drawn from the efficient group by ordering the database using farm ID and setting apart the farms efficient three or more years. For obvious reasons all those efficient farms that were not present in the survey for at least three years were not part of this group. Finally, a third class comprised only the inefficient DMUs (DEA score < 1), or more precisely all those DMUs that were not able to be ‘milk’ and ‘revenue’ efficient simultaneusly.This was just a criterion and it is acknowledged here that things could have been done differently, for example, by relaxing the cut-off value and considering efficient those virtually efficient observations with score > 0.95.

In NZ, the group of farms efficient three or more years was reduced to 41, represented by 142 observations which were only 5.5% of the sample. In Chile, the proportion was larger, increasing to 7.4% with 76 observations and less than 20 farms. In both countries, these farms were actually consistent in their efficiency score and, therefore, called the group of resilient farms. All three groups (inefficient, efficient, resilient) were analysed in depth and compared looking at the KPIs revealed by the RPTs. The comparisons were made by means of one-way ANOVA and Schaffe significance tests.

3.2.3.7 Metafrontier analysis.

The metafrontier approach was capable of investigating whether variations in technical efficiency responded solely to technical limitations or whether differences in technology contributed to some extent to the alleged inefficiency (Battese et al., 2004). Metafrontier is the boundary of an unrestricted technology that envelops the restricted group frontiers (Battese & Rao, 2002); therefore, instead of relying on separate frontiers for each class within countries, technical efficiency was estimated in respect to a common frontier (Moreira & Bravo-Ureta, 2010). The relative efficiency scores across regions and countries were estimated by means of a common metafrontier. The overarching metafrontier was achieved through linear optimisation as for DEA and by pooling all the data under the same set of output (GFR) and input (cows, supplement kg/cow, wages, and operating expenses other than wages) combinations (Battese et al., 2004). Data from both databases needed to be modified in order to obtain comparable inputs and outputs to be used in the models. For instance, to allow for differences in milk solids content, variable standardisation was needed but there was not enough information to use the IFCN method for energy corrected milk (ECM) (IFCN, 2012), which could still have been used by making several assumptions. Finally, GFR was preferred over the physical output milk because its transformation to US$ was straightforward and it is also a standard practice when comparing across countries. The same procedure, using an annualised exchange rate and CPI indexes was repeated for all input and output variables of interest.

4. International Farm Comparison Network Results.

This section presents information on NZ and Chilean dairy farming systems extracted from the database developed by the International Farm Comparison Network (IFCN)[17]. In 2011, the database comprised information from 171 farms from 61 regions and 51 countries, representing 90% of the world's total milk production. Data from this secondary data source was used to compare one typical pasture-based dairy farm in NZ with a typical dairy farm from Chile; since only key findings are highlighted the reader is directed to Appendix 5 for more detailed information. This Chapter sets the scene for the general discussion in Chapter VIII.

4.1 Typical NZ and Chilean Dairy Farms Comparison

The typical NZ farm had a herd size of 348 cows, a forage area of 120 hectares, and a stocking rate of 3.3 livestock units per hectare (LU/ha), whereas the typical Chilean farm had 421 cows, a forage area of 520 ha, and a stocking rate of 1 LU/ha. The typical NZ farm had a production per cow of 4,300 kg of energy corrected milk (ECM) and a land productivity of 12,000 kg ECM per hectare whereas the typical Chilean farm produced 9,300 kg ECM per cow and 8,000 kg ECM/ha. Figures 8 and 9 show different indicators in comparing the behaviour of these farms and their positioning relative to typical farms analysed in 2011 for all countries. The world mean is represented by the value at 0%; a value greater than the mean will compare positively (to the right), while a value below the world mean will compare negatively (to the left).

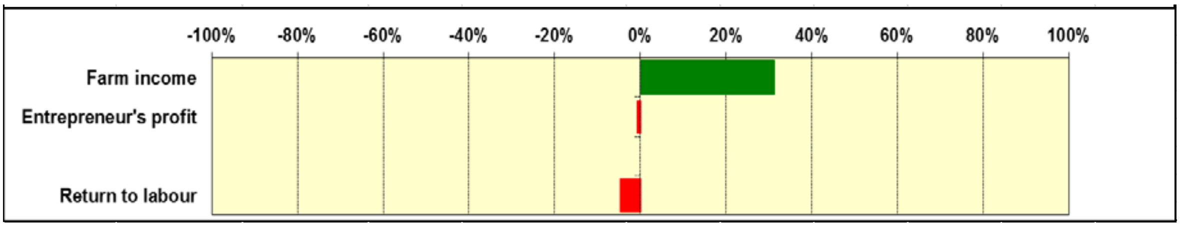

Figure 8: Economic performance of the typical NZ farm relative to the world's average.

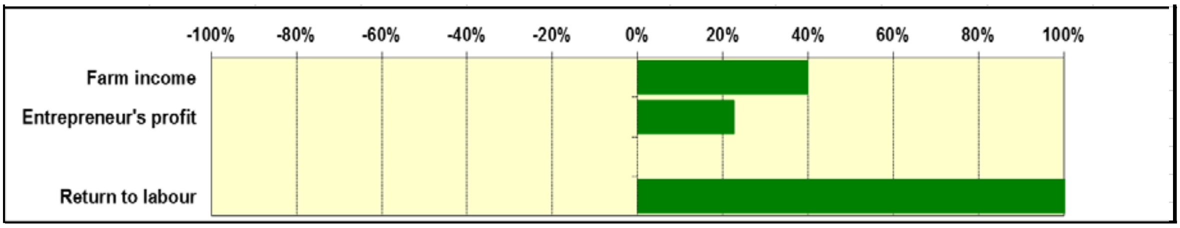

Figure 9: Economic performance of the typical Chilean farm relative to the world's average.

[17] Information on this organisation and its particular TIPI-CAL approach was presented in Chapter II. Two typical farms from traditional pasture-based dairy regions in both countries were selected from the IFCN sample.

Figure 8 shows that only farm income was positive for the typical NZ farm; in contrast, all indicators were positive for the typical Chilean farm (Figure 9)[18]. The farm income reflects the total revenue left after all expenses including rent and interest have been paid, and non-cash adjustments (depreciations) have been made. The entrepreneur's profit and the farm income relate to milk price, while return to labour relates to the regional level of wages. The entrepreneur's profit was calculated by subtracting the opportunity costs of farm owned factors from the FI. The NZ farm income was US$161,400, which is about 30% above the world mean, while the Chilean farm income was US$552,3000, which is about 40% above the world's mean. This indicator is driven by milk price and farm productivity. In NZ milk price is lower than in Chile, but similar in the fact that in both countries it is lower than the world mean. Therefore, differences are mainly explained by land productivity and farm size.

Entrepreneur's profits were markedly different, being US$-4,5000 in NZ and US$312,600 thousands in Chile. Also of interest are the returns on investment calculated using the market values on all assets, this was 4% for the typical NZ farm and 9% for the Chilean farm. The differences in return to labour between the typical farms from NZ and Chile were even more noticeable. The return to labour indicates how much profit an employee, or farmer, generates per hour of work on the farm and is calculated by adding wages for hired labour and opportunity costs for family labour to Entrepreneur's profit, and dividing this partial result by total hours of labour used for the dairy enterprise. It is driven by the wage level of the country, the labour input on the farm and the economic performance of farm. The return to labour was negative for the typical NZ farm, while the typical Chilean farm had a very high positive value. Note that the return to labour positions the typical farm relative to the world sample and to their own local peers, since it uses the national wages to build a ratio. Also of interest is that the average wage on the typical Chilean farm was US$ 5.9 per hour and on the typical NZ farm the average wage was US$ 17.64 per hour.

Figure 10 and 11 provide some explanations for these differences. The NZ and Chilean strong and weak profile respectively, compared to the world's average, again represented by the 0% position. The slim vertical lines indicate the bounds where the particular farm is compared to the IFCN distribution (weakest 10%, weakest 25%, strongest 10% and strongest 25%). The returns profile is presented on top, the profitability indicators are at the bottom, and the costs profile is in between.

[18] Note that, as explained in Chapter II, all indicators, farm income (FI), entrepreneur's profit and return to labour, are relative to their local prices.

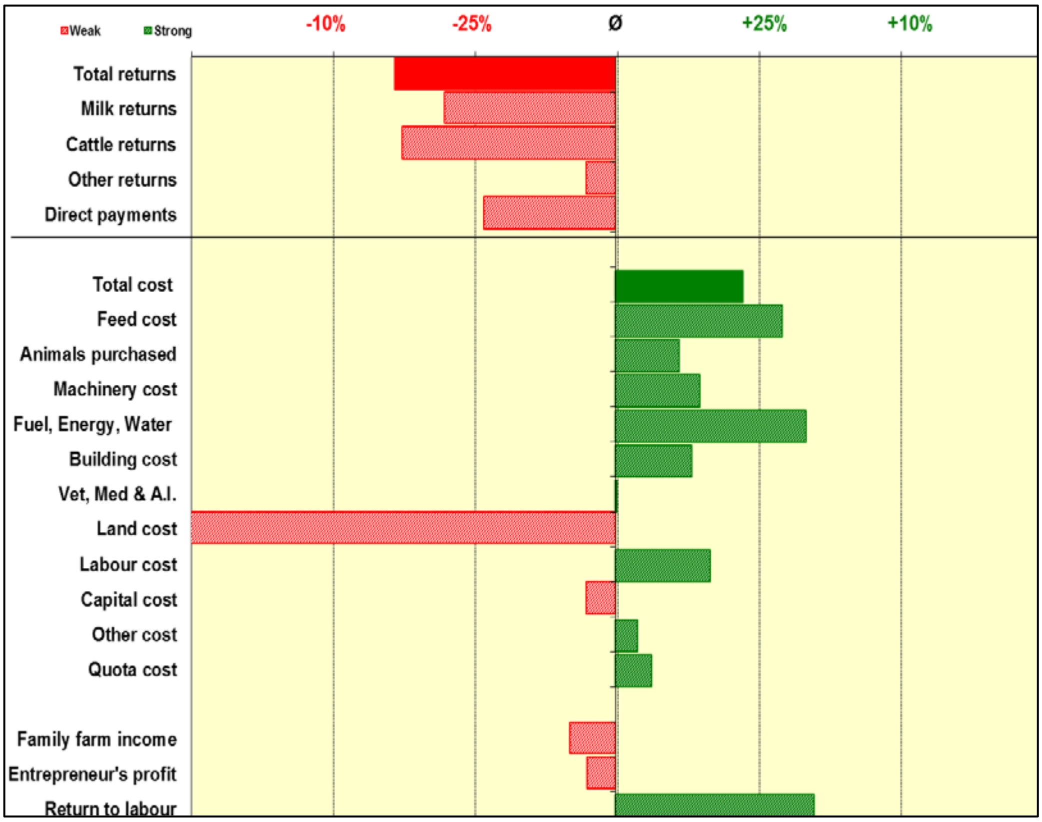

Figure 10: NZ strong and weak profile.

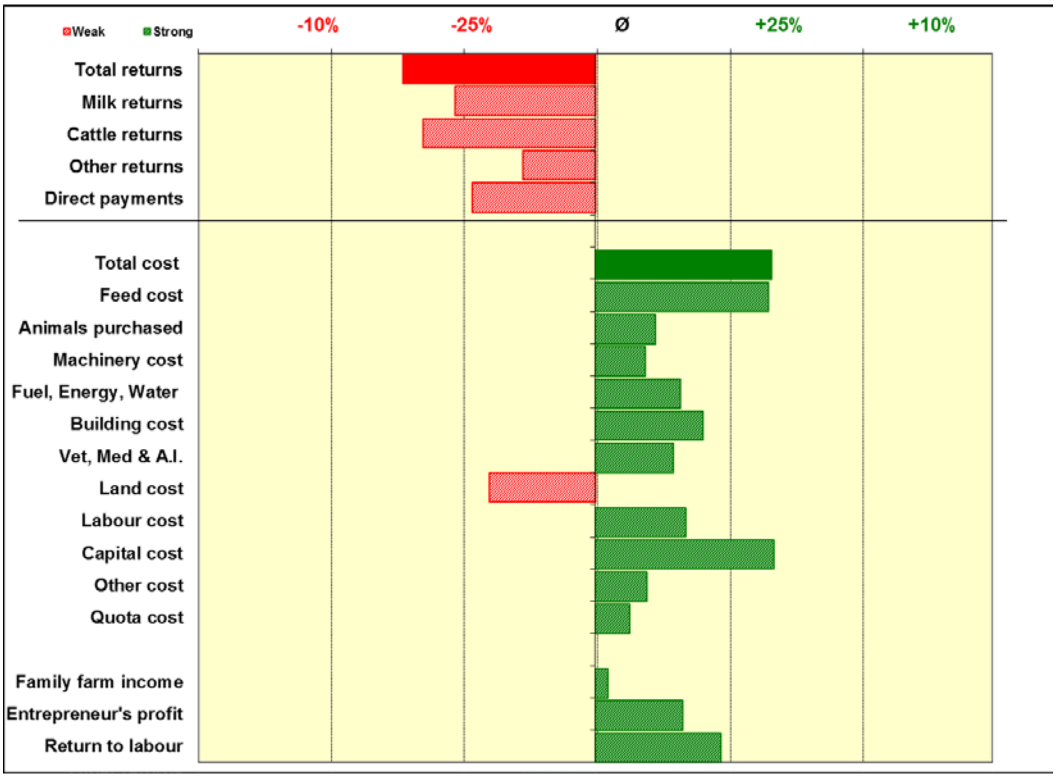

Figure 11: Chile strong and weak profile.

The return profiles for both countries are quite similar, with both in the segment of the 25% weakest, with minor differences favourable to the NZ farm in the variable 'other returns', and also minor differences favourable to the Chilean farm in milk and cattle returns. According to IFCN (2012), a rise in beef prices significantly increased the dairy farm income in most world regions. However, the overall result for NZ and Chilean farms were only slightly affected by changes in non-milk returns.

The differences between the typical farms from NZ and Chile, as shown in Figures 8 and 9, in return to labour and profitability were clearly explained by two significantly different cost profiles. The typical NZ farm had two major weaknesses when compared to the world sample's mean, land and capital costs, whereas the typical Chilean farm was weak in land cost only due to its large size. Under the IFCN approach, land cost consists of regional rent prices for owned land, or rents currently paid by the farmers for rented land per hectare. Capital cost is calculated as a percentage of the sum of owned capital, defined as value of assets excluding land, plus circulating capital; the real interest rate is assumed to be 3% or 6% for borrowed funds. The Chilean land cost is higher than the world's mean but it is far below the NZ land value. The share of land as a proportion of total costs in NZ is very high compared to the Chilean farm due to the relatively higher price of land for dairy. These reflect a land purchase price around US$24,000 per hectare in NZ, and around US$12,000 per hectare in Central southern Chile (IFCN, 2011). The negative comparison of the typical NZ farm relative to the world's sample in capital cost is driven by higher asset values and a lower equity ratio, which lifts the interest rate used from 3 to 6%.

Both the NZ and Chilean farms revealed their major strength in relatively low costs of production. Since these typical farms represented pasture-based farming systems, they both compared positively against the world mean when feed, stock, machinery, energy, building and other costs are considered. 'Labour', 'Other' and 'Quota' compare positively in both NZ and Chile. Quota costs do not exist in either of the two countries. The family farm income compared negatively for the NZ farm and positively for the Chilean farm. The entrepreneur's profit in both countries compared more favourably than the farm income, due to lower opportunity costs in these countries compared to the world's average. Return to labour indicates how competitive the farm is relative to the cost of the labour it is using; note that the average wage in NZ is higher than the world's average of wages. Return to labour features highly positive in both countries, but indicates greater labour efficiency in NZ than in Chile given the wages in each country. Figure 12 shows a direct comparison between Chilean and NZ typical farms, where the horizontal axis contains the deviations with respect to the NZ values in percentage terms.

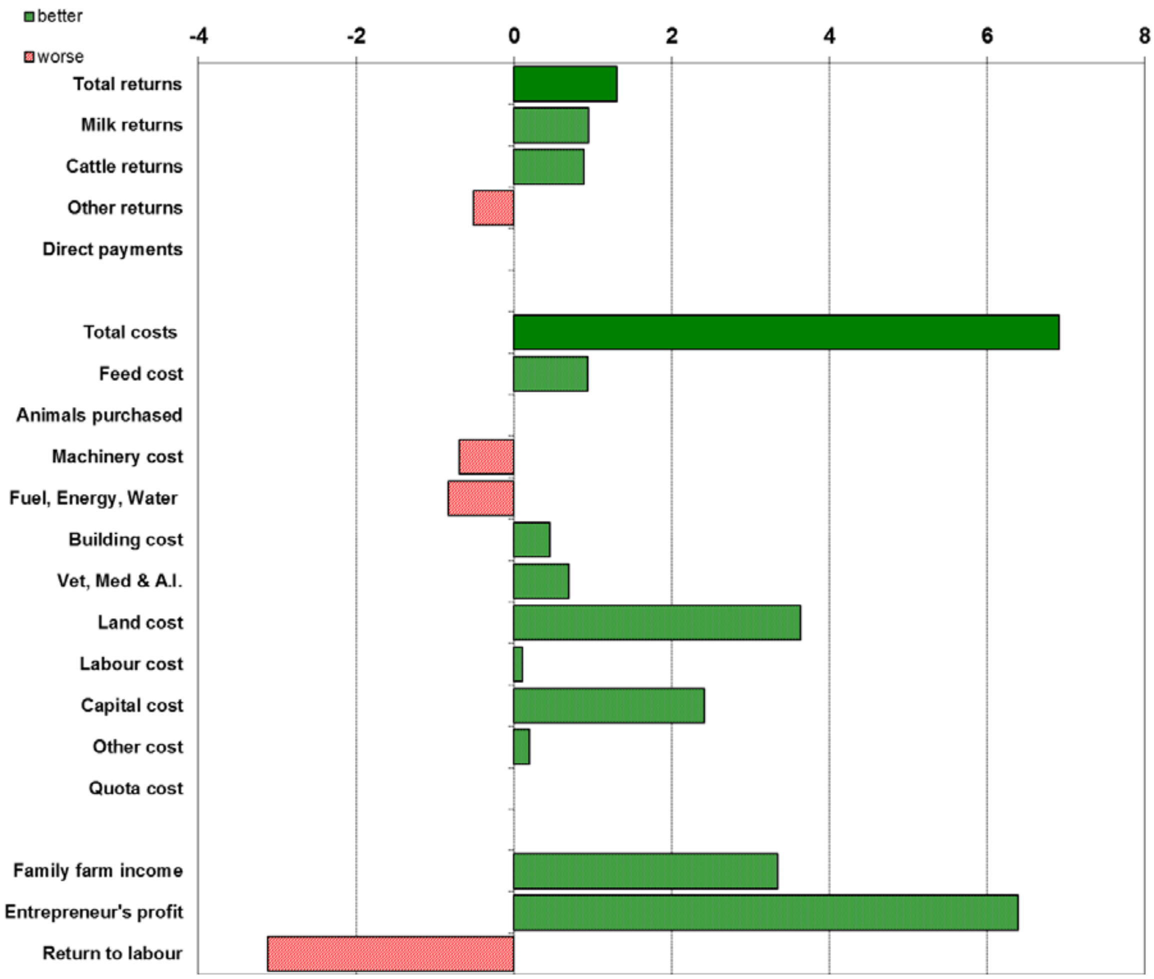

Figure 12: Typical Chilean dairy farm compared to the typical NZ dairy farm.

The typical Chilean farm compares favourably against the NZ farm in all but ‘Other returns’, ‘Machinery cost’, ‘Fuel, energy, water’ and ‘Return to labour’. The typical Chilean farm had higher milk and cattle returns due to more milk and beef produced respectively; also had higher total returns. Land, capital, animal health, building, labour and other costs all are higher in NZ, being land costs the biggest contributor to total costs. Overall, the bottom line also compares very positive for the typical Chilean farm against the NZ farm.

4.2 Discussion and concluding comments on the IFCN comparison

Pasture-based systems are a competitive advantage for those countries or regions that have the potential to grow grass all year round. These systems have recently re-gained worldwide interest due to their generally lower production costs compared to other systems, along with their more environmentally friendly profile (Dillon, et al., 2005; Benson, 2008). Temperate grasslands have a variety of environments as a result of factors such as season, latitude, altitude, aspect and distance from the sea. Their normal conditions are sufficiently favourable for livestock production to operate relatively low input systems. The variety in natural conditions also allows a range of farming systems to be used, differing, for example, in how much pasture they grow, supplement they use, or stock they carry per unit of area. According to expectations, despite some important similarities between NZ and Chilean dairy farming systems, the differences revealed by the results presented in this chapter were significant.

In 2011, both the cost of milk production and the profitability of dairying increased on average compared to the previous year (IFCN, 2012). This costs increase was found to be mainly due to escalating land, feed and energy prices. The opportunity cost for land also increased in this year relative to 2010 since cropping competed with dairy land because of very high prices for cereals and oilseeds. A longer term analysis showed "a sharp increase in cost of milk production in most world regions" (IFCN, 2012, p. 13). However, the relative strength in local currencies in many countries reduced the impact of rising energy and fertiliser prices. Profitability improved mainly driven by the high world milk price, consequence of a strong unsatisfied demand for milk products, which lasted until mid-2011 (IFCN, 2012).

Discussion groups and monitor farms are considered early examples of benchmarking. These activities started in France, after the Second World War, and in NZ in the 1980s, in order to share information, transfer technology and motivate learning and action among farmers (Campbell, 2008). The IFCN provides a modern version of monitor farms at the international level. 'Typical' farms under the IFCN approach represent those that produce the highest share of milk within a region, rather than the majority or average of farms in a country. Clearly, the NZ farm, located within a traditional dairy region (Waikato), was representative of both its region and the country (LIC & Dairy NZ, 2011). The 'typical' Chilean farm, also belonged to a traditional dairy area (X Region, Osorno), however, the farm was not particularly distinctive of its country which is characterised by many heterogeneous, smaller dairy farms that represent around 80% of producers, 40% of the dairy herds, and 20% of the total production (Consorcio Lechero, 2010). Although in Chile, the bigger producers have the greater share of total production (Escobar et al., 2006), according to all the background information reviewed, the typical NZ farm would still be larger than the normal Chilean dairy farm. In contrast, the IFCN Chilean farm had 21% more cows than a typical NZ farm and 400% more land dedicated to dairy. This suggests that the IFCN approach works well representing the average NZ farm, but only represents one segment of the Chilean dairy sector.

Both Chilean and NZ farms had significant differences in most physical parameters including production per cow, stocking rate, and land and farm productivity. The Chilean farm had greater cow and farm productivity than the NZ farm, but lower land productivity due to a significantly lower stocking rate (1 to 3.3 LU/ha). The stocking rate a farm can support is limited by the availability of pasture and the intensity of supplements used, while the potential for pasture production depends mostly on the quality of the land (Penno, 1999; Smith, et al., 2009). Several ecological and geographical factors such as latitude, soils and weather patterns are similar in Southern Chile and New Zealand (Challies & Murray, 2006). Hence, the quality of the land would not be expected to be more than three times higher in production of pasture as reflected in stocking rate differences. In NZ, the mean annual pasture production at the commercial level has been reported at 12 tonnes of dry matter per hectare and year (Holmes, 2003). The quantity of grass grown in Chile would in fact be lower than in NZ. This lower pasture production in Southern Chile may be due to a series of factors reported by Pinochet (2003) including low phosphate and pH values, and poor grazing management.

However, the large difference observed in stocking rates is only partially explained by lower pasture yields on similar quality land. Another component of this difference may be explained by the breeds and strains used for dairying in each country and the 'Livestock unit' employed by IFCN in its database. Stocking rate describes the number of animals supported per hectare or other unit of area and is expressed on a per head ratio, animal unit, or other pre-defined entity basis. A smaller NZ cow would allow more 'livestock units' per hectare. Conversely, the bigger Chilean Holstein type will reduce that figure. In other words, the relationship may be 1 to 2.4[19] (rather than 1 to 3.3) if the stocking rate was measured directly in cows per hectare. Also of interest are the implications of the stocking rate values on the different risk profiles of the farms. According to Penno and Kolver (2000), and Anderson and Ridler (2010), since most types of risk associated with farming are positively correlated with increasing stocking rate, the typical NZ farm will have a more risky profile than the Chilean farm.

In order to completely understand the systems, the stocking rate needs to be related not only to land productivity but also to supplements fed to the cows. For an increment in stocking rate, the milk production response on a per hectare basis is positive and, conversely, it is negative on a per cow basis (McCarthy, Delaby, Pierce, Journot, & Horan, 2011). The typical Chilean farm had very high milk yields per cow (9,300 kg ECM) which can only be achieved on pasture by using significant amounts of supplements (Gazzarin, Frey, Petermann, & Hoeltschi, 2011; National Research Council, 2001). Moreover, the fact that the typical Chilean farm had double the milk yields per cow of the NZ farm suggests that a higher genetic merit for milk production is being well capitalised through the use of concentrates or other supplements in Chile, favouring individual cow performance rather than land performance. It is also likely that the typical Chilean farm has grown its own supplementary feed on the effective grazing area.

Comparative benchmarking is particularly valuable for understanding returns, cost, and business drivers (FCC, 2007). The differences between the typical NZ and Chilean farms were clear

[19] According to an adult live weight relationship of 400 kg (NZ crossbreed) and 550 kg (American Holstein) and the Livestock unit equivalence used by IFCN LU = 650 kg LW

when comparing physical results but not as evident when comparing revenues, costs and results. The return profiles shown in Figure 12 showed minor differences in most indicators under analysis for total, milk, cattle and other returns. The Chilean farm of 520 ha and 421 cows had higher cattle, milk and total returns than the typical NZ farm of 120 ha and 348 cows. This was due to higher farm productivity as a result of larger scale in both, effective dairy area and herd size, and also higher production per cow. In contrast, 'other returns' were higher for the typical NZ farm due to the dividends generated by shares owned by the farm under the distinctive NZ payment system.

In both countries, dairy farms operated as price takers under conditions similar to perfect competition. According to Holmes (2003), given low milk prices at the farm gate, primary producers need a strong cost leadership focus. The cost profiles for the two countries showed differences in the order of 7% in total costs, explained mainly by higher land and capital costs in NZ compared to Chile, with NZ having also slightly higher feed, animal health, building and labour costs. Land cost was the biggest contributor to total costs in NZ because of the higher land and rent market values connected to stocking rate and land productivity. Capital costs are also related to the value of the assets which are significantly higher in NZ as are the levels of debt. The costs of feed and animal health were confounding factors because the supplementary feed used was expected to be lower in NZ than in Chile. A higher proportion of pasture in the diet of the cows was expected in NZ, which, according to Dillon et al., 2005, correlates negatively with total cost of feed. The NZ farm had higher feed cost due to high price per unit of supplement rather than volume used. Similarly, animal health was expected to be lower in NZ than in Chile, where housing increases the animal health issues and the herd was larger. However, it was again more costly for the NZ farm, presumably due to higher veterinary and animal health costs. Higher building costs in NZ may be explained by more infrastructures other than housing to maintain in NZ than in Chile. Finally, labour costs were not surprisingly higher in the typical NZ farm, mainly due to significantly higher wages than in Chile. As expected the typical NZ farm was less mechanized, used less fuel, energy and water, and also demonstrated a higher labour efficiency as reflected by a return to labour greater than that for Chile. Despite these, the bottom line represented by family farm income and entrepreneur's profit compared very positively for the Chilean farm, being more than 3% and 6% higher respectively.

In summary, the IFCN provided valuable background information for both countries. The farms studied shared a series of characteristics and exhibited some differences. One similarity was that both countries produce at low cost although it is not clear if both countries pursued a cost-leadership strategy. NZ pastoral systems are well delineated pasture-based systems and clearly pursue cost-leadership. In contrast, the Chilean example showed to be also low-cost but by producing a lot of milk rather than using low inputs. Both also were exposed to climatic and a price shocks due to natural variability and the absence of subsides and quotes. The differences between the countries were mostly in the cost profiles as previously explained, and in the risk profiles as a result of very different stocking rates in similarly uncertain productive environments. However, the comparison of these 'typical' farms for only one particular year did not allow a good characterisation of pasture-based dairy farming systems in NZ and Chile. This reinforces the need for a more comprehensive study, including a broader sample from a wider geographic coverage.

5. New Zealand Results.

This chapter presents the NZ results, consisting of the data envelopment analyses and the second stage recursive partitioning analyses.

5.1 Data Envelopment Analyses

This section presents the NZ results for the data envelopment analysis. Table 17 presents a summary of the NZ results over a five year period from 2006/07 to 2010/11 showing corresponding weighted averages for the outputs milk solids (MS) and gross farm reveue (GFR) while Tables 18, 19, 20, 21 and 22 show the class results for both MS and GFR analyses per season over the five-year period.

Table 17

Weighted Averages for DEA Results by Year

		Weighted Averages	
Season	n	MS	GFR
2006/07	616	0.885	0.877
2007/08	609	0.884	0.854
2008/09	492	0.892	0.867
2009/10	558	0.884	0.876
2010/11	323	0.92	0.918
Period	2598	0.89	0.88

Results per class are not strictly comparable since several DEA have been carried out independently, and sample sizes and DMUs observed are not the same over the period. Therefore, significance tests would only encourage misleading comparisons, and have not been conducted. A score of 1 represents full efficiency; the range from 0.95 to 1 is referred to as virtually efficient; the range from 0.90 to 0.95 is considered very high efficiency; and from 0.85 to 0.90 is high. From June 2006 to May 2011 the NZ efficiency proved to be high to very high with fluctuations over the period. The milk solids weighted efficiency for the owner-operators suveyed in *DairyBase* ranged from 0.884 to 0.920 and the gross farm revenue weighted efficiency ranged from 0.854 to 0.918.

The similarity between MS and GFR efficiencies values was expected since the correlation between these variables was very high (0.95), and GFR was driven to a large extent by MS and milk price. The results suggest that milk efficiency was also driven by price relationships such as the milk:feed ratio, and by the presence/absence of weather related shocks such as droughts or flooding. Over the period milk and feed prices as well as the climate showed marked variability. International milk prices were exceptionally high in 2007 and the beginning of 2011, and a pronounced drop was observed in June 2009 (IFCN, 2012).

This study looked at the *DairyBase* physical data to gain context and better interpret the results. The *DairyBase* physical data comprised 657 observations across the period (88 observations in 2006/07, 151 in 2007/08, 156 in 2008/09, 187 in 2009/10 and 75 in 2010/11). Seasons 2006/07, 2007/08, and 2009/10 had lower rainfall than 2008/09 and 2010/11, which led to lower pasture growth and quality, and also lower total feed eaten and productivity in terms of milk solids per cow per day. Further consequences of the lower pasture growth were a higher share of supplements in total feed eaten, lower annual productivity per cow, and less days in milk. Consequently, the lower physical efficiency found in 2006/07, 2007/08 and 2009/10 years than in 2008/09 and 2010/11 was expected.

In 2006/07 and 2007/08, the weighted mean efficiency converting inputs into milk was high (0.885, 0.884) and the conversion of inputs into revenue was lower but still high (0.877, 0.854). In response to milk price, in 2008/09 and despite a high mean physical efficiency (0.892), the revenue efficiency was again significantly lower (0.867). In 2009/10, the mean milk efficiency was high (0.884), while the revenue efficiency was identical to that of the previous year (0.867). Season 2010/11 showed a very high overall efficiency; converting inputs into physical product was high (0.920) as was the revenue efficiency (0.918), with both being well above the means for the five-year period (0.89 and 0.88, respectively). During the whole period revenue efficiency was below milk efficiency, which is also reflected in the general mean for the period. Table 18 shows the DEA outcomes for season 2006/07 (mean efficiencies and standard deviations for each class).

Table 18

DEA Results per Class Within Season 2006/07

Season 2006-07	n	MS oriented efficiency M	MS oriented efficiency SD	GFR oriented efficiency M	GFR oriented efficiency SD
Rest of North Island - Low use of supplements	189	0.857	0.111	0.849	0.116
Northland-Tasman/West coast	119	0.887	0.101	0.878	0.100
Rest of North Island - High use of supplements	67	0.897	0.097	0.908	0.094
Rest of North Island - Medium use of supplements	106	0.900	0.100	0.898	0.096
Canterbury/Southland	135	0.902	0.085	0.883	0.097

In 2006/07, Rest of North Island-LOW had the lowest efficiency (0.857) and the greatest variability as denoted by standard deviation[20]. Attention is drawn to the higher efficiency classes, Canterbury/Southland (0.902) and Rest of North Island-MEDIUM (excluding Northland and using medium levels of imported feed; 0.900). The mean efficiencies were very close to each other, but Canterbury/Southland had a narrower efficiency range and lower variability. For the gross farm revenue results, Rest of North Island-LOW (0.849) had the lowest efficiency and was largest variability class. It is interesting to note that Canterbury/Southland's (0.883) ranking went from being the most efficient class producing MS to only third best producing revenue after Rest of North Island-MEDIUM (0.898) and HIGH (0.908). Also of interest is that greater variability is found among the revenue results than among the milk scores.

Table 19 shows the DEA outcomes for season 2007/08.

[20] The standard deviation (SD) of the mean measures the spread of values in a distribution being calculated as the square root of the variance. The spread of a distribution is also referred to as 'dispersion' and 'variability'. All three terms mean the extent to which values in a distribution differ from one another.

Table 19 *DEA*

Results per Class Within Season 2007/08

Season 2007-08	n	MS oriented efficiency		GFR oriented efficiency	
		M	SD	M	SD
Northland-Tasman/West coast	117	0.863	0.111	0.817	0.139
Rest of North Island - Low use of supplements	157	0.864	0.112	0.812	0.121
Rest of North Island - High use of supplements	90	0.871	0.109	0.870	0.098
Rest of North Island - Medium use of supplements	119	0.886	0.107	0.855	0.112
Canterbury	73	0.928	0.081	0.930	0.079
Southland	53	0.948	0.068	0.923	0.090

The 2007/08 season exhibited a similar pattern to that of 2006/07. The milk solids output shows that the lower efficiency classes, on average, were Northland-Tasman/West Coast (0.863) and Rest of North Island-LOW (0.863) for a second time, while higher efficiency classes were again Canterbury (0.928) and Southland (0.948). For the revenue results, attention is drawn to the consistency among the lower and higher efficiency classes. Rest of North Island-LOW (0.812) and Northland-Tasman/West Coast (0.817) had lower efficiencies again and also showed the larger variabilities. Canterbury (0.930) and Southland-Otago (0.923) produced revenue very efficiently, just under the mean score reached producing milk. Greater variability was once again found among the revenue results than among the milk scores.

Table 20 shows the DEA outcomes for season 2008/09.

Table 20

DEA Results per Class Within Season 2008/09

Season 2008-09	n	MS oriented efficiency		GFR oriented efficiency	
		M	SD	M	SD
Rest of North Island - Low use of supplements	109	0.866	0.111	0.888	0.109
Rest of North Island - High use of supplements	63	0.878	0.120	0.868	0.119
Northland-Tasman/West coast	92	0.887	0.112	0.862	0.132
Rest of North Island - Medium use of supplements	123	0.899	0.101	0.869	0.113
Canterbury/Southland	105	0.925	0.083	0.845	0.127

In 2008/09, the lowest milk efficiency class was Rest of North Island-LOW (0.863), while the highest mean was exhibited by Canterbury and Southland-Otago classes (0.925). For Rest of North Island-HIGH, the variability of these results was much higher than that observed in the previous season. For the revenue results, note the dramatic change in ranking compared to both, the milk results and the previous seasons. Rest of North Island-LOW (0.888) exhibited the highest revenue efficiency. Conversely, Canterbury and Southland-Otago (0.845) showed the lowest mean efficiency and a very high standard deviation.

Table 21 shows the DEA outcomes for season 2009/10.

Table 21

DEA Results per Class Within Season 2009/10

		MS oriented efficiency		GFR oriented efficiency	
Season 2009-10	n	M	SD	M	SD
Northland-Tasman/West coast	105	0.847	0.126	0.853	0.120
Rest of North Island - High use of supplements	96	0.850	0.126	0.845	0.115
Rest of North Island - Low use of supplements	121	0.878	0.099	0.863	0.103
Rest of North Island - Medium use of supplements	110	0.888	0.103	0.892	0.097
Canterbury	74	0.939	0.076	0.910	0.092
Southland	52	0.951	0.063	0.930	0.083

In 2009/10, the lowest milk efficiency class was Northland-Tasman West Coast (0.847), followed very closely by Rest of North Island-HIGH (0.850), with both exhibiting moderately high milk efficiency. In contrast, Southland was virtually efficient (0.951) with a low standard deviation. Canterbury had the same pattern, having a very high milk efficiency (0.939). In between, Rest of North Island-LOW and MEDIUM exhibited very high efficiency and moderate variability. The ranking for milk results almost perfectly matched the ranking for the revenue results. However, the lowest refficiency class changed to Rest of North Island-HIGH (0.845), which was at that lowest position for the first time in the series.

Table 22 shows the DEA outcomes for season 2010/11.

Table 22

DEA Results per Class Within Season 2010/11

Season 2010-11	n	MS oriented efficiency M	MS oriented efficiency SD	GFR oriented efficiency M	GFR oriented efficiency SD
Rest of North Island - High use of supplements	73	0.908	0.095	0.924	0.089
Rest of North Island - Low use of supplements	67	0.910	0.103	0.899	0.106
Rest of North Island - Medium use of supplements	63	0.913	0.089	0.914	0.080
Northland-Tasman/West coast	57	0.923	0.095	0.916	0.097
Canterbury/Southland	63	0.947	0.065	0.937	0.076

In 2010/11, mean efficiencies for both MS and GFR were markedly higher than for the previous seasons. The MS results show that the lower efficiency class were Rest of North Island-HIGH (0.908) and LOW (0.910), but these values were still in the range of very high milk efficiency range. In contrast, Canterbury and Southland exhibited a very high average efficiency (0.947) with a low standard deviation. This highest efficiency class also kept its place when looking at the revenue results (0.937), although the rest of the ranking did change. Interestingly, Rest of North Island-HIGH (0.924) jumped from last to the second best efficiency class and conversely, Rest of North Island-LOW went from very high efficiency to bottom of the table (0.899).

In summary, variability was evident in both milk and revenue efficiencies throughout the period but the variability was greater among the GFR results than among the MS scores. The best year of the series clearly was 2010/11 due to a favourable milk price scenario and the absence of weather shocks. The lowest efficiency class for both milk and revenue for most years was Northland-Tasman/West Coast, while Canterbury and Southland had the higher milk efficiency almost every year but failed to deliver the same good results when revenue efficiency was analysed.

The 2007/08 season exhibited a similar pattern to that of 2006/07, but the milk price was significantly higher and thus, attention is drawn to the fact that lower and higher milk efficiency classes exactly matched the revenue efficiency class rankings. Rest of North Island-LOW (0.812) and Northland-Tasman/West Coast (0.817) had lower efficiencies again and also showed the larger variabilities. Canterbury (0.930) and Southland/Otago (0.923) produced revenue very efficiently, with just under the mean score reached producing milk. Greater variability was once again found among the GFR results than among the MS scores. In 2008/09 (Table 20), a year characterised by a high initial milk price followed by a pronounced drop when the season was well under way, the lower MS efficiency classes generally had the higher revenue efficiency averages. In 2008/09, clearly only those who effectively managed the change in milk price scenario were able to maintain efficiency producing revenue. In 2009/10 the MS results positioned Northland-Tasman West Coast (0.847) as the lowest efficiency class, closely followed by Rest of North Island-HIGH (0.850). In contrast, Southland was virtually efficient (0.951) with a low standard deviation and Canterbury exhibited the second best efficiency (0.939) and also low variability. Interestingly, the ranking for MS results almost perfectly matched the ranking for the GFR results. In 2010/11 mean efficiencies were markedly higher than for 2009/10. The efficiency at producing milk had an inverse relationship with the efficiency at producing revenue in some classes in the North Island of NZ. In contrast, classes in the South Island had a direct association between milk and revenue efficiency.

5.2 Recursive Partitioning Trees results

Both the milk and revenue efficiency scores obtained in the DEA stage were incorporated into the original dataset including all years and regions, and subsequently used in a series of country-specific RP trees with the efficiency values used as the response variable *y*. This section presents the milk trees first and later the revenue trees, followed by a summary of key performance indicators identified.

5.2.1 Milk Solids Results

Figure 13[21] represents a milk solids tree, obtained from the regression of DEA estimates on a dataset that included all 176 discretionary and non-discretionary inputs and ratios contained in *DairyBase* (refer to Appendix 1). A general concept useful to navigate and understand the trees, was that right branches always cluster the subsample with the highest mean efficiency and, on the contrary, left branches contains the lowest mean efficiency class. Figure 13 shows 13 terminal nodes within two major branches split by a top level or root variable.

[21] See Chapter III: Method for more detail in trees' structure and how to navigate them.

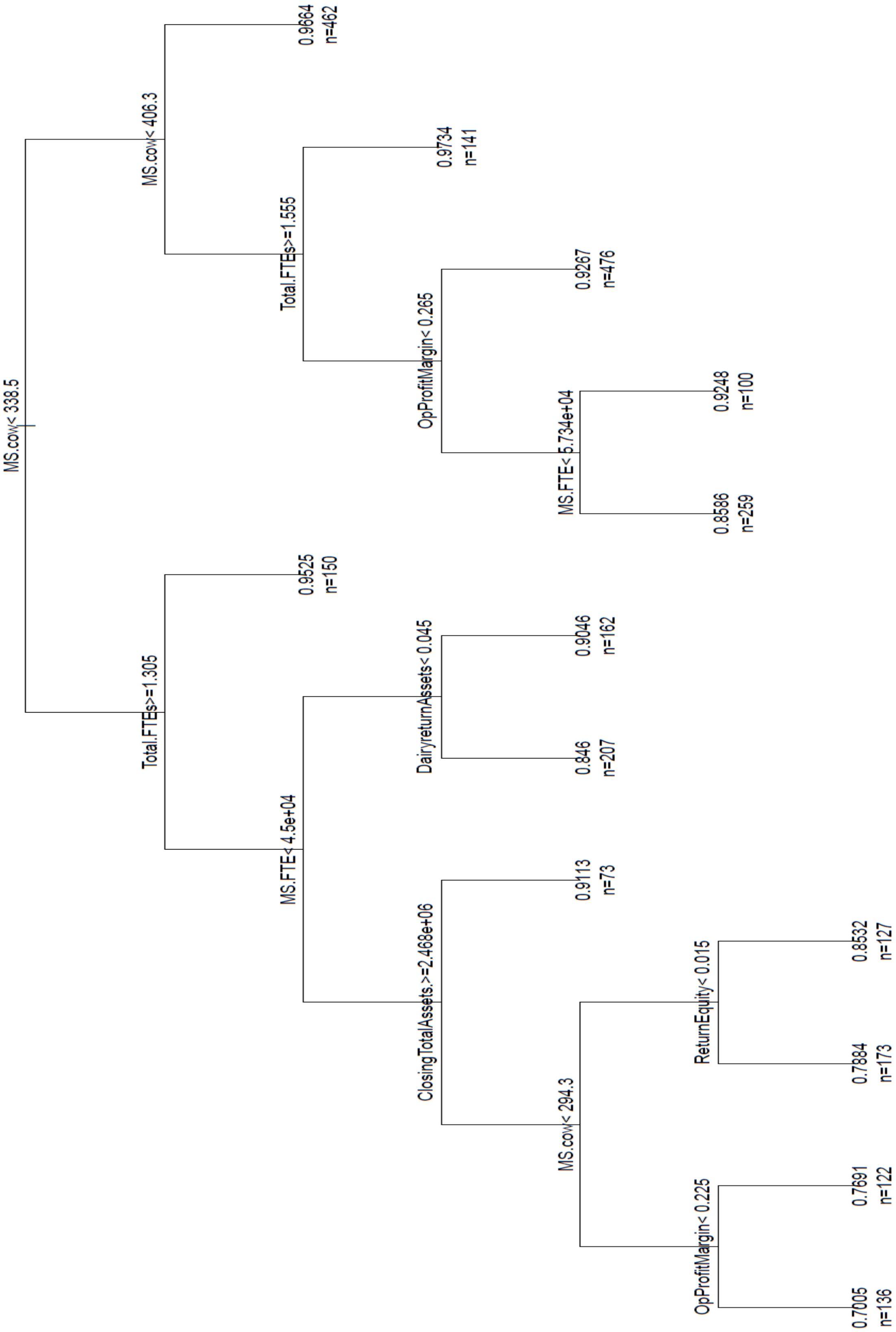

Figure 13: MS DEA partitioning tree.

Milk solids measured in kilograms per cow (MS/cow) was the root variable. Based on a threshold value of 338.5 kg, MS/cow split the sample into left and right branches. The left branch which accounted for 1,150 DMUs or observations that produced less than the pivotal value (339 kg MS/cow) resulted in eight leaves. A virtually efficient class (0.9525) contained those 150 DMUs with total labour units lower than 1.305 full time equivalents (FTE). On the outer left side, total FTE interacted with a third split on MS/FTE, which led to two fourth level variables, Closing Total Assets and dairy return on assets (dROA). Following the outer track, the two lower efficiency classes clustered 258 DMUs. The lowest efficiency leaf (0.7075) was composed of observations that produced less than the threshold MS/cow (294 kg), further split by operating profit margin (OPM) at a critical value of 22.5%.

The right branch clustered those DMUs with production levels higher than 339 kg MS/cow into four leaves containing 1,438 observations. This branch revealed four more partitioning levels using the same variables as in the left branch. However, these variables all acted at different levels, revealing varied main effects and interactions between them. Again MS/cow was the second order split and in itself was able to define an outer leaf; this was the largest class (n = 462), and was virtually efficient (0.9664), with production levels greater than 406 kgMS per cow. On the inner side, the second split led to the third level variable, FTE, which revealed the most efficient class (0.9734; n = 141); this had a combination of moderate yields per cow (between 339 and 406 kg MS/cow), employed less than 1.56 FTE, and comprised just under 10% of the sub sample.

MS/cow, FTE, and MS/FTE were very dominant in Figure 13, and it was considered that this could be masking some interesting relationships among other less strong variables; hence, a modification was proposed. Figure 14 shows a second tree generated using the same DEA scores based on the physical output MS with twelve of the milk-related ratios excluded from the dataset (MS/cow, MS/FTE, MS/ha; Milk fat, MFat per cow and ha, Protein, Protein/cow, Protein/ha, Total milk, Milk litres per cow and L/ha). The analysis regressed DEA estimates on 163 variables, yielding 13 terminal leaves, as shown in Figure 14.

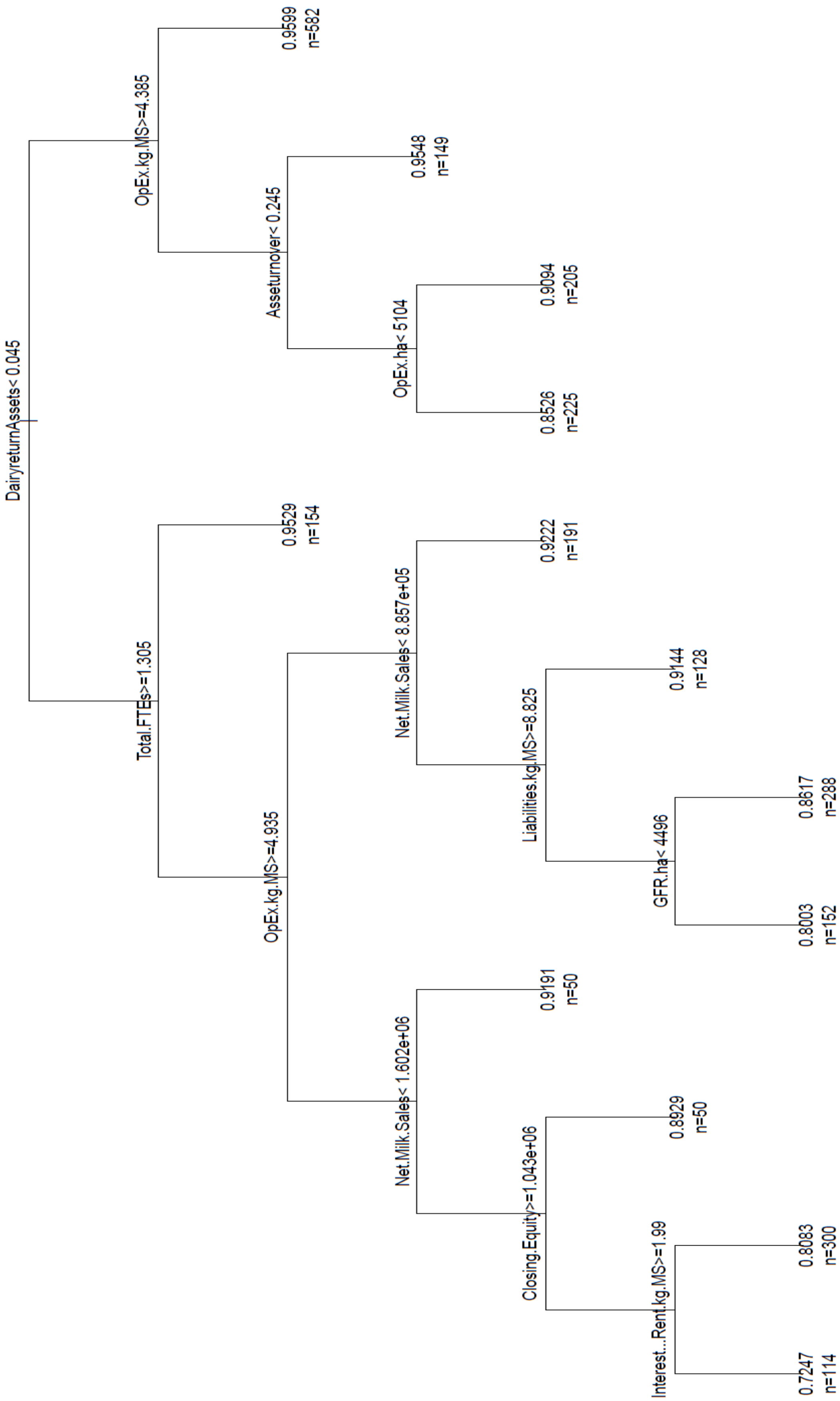

Figure 14: Modified MS DEA partitioning tree.

The modified tree exposed relationships among variables that had not appeared before. There were 1,427 observations with a dROA lower than the threshold value of 4.5% which were split to the left ending in nine leaves drawn by means of six levels of partition. The second split on the left branch FTE created a virtually efficient (0.9529), medium sized class (n = 154), having less than 4.5% of dairy ROA and fewer than 1.3 FTEs. In parallel, following the outer track the sample was further split by operating expenses ratio expressed in NZ dollars per kgMS (OpEx/kgMS) at the threshold value of NZ$ 4.935/ kgMS. Net milk sales (NZ$) was at the next level down, splitting at two different pivotal values. The lowest efficiency class (n = 114, 0.7247) had an intermediate value for net milk sales, a value of equity equal or greater than NZ$1.043 million and paid more than NZ$ 1.99 per kgMS in interest and rent. In parallel, the left inside third level split also led to net milk sales, then to liabilities ratio (NZ$/kgMS), and finally to gross farm revenue per hectare (GFR/ha), defining four leaves ranging in efficiency from 0.9222 to 0.8003.

The root variable dROA also split 1,161 observations for those having a threshold value greater than 4.5% to the right branch. On the outer side, OpEx was a second level variable at the pivotal value of NZ$ 4.385/kgMS clustered observations into the most efficient (0.9599) and largest class (n = 582): 22.5% of the sample fitted into this leaf. On the inner pathway, a further split originated on the third level variable, Assets Turnover Ratio (ATR), at a threshold value of 24.5%. Again, on the outer side, a virtually efficient class (0.9548) comprised of 149 observations which were very profitable, as indicated by the dROA, but less cost efficient, however, they made good use of their assets as indicated by ATR.

Table 23 highlights the order and frequency of appearance of the variables exposed by both trees based on milk solids DEA which were located from the root to the fourth level split in Figures 13 and 14.

Table 23

Key Performance Indicators as Revealed by MS Trees

	KPI	LEVEL
	MS/Cow	1ST
	MS/Cow	2ND R
	FTE	2ND L
Figure 13	FTE	3RD R
	MS/FTE	3RD L
	OPM	4TH R
	dROA	4TH L
	CTASS	4TH L
	dROA	1ST
	OpEx/kg	2ND R
	FTE	2ND L
Figure 14	ATR	3RD R
	OpEx/kg	3RD L
	OpEx/HA	4TH R
	Net milk sales	4TH L
	Closing Equity	4TH L

A key property of the RPT approach is that it identified the relative importance of each variable. Not only is the order of entrance of a particular variable important, but also its reappearance at different levels and combination with other variables. Table 23 shows the strong variables, such as MS/COW, FTE, dROA, and OpEx, which appeared at least twice and sometimes ‘participated’ in building up other ratios like MS/FTE. When this is the case, the significance of the relevant variable was reinforced.

5.2.2 Gross Farm Revenue Results.

The following trees (Figures 15 and 16) used DEA scores based on the economic output GFR instead of MS. Figure 15 included all DMUs and all variables used for the first tree MS.

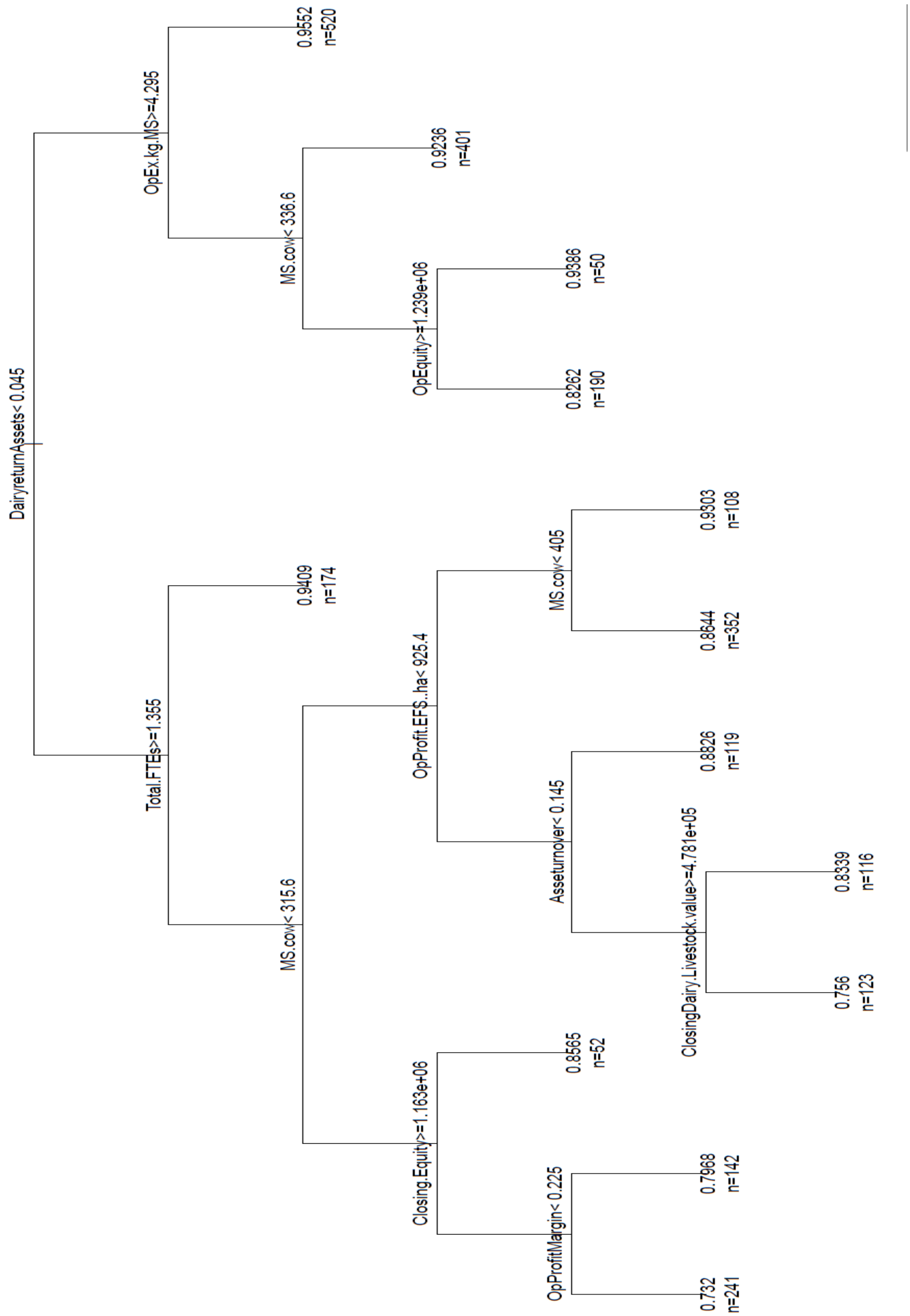

Figure 15: GFR DEA partitioning tree.

Figure 15 exposed 13 terminal nodes, six levels of partition, and overall, was very similar to Figure 14. Similarly, the top level variable was the ratio dROA at the same critical value of 4.5%, which split the sample into the left branch (n = 1427) and the right branch (n = 1161). Nine leaves were drawn from the left subsample, which had the same structure and complexity as those shown in tree number two (Figure 15). The second level variables were again total FTE and OpEx/kgMS, although the threshold values were slightly different. In short, Figure 16 revealed that the highest efficiency class (0.9552) on the right branch, was attainable by having higher than 4.5% dairy ROA and operating costs lower than $ 4.295/kgMS. This was the situation for 520 observations which was approximately 20% of the whole sample. In contrast, one tenth of the sample was included in the lowest efficiency class (0.732) which had ROA below 4.5%, total FTE above 1.36 and produced less than 315.6 kgMS/cow. This lowest efficiency class also had higher closing Equity than the pivotal value and an operating profit margin lower than 22.5%.

Figure 16 shows a tree based only on inefficient farms, that is those non-efficient DMUs left after the 570 efficient farms (DEA score = 1) were removed from the dataset so as to search for new interactions.

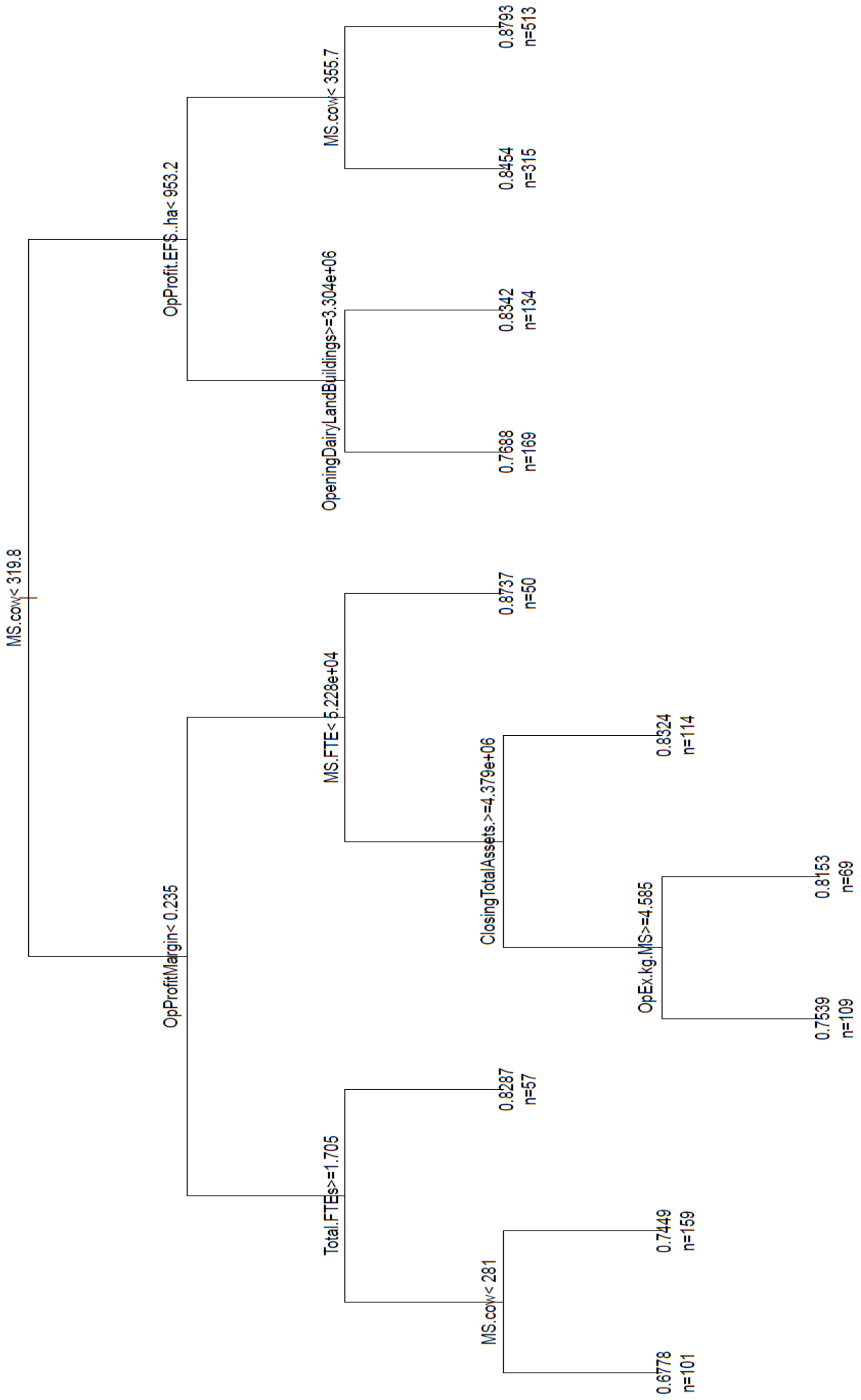

Figure 16: Modified GFR DEA partitioning tree.

This tree yielded 11 terminal leaves, by means of five partitioning levels. Similar to tree number one (Figure 13), the root node split 659 observations to the left and 1131 to the right based on the ratio MS/cow. On the right branch and to the outer side, the highest efficiency class (0.8793) was also the largest (n = 513) comprising 27% of the whole sample; it was defined by an operating profit per hectare greater than the critical value of NZ$ 953 and a production per cow higher than 355.7 kgMS. The second highest efficiency class (0.8737) was found on the inner left branch. This was a small class (n = 50) having less than 320 kgMS/cow, more than 23.5% OPM and a high labour productivity (> 5228 kgMS/FTE). In contrast, the lowest efficiency class (0.6778) which was also on the left branch was determined by less than 23.5% OPM, more than 1.705 FTE and a production per cow lower than 281 kg MS.

Table 24 highlights the order and frequency of appearance of the variables exposed by Figures 15 and 16.

Table 24

Key Performance Indicators as Revealed by GFR Trees

	KPI	LEVEL
	dROA	1ST
	OpEx/kg	2ND R
	FTE	2ND L
Figure 15	MS/Cow	3RD R
	MS/Cow	3RD L
	Opening Equity	4TH R
	Closing Equity	4TH L
	Operating profit/ha	4TH L
	MS/Cow	1ST
	Operating profit/ha	2ND R
	OPM	2ND L
Figure 16	Opening Land&Building Assets	3RD R
	MS/Cow	3RD R
	FTE	3RD L
	MS/FTE	3RD L
	MS/Cow	4TH L
	Closing Total Assets	4TH L

In summary, the RPT approach identified those indicators which were important in defining efficiency classes in New Zealand; presented a number of threshold or pivotal values that determine the pathway and the class where a particular DMU is likely to sit; and ultimately exposed the pathway, or combination of indicators, that identified homogenous groups accounting for different dairy performance in NZ ($p = 0.05$ as pre-defined in RPT code). These results show that there is no one pathway to attain high efficiency, and that many variable combinations of good practices can result in high and very high efficiency scores. The variable MS/cow was revealed as a multiple order indicator that came out in different trees and levels, sometimes more than once. Similarly FTE was found in all studied trees and also the relationship MS/FTE appeared as a third and fourth level indicator, reinforcing the importance of both physical production and labour. dROA appeared repeatedly, from top to fourth order. OPM came up four times, as a second, fourth and sixth level indicator in several trees, having the higher level in the last tree which excluded the efficient farms and looked for a more discerning analysis. ATR was revealed once, as a third level indicator, as did OpEx/kg.

5.2.3 The fifth NZ tree

A fifth NZ tree used ROA as the response variable instead of efficiency scores. This is presented in Appendix seven since it is out of the scope of this work. However, it was considered to be an effective way to show relationships between variables without the need for estimating efficiency scores using DEA. Such a tree could also be used as a prediction tool, even with a different New Zealand dataset, for example, for appraisal of past or future seasons.

5.3 NZ Benchmarks Set

The NZ benchmark sets, identified in the previous analyses, consisted of key performance indicators that acted at the first, second and third level variables, on the trees presented earlier. Table 25 presents this set split into two groups, one column showing the physical and other column showing the financial indicators drawn from the trees. It is worth noting that the present set can be expanded by adding as many levels as required.

Table 25

NZ Benchmarks Set Comprising Physical and Financial KPIs

Benchmarks set	
Physical KPIs	Financial KPIs
MS/COW (kg)	dROA (ratio)
FTE (units)	OPERATING PROFIT/HA ($)
MS/FTE (kg)	OPM (ratio)
	OpEx/kgMS ($)
	ATR (ratio)

This set of benchmarks, which comprises three physical and five financial indicators, was next used to describe the data contained in *DairyBase*. The NZ sample was grouped according to the following criteria: inefficient DMUs, with a score < 1 in any of the MS or GFR analyses, made up the largest group (n = 1944), and efficient DMUs, whose score = 1 overlapping in both analyses. This second group was further split into two sub sets by ordering observations using farm ID: those farms which were efficient just once or twice over the five year period were set apart (n = 502) from those which were consistently efficient three or more times over the same period (n = 142). These resulting groups are thereafter referred to as Inefficient, Efficient, and Resilient respectively.

Table 26 presents a summary of the descriptive statistics for the physical indicators for each group. This is followed by indicator-specific tables (Tables 27 and 28) where significance tests are presented.

Table 26

Descriptive Statistics on Selected Physical KPIs

		N	M	SD	MIN	MAX
MS/cow	Resilient	142	391	88	213	650
	Efficient	502	376	64	178	564
	Inefficient	1944	342	56	118	525
	Total	2588	351	62	118	650
Total FTEs	Resilient	141	3.04	2.62	.58	12.44
	Efficient	502	3.13	2.45	.69	17.56
	Inefficient	1944	2.95	1.48	.77	13.24
	Total	2587	2.99	1.79	.58	17.56
MS/FTE	Resilient	141	59294	19098	16260	102677
	Efficient	502	59024	20764	18522	143826
	Inefficient	1944	48293	14707	13593	120172
	Total	2587	50975	16957	13593	143826

As shown in Table 26, resilient farms had greater variability in MS/cow and FTE, but on average, they produced more output, both per cow and per labour unit expressed in kg of milk solids, than the other groups. Differences in total FTE between groups were minor and not significant. Tables 27 and 28 show the means' comparison for the production ratios of interest. The layout indicates no significant differences in the means when these are shown in the same column. The columns represented the number of subsets of means drawn for a confidence value of 95%. Significance Schaffe tests for unequal group sizes, were conducted to compare the groups by using one-way ANOVA.

Table 27

Comparison of Means for the Output Produced per Cow Indicator

Class	n	MS/Cow		
Inefficient	1944	342		
Efficient	502		376	
Resilient	142			391

Table 28

Comparison of Means for the Output produced per Labour Unit Indicator

Class	n	MS/FTE	
Inefficient	1944	48293	
Efficient	502		59024
Resilient	141		59294

The differences in production per cow and labour unit were large and significant, especially between the group of resilient farms and the inefficient group. The differences between the groups found in absolute and statistical terms support the relevance of the selected physical indicators as KPIs in NZ. In a similar layout, financial KPIS will be presented.

Table 29 shows the summary on selected financial KPIs followed by the indicator-specific tables (Tables 30 to 34).

Table 29

Descriptive Statistics on Selected Financial KPIs

		N	M	SD	MIN	MAX
Dairy Return on Assets (ratio)	Resilient	142	.081	.076	-.030	.495
	Efficient	502	.072	.066	-.111	.664
	Inefficient	1944	.041	.033	-.087	.287
	Total	2588	.049	.047	-.111	.664
Operating Profit/ha ($.ha)	Resilient	142	2920	2024	-2654	10431
	Efficient	502	2711	1788	-1207	8624
	Inefficient	1944	1871	1493	-2498	8860
	Total	2588	2092	1632	-2654	10431
Operating Profit margin (ratio)	Resilient	142	.341	.173	-.275	.715
	Efficient	502	.328	.155	-.252	.616
	Inefficient	1944	.251	.161	-.479	.714
	Total	2588	.271	.164	-.479	.715
Operating Expenses/kgMS ($/kg)	Resilient	142	4.49	1.15	2.33	8.43
	Efficient	502	4.55	1.08	1.98	9.07
	Inefficient	1944	4.97	1.09	2.54	10.72
	Total	2588	4.86	1.11	1.98	10.72
Asset turnover (ratio)	Resilient	142	.268	.237	.068	1.444
	Efficient	502	.246	.222	.046	1.802
	Inefficient	1944	.151	.064	.020	.978
	Total	2588	.176	.132	.020	1.802

For all the analysed financial variables, the resilient farms showed greater variability as indicated by standard deviations. They were also consistently more profitable than the other groups, and exhibited lower operating expenses and better use of assets. Efficient DMUs tended to be similar to the resilient group, but sometimes exhibited lower minimum and higher maximum values. Differences between resilient and inefficient observations were noticeable in all the indicators, but were more marked for dairy ROA where resilient farms had twice the return of inefficient observations. Furthermore, resilient farms had 77% higher ATR and 56% greater profitability per hectare than the group of inefficient observations. Table 30 shows the means' comparison for the profitability ratio Dairy return on assets (d ROA).

Table 30

Comparison of Means for Dairy ROA

Class	n	DairyreturnAssets		
Inefficient	1944	0.041		
Efficient	502		0.072	
Resilient	142			0.081

As expected because of the large gap in returns between the resilient farms and the groups of inefficient and efficient, the differences in ROA were significant between all groups. In absolute terms, the efficient observations were closer to the resilient than to the inefficient group, but still a difference of 0.009 can be considered large for this particular indicator. Table 31 shows the statistical comparison for another profitability ratio, operating profit margin.

Table 31

Comparison of Means for Operating Profit Margin

Class	n	OpProfitMargin	
Inefficient	1944	0.25	
Efficient	502		0.33
Resilient	142		0.34

In operating profit margin, both in absolute and statistical terms, efficient observations behaved very similarly to the resilient farms. This measure indicates how well a farm generates profit from its revenue and/or how effective cost control is. Table 31 clearly demonstrates that resilient and efficient groups are performing much better than the Inefficient DMUs. Taking this into consideration, Operating Profit per hectare was also expected to be significantly different, at least between two groups. Table 32 shows the comparisons carried out on that indicator.

Table 32

Comparison of Means for Operating Profit per Hectare

Class	n	Operating Profit/ha ($.ha)	
Inefficient	1944	1871	
Efficient	502		2711
Resilient	142		2920

As shown in Table 32, the Operating Profit per hectare demonstrated that, in absolute and statistical terms, efficient observations behaved very similarly to the resilient farms, and both groups were again far away from the inefficient group. Two columns set these apart from efficient and resilient observations, which were clustered together by much higher levels of profit per hectare. These results may be in part explained by lower operating costs, as shown in Table 33.

Table 33

Comparison of Means for Operating Expenses per Kg of Output

Class	n	Operating Expenses/kgMS ($/kg)	
Inefficient	1944		4.97
Efficient	502	4.55	
Resilient	142	4.49	

Resilient and efficient observations, as seen in Table 33, had approximately 10% lower operating costs, which were statistically different than those for inefficient DMUs. Two columns were drawn from the means' comparison for this variable, indicating that efficient and resilient observations had no significant differences in operating expenses per kg of output. The last indicator in the NZ benchmark set measures how well a farm generates dairy revenue from its assets. The results for this indicator are presented in Table 34.

Table 34

Comparison of Means for Assets Turnover Ratio in Different Classes

Class	n	Asseturnover	
Inefficient	1944	0.15	
Efficient	502		0.25
Resilient	142		0.27

Table 34 supports to the considerable differences between resilient farms and inefficient observations. Inefficient DMUs had an ATR of 0.15 versus 0.25 and 0.27 for the efficient and resilient, respectively, which is a difference 40% more favourable to these two groups (differences between them did not allow for statistical significance). As has happened with physical indicators, the differences found in absolute and statistical terms support the relevance of the selected financial KPIs for NZ dairy farming.

6. Chilean Results.

This chapter presents the Chilean results, consisting of the Data Envelopment Analyses (DEA) and a second stage DEA using recursive partitioning analyses. It follows the same structure and order of Chapter 5, but employs fewer tables given the smaller size of the Chilean sample.

6.1 Data Envelopment Analyses (DEA)

This section presents the Chilean data envelopment analysis results. Table 35 presents a summary for the five year period from 2007 to 2011, while Table 36 shows the results for both milk (L) and gross farm revenue (GFR) analyses for each class[22]. As in Chapter 5, results per class were not strictly comparable since DEA were carried out independently, so significance tests were not attempted at this stage. The considerations about milk and input prices made in Chapter 5 over the period are valid for the present section. According to the Dirección Meteorological of Chile (2007, 2008, 2009, 2010, and 2011), there was a diverse rainfall pattern for the period. In 2007, Valdivia had more than 1,200 mm of rain and Osorno had just less than 900 mm. In 2008, rainfall was 1,995 mm and 1,028 mm, respectively, while in 2009, Valdivia had 1,950 mm and Osorno a maximum of 1,345 mm. In 2010, Valdivia had annual rainfall closer to the average of 1,491 mm, while Osorno totalled 1,041 mm which was similar to the results observed in 2011 which were 1,618 mm and 995 mm, respectively.

Table 35

Weighted Averages for DEA Results by Year

		Weighted Average	
Year	n	MILK	GFR
2007	245	0.893	0.877
2008	231	0.895	0.885
2009	231	0.894	0.880
2010	197	0.898	0.894
2011	124	0.879	0.881
Period	1028	0.893	0.883

[22] Note that the Chilean classification system has been explained in the Method chapter; the system comprises ten classes derived from splitting the sample into years and classifying observations into LOW or HIGH intensity, depending on the supplement feed to the cows, with a cut off value of 2,000 kg/cow/year.

In the results where a score of 1 represents ‘full’ efficiency; the range from 0.95 to 1 is referred to as ‘virtually efficient’; the range from 0.90 to 0.95 is considered ‘very high efficiency’; and from 0.85 to 0.90 is ‘high efficiency’. In 2007 and 2008, the weighted mean milk efficiency was high (0.893, 0.895), and the conversion of inputs into revenue (GFR) was lower but still high (0.877, 0.885). In 2009, the mean physical efficiency was again high (0.894), and the revenue efficiency was considerably lower (0.880). In 2010, both weighted averages increased, but GFR efficiency improved significantly with respect to the previous year; the mean efficiency converting inputs into physical product was 0.898, and the efficiency producing revenue was 0.894. In 2011, there was a distinct fall in physical efficiency (0.879), along with a drop in revenue efficiency to the level experienced in 2009 (0.881). In the whole period, 2007-2011, the weighted mean efficiency was greater producing milk (0.893) than producing revenue (0.883). Overall, in 2007, 2008, 2009, and 2010, the revenue efficiency was below the physical efficiency, though this relationship was inverted in 2011. Table 36 shows more detailed information on the DEA outcomes for the period 2007-11.

Table 36

DEA Results per Class for the Period 2007-11

	n	MILK efficiency		GFR efficiency	
Chilean class		M	SD	M	SD
2007-LOW use of supplements	131	0.87	0.11	0.85	0.12
2007-HIGH use of supplements	114	0.92	0.07	0.91	0.07
2008-LOW use of supplements	113	0.88	0.10	0.87	0.11
2008-HIGH use of supplements	118	0.91	0.08	0.90	0.08
2009-LOW use of supplements	143	0.87	0.10	0.86	0.11
2009-HIGH use of supplements	88	0.92	0.06	0.92	0.06
2010-LOW use of supplements	113	0.88	0.11	0.88	0.11
2010-HIGH use of supplements	84	0.92	0.07	0.91	0.08
2011-LOW use of supplements	66	0.84	0.14	0.85	0.14
2011-HIGH use of supplements	58	0.92	0.08	0.92	0.09

Table 36 shows mean efficiencies and standard deviations for the ten Chilean classes. The milk results ranged from 0.84 (moderately high) to 0.92 (very high), while the standard deviations fluctuated between a relatively low 0.06 to a high 0.14. Similarly, the revenue results ranged from a high 0.85 to a very high 0.92, while the standard deviation fluctuated within the same range. Interestingly, the higher efficiency classes in both milk (0.92) and revenue analyses (0.92) were found in two contrasting years from the milk price stand point, 2009 and 2011, in classes with a HIGH use of supplements. These were followed by other very high efficiency classes in 2007 and 2010, again using HIGH levels of supplements (0.92 and 0.91). Results in all these four classes were tight and standard deviations were consistently low. Also of interest is the fact that the lowest milk efficiency class (0.84) was found in 2011, comprising observations with a LOW use of supplements. This class was only slightly better at producing revenue from the same inputs (0.85). The other lower efficiency class producing revenue (0.85) was found in 2007, also using LOW levels of supplements and producing milk at a higher efficiency level (0.87). Despite a tendency to higher physical than revenue efficiencies, the Chilean milk and revenue scores were very close. The variability tended to be greater in revenue than in milk efficiency and, consistently, all LOW classes showed higher standard deviation values in both measures of efficiency.

6.2 Recursive Partitioning Tree results

As explained in Chapter 5, both the milk and revenue efficiency scores obtained in the Chilean DEA stage were attached to the complete original dataset and subsequently used to develop a series of country-specific RP trees using the efficiency scores as the response variable *y*. This section presents the milk trees first and later the revenue trees, followed by a summary with the identified indicators.

6.2.1 Milk results.

Figure 17 shows the milk efficiency tree obtained from the regression of DEA estimates on all 90 discretionary and non-discretionary inputs and ratios contained in the *TodoagroBase* (refer Appendix 2). The diagram shows 11 terminal nodes on two major branches split by the root variable, litres of milk per cow (L/Cow), at a threshold value of 4,664 L.

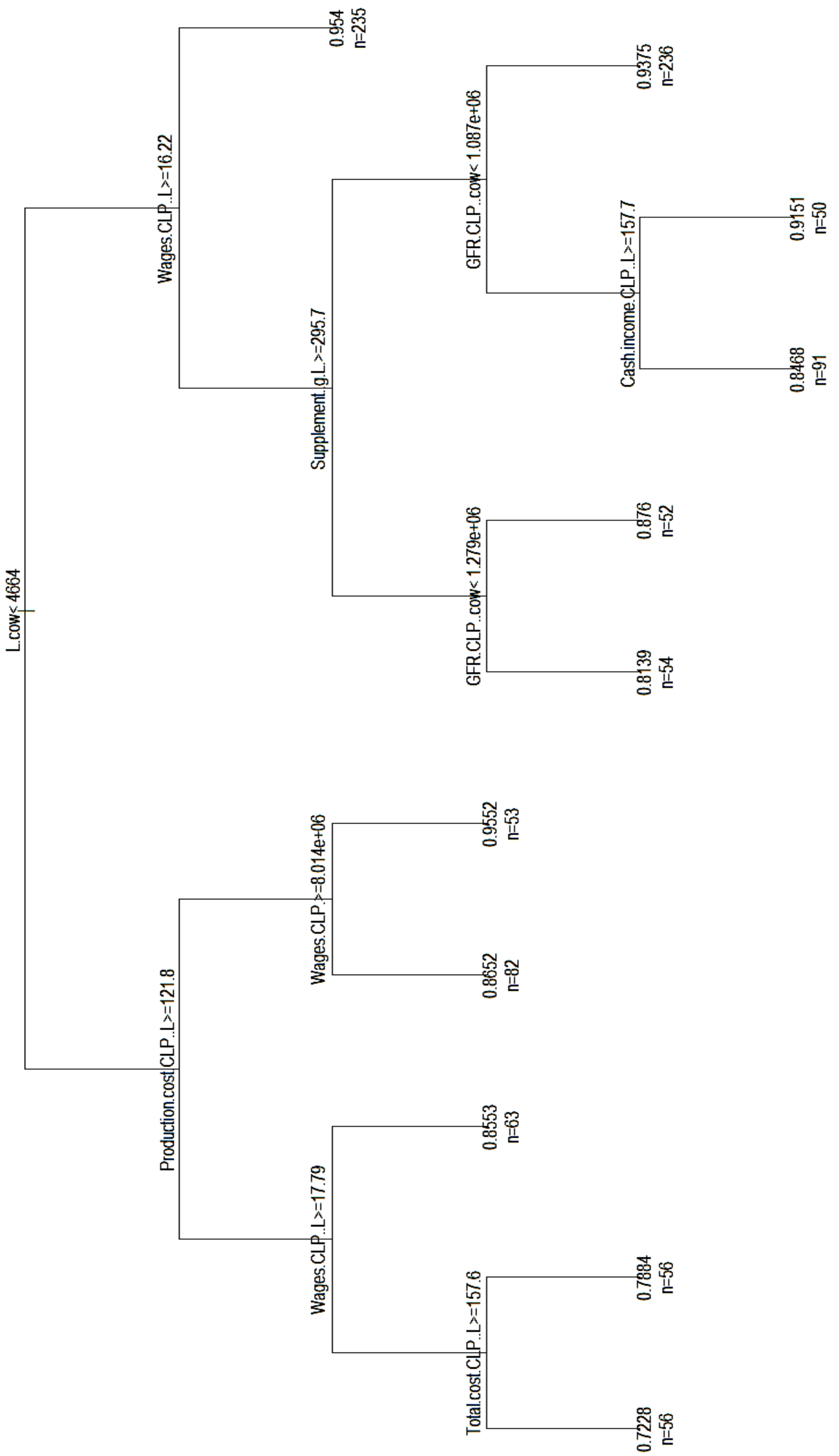

Figure 17. MS DEA partitioning tree.

The root variable, litres per cow, split the sample into right and left branches. The right branch accounted for more than two thirds of the sample, clustering those DMUs producing more than 4,664 L/cow and year. One virtually efficient class (0.954, n = 235) was drawn as the result of a second split made by the ratio wages paid per litre of milk. The threshold value was CLP$16.22/L, equivalent to NZ$0.41[23] per 10 L of milk[24]. The second best efficiency class (0.9375; n=236) in this branch had a higher wages ratio and used less than 295.7 g/L of supplements, but almost offset these with a gross farm revenue per cow greater than CLP$1.087 million, equivalent to NZ$2,764 per cow. These two large classes made up almost half of the total sample.

The root variable split just over one third of the Chilean sample into the left branch. The least efficient class (n = 56) was found on this branch at the end of the outer pathway. It had an average efficiency of 0.7228, which resulted from the combination of lower production per cow, a higher than the threshold value for production costs and wages, and also a higher total cost, including rent and interests. The second split on this branch was the ratio production costs per litre of milk, which is a Chile-specific variable similar to the well-known farm working expenses in New Zealand (see definition Chapter II). The critical value was CLP$121.80/L, equivalent to NZ$3.10 per 10 L of milk. The third split was again the wages ratio at the threshold value of CLP$17.79/L, equivalent to NZ$0.45 per 10 L of milk produced.

Following the same reasoning as with the New Zealand sample, a modification was carried out to expose any hidden relationships among the less strong variables. Figure 18 shows a second tree generated by using the same DEA scores based on the milk output, with six milk-related ratios excluded from the dataset (the analysis regressed DEA estimates on 84 variables).

[23] Based on an exchange rate of CLP$394.65 per NZ$.

[24] Based on the assumption that 10 litres of Chilean milk (3.4% Protein, 3.7% Fat) would be roughly equivalent to one kilogram of milk solids.

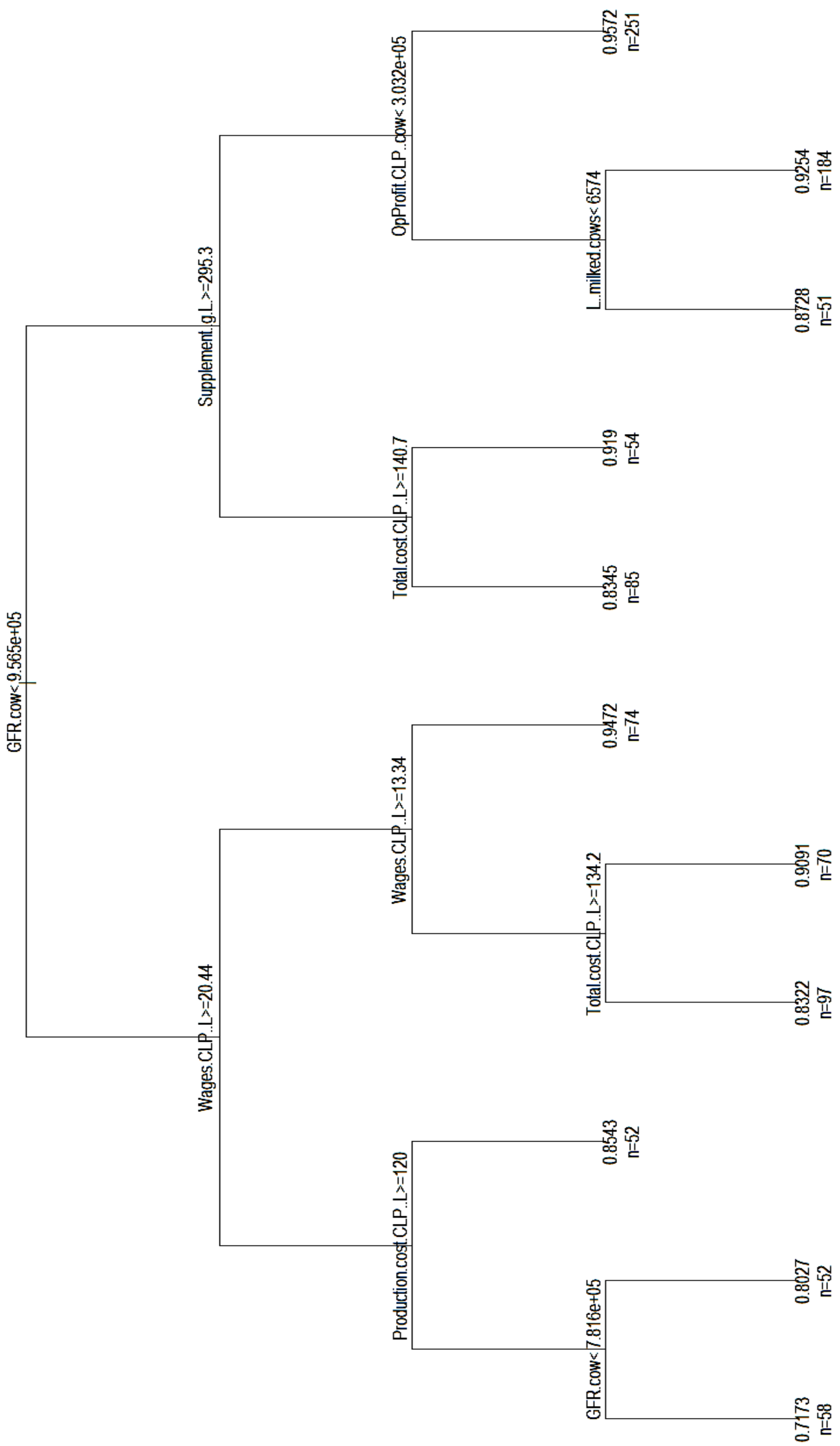

Figure 18. Modified MS DEA partitioning tree.

Figure 18 revealed new relationships, but these were fewer than expected. Only two different variables came out compared to those in Figure 17: operating profit per cow, and litres produced per milked cow. It is worth clarifying that 'milked cows' are the average number of cows effectively milked throughout the year, which is different from 'total cows' which includes milked, pregnant, and empty cows on the farm. These new variables appeared at the third and fourth levels, respectively. The root variable changed from L/cow, which was exempt from available variables, to gross farm revenue per cow, confirming a strong association between these two ratios.

The right branch clustered 625 observations that had gross farm revenue per cow higher than CLP$956,500, equivalent to NZ$2,424. The second level split was made by the ratio Supplement fed per litre of milk, at the threshold value of 295.3 g/L. DMUs using lower levels of supplement were further split to the outer side. Following this pathway, operating profit created the highest efficiency class (0.9572, n = 251), exhibiting a profit per cow greater than CLP$303,200, equivalent to NZ$768/cow. The third highest efficiency class (0.9254) comprised those 184 observations that had a lower profit than the threshold and also produced more than 6,574 L/milked cow.

The root variable also split 403 observations to the left branch. Surprisingly, the second best efficiency class (0.9472) was located on this branch, at the end of a very different pathway than that followed to reach the best performing leaf. This second best class had a lower revenue per cow than the threshold, but this was offset by a lower than CLP$13.39 or NZ$0.34 per 10 L value for wages per litre of milk produced. In contrast, the lowest efficiency class also had a lower revenue per cow, but a much higher value of wages per litre at CLP$20.44 or NZ$0.52 per 10 L; this infers that paid labour was 53% less productive on these low efficient observations. This class was also affected by higher direct costs of production, and again, GFR CLP$/cow. Table 37 highlights the order and frequency of appearance of the variables exposed by both trees based on milk DEA results, from root to fourth level split as revealed by Figures 17 and 18.

Table 37

Key Performance Indicators (KPIs) as Revealed by MS Trees

	KPI	Level
Figure 17	L/cow	1ST
	Wages CLP$/L	2ND R
	Production cost CLP$/L	2NDL
	Supplement g/L	3RD R
	Wages CLP$/L	3RD L
	GFR CLP$/cow	4TH R
	Total cost CLP$/L	4TH L
Figure 18	GFR CLP$/cow	1ST
	Supplement g/L	2ND R
	Wages CLP$/L	2NDL
	Operating profit CLP$/cow	3RD R
	Production cost CLP$/L	3RD L
	L/VO	4TH R
	Total cost CLP$/L	4TH L

Benchmarks, such as L/Cow, GFR/cow, Supplement g/L, and Wages/L, appeared as very strong variables at the first, second, third, and fourth levels, and repeatedly played a role in the physical–oriented trees. The structure of these trees is more or less similar to that found for the New Zealand trees. The milk production ratio per cow consistently appeared on top fo the tree, and labour, expenditure, and profit also came out as strong variables.

6.2.2 GFR results.

The following results used DEA scores based on the economic output, GFR, instead of milk production. Figure 19 presents a tree based on an analysis that included all Chilean DMUs, ratios, and variables.

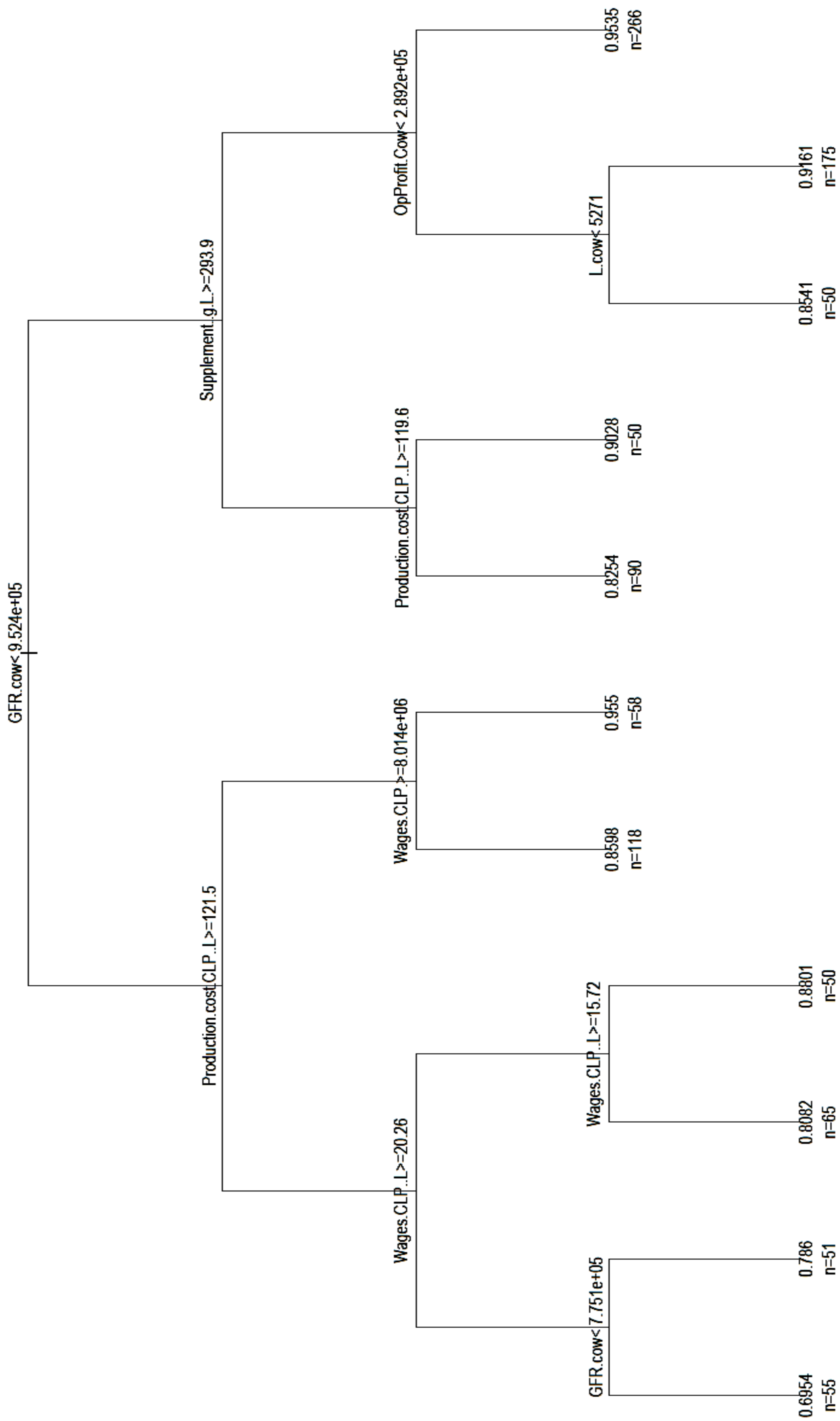

Figure 19. GFR DEA partitioning tree.

Figure 19 exposed 11 terminal nodes and four levels of partition. The top level variable was again gross farm revenue per cow at the critical value of CLP$952,400/cow, equivalent to NZ$2,413. The sample was split into the right (n = 631) and the left branch (n = 394). The 631 observations on the right branch had GFR per cow higher than the threshold value and were clustered into five leaves. The second split on supplement fed to the cows (g/L) led to the largest class (0.9535, n =266), comprising the observations that combined lower than 293.9 g/L use of supplement, with an operating profit higher than CLP$289,200/cow, equivalent to NZ$733.

On the left branch, six small classes were drawn, including the highest efficiency class (0.955, n = 58). DMUs at lower than the threshold value for the root variable were further split by direct production cost per litre at the critical value of CLP$121.50. The highest efficiency class comprised observations with lower production costs that paid less than CLP$8.014 million or NZ$20,307 in total wages. In contrast, the lowest efficiency class (0.6954, n = 55) was found at the end of the outer pathway and had a higher production cost; it paid more than CLP$20.26/L on wages and exhibited a GFR lower than CLP$75,100 or NZ$1,964 per cow.

In the search for new interactions and replicating the succession of steps taken with the New Zealand data, a modified tree was proposed based only on inefficient farms. This subsample, consisting of 807 DMUs with revenue efficiency score below 1, was set apart from 222 efficient farms (DEA score = 1). Figure 20 presents a tree including all Chilean ratios, and variables but excluding all efficient (score = 1) observations.

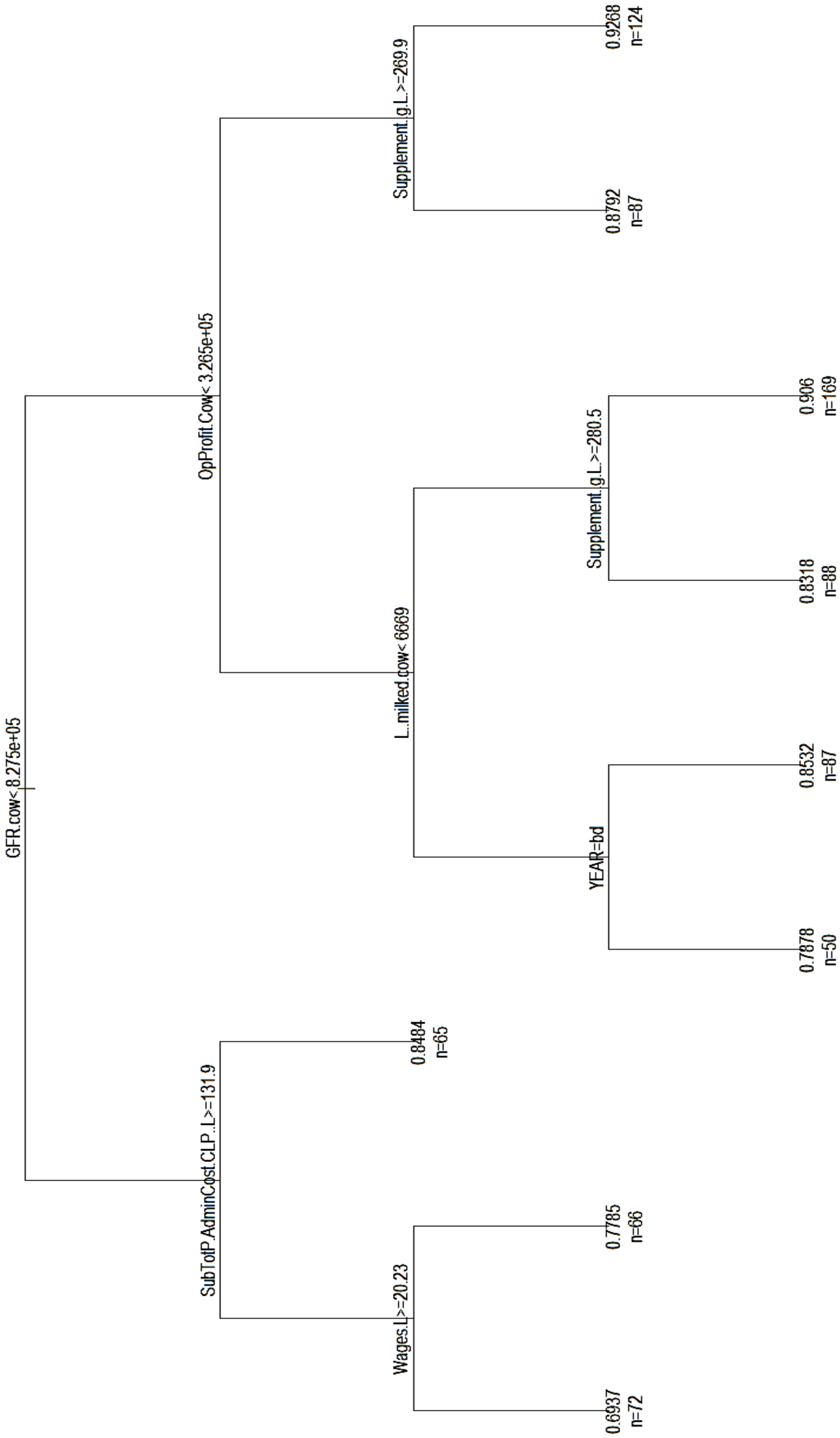

Figure 20. Modified GFR DEA partitioning tree.

Figure 20 presents the fourth tree of the series. Similar to Figures 18 and 19, it had gross farm revenue per cow as the root node at a lower threshold of CLP$827,500, and it split the sample into 605 observations to the right and 202 to the left. In fact, the variables were almost the same as those that appeared in the previous trees, but the critical values all tended to be lower. Interestingly, 'Year' came out as a fourth level variable, which never happened before in the previous trees. This suggests that in 2011 (b) and 2007 (d), there was a price component affecting revenue efficiency that could not be removed by the class-specific DEA. Table 38 highlights the order and frequency of appearance of the variables exposed by both trees based on revenue DEA results, from root to fourth level split as revealed by Figures 19 and 20.

Table 38

Key Performance Indicators as Revealed by GFR Trees

	KPI	Level
Figure 19	GFR CLP$/cow	1ST
	Supplement g/L	2ND R
	Production cost CLP$/L	2NDL
	Operating profit CLP$/cow	3RD R
	Wages CLP$	3RD L
	L/cow	4TH R
	Wages CLP$/L	4TH L
Figure 20	GFR CLP$/cow	1ST
	Operating profit CLP$/cow	2ND R
	Subtotal Prod,Adm Costs CLP$	2NDL
	L/VO	3RD R
	Wages CLP$/L	3RD L
	Year 2008 and 2007	4TH R

In summary, as in the NZ case the RPT approach applied to *TodoagroBase* showed multiple pathways to achieve a high efficiency; revealed those important indicators in defining efficiency classes; presented a number of threshold or pivotal values that determine the pathway and the class where a particular DMU may sit; and ultimately exposed the pathway or combination of indicators that identified homogenous groups accounting for different dairy performances in Chile.

6.2.3 The fifth Chilean tree

The striking absence of return on assets (ROA), and return on equity (ROE) in the Chilean trees was addressed by running a final tree that only included 862 observations whose asset values were considered reliable. The tree is presented in Appendix 5, and shows assets turnover (ATR) came out as the root variable at the pivotal value of 29.5%, accompanied by the ratio production costs per litre of milk and, again, ATR at the second level. The persistent absence of ROA coming out as a KPI was noticeably and a possible explanation will be addressed in the discussion (Chapter VIII).

6.3 Chilean Benchmarks Set

The previous analyses suggested a set of benchmarks appropriate to describe the Chilean sample. These comprised variables and ratios that acted at the first, second, and third levels on the trees presented earlier. Table 39 shows this set divided into two groups depending on whether they were physical or financial indicators.

Table 39

Chilean Benchmarks Set Comprising Physical and Financial KPIs

Benchmarks set	
Physical KPIs	Financial KPIs
L/cow	GFR CLP$/cow
Supplement g/L	Wages CLP$/L
	Production cost CLP$/L
	Operating profit CLP$/cow

The tree presented in Appendix five used efficiency scores estimated using backwards calculated assets as an input in DEA for a small group of observations for which there was more confidence in the reliability of the data. Appendix five shows that ATR comes out as the root variable and again at the second level would suggest that the methodology was sensitive to the inclusion/exclusion of assets. It also meant that ATR could be included in the list of financial benchmarks. However it was not because there was little confidence in the asset values and, therefore, it could not be included as a key descriptor.

The Chilean sample was grouped using the previously explained criteria to classify DMUs: inefficient, efficient, and resilient DMUs. Inefficient observations (score < 1 in any of two milk or revenue efficiencies) were set apart and made up the largest group (n = 752). The remaining 276 efficient DMUs (score = 1 in both milk and revenue efficiencies) were clustered by farm ID and split into efficient once or twice (n = 200), and consistently efficient or resilient three or more times (n = 76, called) over the five year period. As happened in the NZ case, the fact that *TodoagroBase* contains unbalanced panel data could have resulted in a resilient farm being classified as non-resilient just because it had insufficient number of records (minimum of three). Results are presented as a summary (Table 40) containing descriptive statistics of physical indicators for each class, followed by indicator–specific significance tests. Statistical significance was reflected in the number of subsets of means drawn for a *p* value of 0.05. Significance Schaffe tests for unequal class sizes were conducted to compare the groups by using one way ANOVA. Financial indicators were then introduced in a similar layout. Descriptive statistics of physical variables of interest are shown in Table 40.

Table 40

Descriptive Statistics in Physical KPIs

		n	M	SD	MIN	MAX
L.cow (VM)	Resilient	44	5472	1842	2029	8971
	Efficient	154	5450	1886	1706	10552
	Inefficient	830	5437	1327	1735	8910
	Total	1028	5441	1447	1706	10552
Supplement (g/L)	Resilient	44	183	98	0	330
	Efficient	154	176	102	0	465
	Inefficient	830	224	78	16	527
	Total	1028	215	85	0	527

Table 40 shows that over the five year period, all groups produced, on average, almost the same output per cow. However, differences can be found looking at subsamples' characteristics other than the mean: the groups of the resilient and efficient showed greater variability than inefficient DMUs, as indicated by the standard deviation values. Resilient DMUs also exhibited the highest minimum and a moderately high maximum. Interestingly, the efficient DMUs exhibited the highest maximum and the lowest minimum, along with the greatest variability.

All classes achieved these results by using variable levels of supplement per litre of milk produced. Again, the greatest variability is shown by the efficient DMUs. These, and the resilient farms, used less supplement than the sample mean (215 grams per litre), with some DMUs not using supplements at all. In contrast, the Inefficient DMUs used supplements at levels well above the mean with a minimum of 16 g/L. Also of interest were the maximum values for by each class: resilient farms used up to 330 g/L; efficient DMUs used up to 465 g/L; and the group of inefficient observations exhibited a maximum of 527 g/L. Tables 41 and 42 show the comparison of means for the indicators of interest.

Table 41

Comparison of Means for Litres per Cow Indicator (L/cow)

Class	n	L/cow
Inefficient	830	5437
Efficient	154	5450
Resilient	44	5472

The comparison of means identified no significant differences between the groups for the physical indicator of production 'L/cow'. Table 41 shows that the figures that looked very similar at a glance, were not significantly different one from another. Table 42 shows the ANOVA for the indicator 'Supplement g/L'

Table 42

Comparison of Means for Supplement Used Per Litre of Milk produced (g/L)

Class	n	Supplement (g.L)	
Inefficient	830		224
Efficient	154	176	
Resilient	44	183	

The mean use of supplement per litre of milk produced was significantly different between the resilient and efficient, and the inefficient groups. On average, inefficient DMUs used 22.4% more supplements than the resilient farms and 27.3% more than the efficient observations. Considering that production per cow from the inefficient group averaged 5,437 L/cow, the extra supplement is equivalent to an extra 223 and 261 kilograms of feed per cow, respectively.

Descriptive statistics on financial indicators of interest are shown in Table 43.

Table 43

Descriptive Statistics of Financial Indicators

		N	M	SD	MIN	MAX
GFR CLP$/cow	Resilient	44	1057330	383865	343785	1772877
	Efficient	154	1086500	466702	318046	3856439
	Inefficient	830	1051410	286250	300090	1833900
	Total	1028	1056920	323907	300090	3856439
Wages CLP$/L	Resilient	44	17.5	7.3	5.7	35.9
	Efficient	154	15.6	6.4	5.3	48.0
	Inefficient	830	21.1	8.3	4.6	106.6
	Total	1028	20.2	8.3	4.6	106.6
Production cost CLP$/L	Resilient	44	124.0	25.9	66.5	185.0
	Efficient	154	115.3	29.1	57.9	258.5
	Inefficient	830	131.9	27.6	67.2	279.0
	Total	1028	129.1	28.4	57.9	279.0
SubTot Prod,Adm CLP$/L	Resilient	44	137.0	26.2	78.0	195.3
	Efficient	154	127.9	29.1	72.6	261.2
	Inefficient	830	146.0	28.7	88.0	356.6
	Total	1028	142.9	29.4	72.6	356.6
OpProfit CLP$/Cow	Resilient	44	264565	188129	-117156	589697
	Efficient	154	332365	242094	-309328	945882
	Inefficient	830	206434	208872	-1126574	814844
	Total	1028	227787	217936	-1126574	945882

Similar to that observed for the physical indicator, 'L/cow,' differences in mean GFR per cow were small between the groups. The comparison of means using the Schaffe test indicated that there were no statistical differences either. Again, only differences were found by looking at other descriptive measures. The resilient and efficient observations showed much greater variability than the group of inefficient DMUs, as denoted by the standard deviation values. Interestingly, the resilient farms had the smallest range, with the highest minimum and the lowest maximum. Also of interest was that the efficient DMUs had the highest maximum and the second lowest minimum, along with the greatest standard deviation.

Differences were significant when the other indicators were analysed. The three classes spent very differently as demonstrated by results on three different cost ratios per litre of milk produced: wages, direct costs of production, and the sum of production and administration costs. The group of resilient farms showed an intermediate behaviour in all indicators considered, having the lowest standard deviation in the production, and production plus administration cost ratios. This group also showed the lowest variability in operating profit per cow. The efficient DMUs performed well overall: they exhibited the highest mean revenue and profit, but also the lowest minimum cost ratios. Their weakness as a group is their high variability in all these parameters as demonstrated by they low minimums and high maximums, which in almost all cases resulted in high standard deviations.

Table 44 shows the comparison of means for the wages ratio.

Table 44

Comparison of Means for the Wages ratio (CLP$/L)

Class	n	Wages CLP$/L	
Inefficient	830		21
Efficient	154	16	
Resilient	44	18	

The wages paid per litre of milk produced were not significantly different between the resilient and efficient DMUs, and both had significantly lower wage ratios than the inefficient group. This pattern changed when more inclusive ratios were taken into account.

Table 45 present the comparison of means for the indicator of direct production costs.

Table 45

Comparison of Means for the Production Cost Indicator (CLP$/L)

Class	n	Production cost CLP$/L	
Inefficient	830		132
Efficient	154	115	
Resilient	44	124	124

Production cost per litre of milk produced as well as the subtotal of production plus administration cost showed a similar behaviour. Tables 45 shows that the resilient and efficient groups had no significant differences in terms of expenditure, with only the efficient group having a mean significantly lower than the inefficient group.

Table 46 shows the comparison of means for the operating profit per cow indicator

Table 46

Comparison of Means for the Operating Profit per Cow Indicator (CL$/Cow)

Class	n	OpProfit CLP$/Cow	
Inefficient	830	206434	
Efficient	154		332365
Resilient	44	264565	264565

The resilient farms had no significant differences regarding mean operating profit per cow when compared against the efficient observations. However, neither had any differences related to the inefficient group. In turn, the mean operating profit exhibited for this last group was significantly lower when compared against the group of efficient DMUs.

7. Metafrontier Analyses.

Chapter 7 presents the individual New Zealand and Chilean metafrontier results, followed by a metafrontier analysis across both countries for two selected years of interest. A 'good' year was represented by the 2010/11 season in New Zealand and the 2011 year in Chile, while the contrasting 'poor' year was the 2008/09 season in New Zealand and the 2009 year in Chile. Inputs used in these analyses were only three: herd size (cows), supplements (kg/cow), and CPI–adjusted operating expenses expressed in US$. The selection of inputs was reduced to the variables present in both databases that were reliable, and were selected to keep consistency with the previous efficiency analyses. Assets were deliberately excluded from the metafrontier analyses because of the unreliability of the backwards calculation in *TodoagroBase.*

Despite the default output in this type of technical efficiency analysis is 'milk', expressed either in kilogram of milk solids or in litres, the metafrontier output was CPI-adjusted gross farm revenue, also expressed in US$. The use of this variable so affected by output price was the straightforward option given the lack of information about milk solids' content in *TodoagroBase*. Alternatives to this could have been the use of several assumptions to correct litres of milk contained in *TodoagroBase* to energy corrected milk (ECM) using the IFCN methodology. However, the revenue option avoided using the assumptions, while price information meant the results could be contextualised in the discussion.

Similar to Chapters 5 and 6, a summary table per country shows the descriptive statistics for the metafrontier results and the inputs/outputs used, followed by a series of tables showing statistical differences revealed ANOVA and Schaffe tests.

7.1 New Zealand Metafrontier Results

The New Zealand metafrontier used all the observations, across all years, totalling 2,588 DMUs. Table 47 presents the descriptive statistics for the metafrontier results first, then the output and the three inputs used in the New Zealand metafrontier efficiency analysis.

Table 47

Descriptive Statistics and Inputs/Output used for Metafrontier Efficiency in New Zealand

		n	M	SD	MIN	MAX
Metafrontier efficiency						
	200607	618	0.37	0.11	0.16	1
	200809	496	0.37	0.11	0.19	1
	200910	564	0.41	0.11	0.22	1
	201011	296	0.48	0.12	0.28	1
	200708	614	0.51	0.14	0.25	1
Period		2588	0.42	0.13	0.16	1
GFR CPI US$						
	200809	496	702,635	576,887	62,802	4,621,358
	200910	564	850,997	653,930	90,615	5,116,878
	200708	614	1,029,702	864,510	131,996	7,367,019
	200607	618	569,488	426,677	74,268	3,981,424
	201011	296	1,024,704	852,500	195,351	6,316,417
Period		2588	817,605	702,279	62,802	7,367,019
CPI OPEX US$						
	200809	496	560,311	492,399	57,822	4,168,995
	200910	564	542,761	414,478	68,872	3,489,759
	200708	614	562,436	450,873	57,245	3,975,797
	200607	618	400,064	307,174	79,361	3,137,947
	201011	296	573,093	465,332	113,133	3,058,534
Period		2588	520,186	428,666	57,245	4,168,995
Peakcows						
	200809	496	459	353	60	2,894
	200910	564	461	318	55	2,800
	200708	614	424	310	60	2,966
	200607	618	408	281	99	2,800
	201011	296	444	338	87	3,100
Period		2588	437	318	55	3,100
Supplement kg/cow						
	200809	496	313	232	0	2,308
	200910	564	339	249	0	1,936
	200708	614	329	258	0	2,029
	200607	618	335	234	0	1,781
	201011	296	317	222	0	1,545
Period		2588	328	242	0	2,308

As expected, the metafrontier scores were lower than the individual year results presented in Chapter 5, which were in the range of 0.8 to 0.9. The highest average efficiency was observed in 2007/08, and the lowest in 2006/07. The standard deviation values were relatively low though, which suggests moderate variability and consistent results. The lowest minimum value (0.16) was recorded in 2006/07, and the highest minimum value was estimated in 2010/11 (0.28). The years with lower efficiencies had lower milk prices and, conversely, the higher efficiency years had higher milk prices.

Table 48 shows the annual comparison of means for the metafrontier efficiency scores.

Table 48

Comparison of Means for the Metafrontier Scores

Class	n	Metafrontier efficiency			
200607	618	0.37			
200809	496	0.37			
200910	564		0.41		
201011	296			0.48	
200708	614				0.51

Efficiency producing revenue over all the years were significantly different from each another, except for 2006/07, which was statistically similar to 2008/09. Efficiency was relatively low during 2006/07 (0.37) due to a comparatively low milk price, then efficiency peaked in 2007/08 (0.51) and came back to the 2006/07 level in 2008/09 (0.37). In 2009/10, it was significantly higher again (0.41), and continued to increase in 2010/11 (0.48). A similar pattern can be observed in Table 49 for the metafrontier output, CPI-adjusted gross farm revenue.

Table 49

Comparison of Means for the CPI -adjusted Gross Farm Revenue

Class	n	CPI GFR US$		
200607	618	569,488		
200809	496	702,635		
200910	564		850,997	
201011	296			1,024,704
200708	614			1,029,702

The comparison of means shows a similar pattern to the average metafrontier scores through the period, except for years 2007/08 and 2010/11 that were similar in statistical terms. Interestingly, the CPI-adjusted GFR increased 81% from the beginning to the end of the period, whereas efficiency only improved by 38%. Table 50 presents the comparison of means for the CPI-adjusted operating expenses.

Table 50

Comparison of Means for the CPI-Adjusted Indicator Operating Expenses

Class	n	CPI OPEX US$	
200607	618	400064	
200910	564		542761
200809	496		560311
200708	614		562436
201011	296		573093

Total operating expenditure, on average, was only statistically different from other years in 2006/07. It is interesting that even when facing a bad milk price scenario in 2008/09, expenses were not significantly lower or higher than other more favourable years. This suggests a high share of fixed costs in total expenses in New Zealand. Throughout the period, and under ANOVA and Schaffe tests, there were no significant differences in the average size of the herd or in the use of supplements per cow, which were two inputs also used in the metafrontier analysis.

7.2 Chilean Metafrontier

The Chilean metafrontier used the observations across all years, totalling 1,028 DMUs. Table 51 presents descriptive statistics of results, output and inputs used .

Table 51

Descriptive Statistics and Inputs/Output used for Metafrontier Efficiency in Chile

		n	M	SD	MIN	MAX
Metafrontier efficiency						
	2007	245	0.68	0.11	0.47	1
	2008	231	0.74	0.10	0.51	1
	2009	231	0.56	0.12	0.34	1
	2010	197	0.67	0.12	0.42	1
	2011	124	0.72	0.11	0.47	1
Period		1028	0.67	0.13	0.34	1
CPI GFR US$						
	2007	245	569,645	509,866	37,934	4,079,934
	2008	231	674,610	543,042	38,001	4,276,795
	2009	231	403,872	371,571	18,120	2,591,149
	2010	197	685,142	617,539	44,454	4,289,108
	2011	124	904,760	919,340	50,684	5,972,281
Period		1028	618,536	595,916	18,120	5,972,281
CPI OPEX						
	2007	245	426,303	389,302	27,097	3,536,960
	2008	231	477,375	386,868	26,105	2,998,412
	2009	231	359,477	320,961	16,398	1,956,635
	2010	197	554,249	483,154	40,191	2,990,723
	2011	124	657,845	698,207	33,940	4,596,861
Period		1028	475,211	452,043	16,398	4,596,861
Cows						
	2007	245	250	182	25.3	1207
	2008	231	251	167	22	1225
	2009	231	270	199	29.2	1404
	2010	197	292	221	32	1738
	2011	124	369	306	24	2118
Period		1028	277	212	22	2118
Supplement Kg/cow						
	2007	245	1252	671	3	2697
	2008	231	1323	660	2	2652
	2009	231	1128	651	0	2680
	2010	197	1152	591	0	2609
	2011	124	1370	606	4	2683
Period		1028	1235	647	0	2697

As expected, the metafrontier scores were lower than the individual year results presented in Chapter 6, with most of these in the range 0.8 to 0.9. The highest and lowest average efficiencies were recorded in 2008 (0.74) and 2009 (0.54). The results were consistent as shown by relatively low standard deviation values. The lowest minimum value (0.34) was recorded in 2009, and the highest minimum value was estimated in 2011 (0.51). Table 52 shows the comparison of means for the metafrontier efficiency scores.

Table 52

Comparison of Means for the Metafrontier Scores

Class	n	Metafrontier efficiency		
2009	231	0.56		
2010	197		0.67	
2007	245		0.68	
2011	124			0.72
2008	231			0.74

The metafrontier efficiency in 2009 was significantly lower than the rest of the period. The years 2010 and 2007 were characterised by intermediate mean efficiencies, while the years 2011 and 2008 stood out with higher mean efficiencies. Throughout the period, there were alternative highs and lows, which may reflect the influence of weather and price shocks. Overall, New Zealand and Chile behaved in similar ways: the New Zealand 2008/09 season can be compared to the Chilean 2009 year, even if not exactly the same time period. Correspondingly, the New Zealand 2010/11 season can be compared to the Chilean 2011 year. Table 53 shows the comparison of means for the CPI-adjusted gross farm revenue.

Table 53

Comparison of Means for the CPI-Adjusted Gross Farm Revenue

Class	n	CPI GFR US$		
2009	231	403,872		
2007	245	569,645	569,645	
2008	231		674,610	
2010	197		685,142	
2011	124			904,760

The mean GFRs in 2009 and 2007 were not statistically different. In addition, 2007 was found to be statistically no different from 2008 and 2010. The 2011 year was clearly different from the others, exhibiting very high mean revenue. Interestingly, the CPI-adjusted GFR was 59% higher in 2011 than at the beginning of the period (2007), and more than doubled the US$403,872 average in 2009. As in the New Zealand analysis, the changes in efficiency were smoother than the fluctuations observed in mean gross farm revenue; in addition, the greatest difference between maximum and minimum efficiencies was in the order of 32%. Table 54 presents the comparison of means for the CPI-adjusted operating expenses.

Table 54

Comparison of Means for the CPI-Adjusted Operating Expenses

Class	n	OPEX US$		
2009	231	359,477		
2007	245	426,303	426,303	
2008	231	477,375	477,375	
2010	197		554,249	554,249
2011	124			657,845

From 2007 to 2011, despite fluctuations, there was an overall trend in increasing operating expenses over time. However, there were no statistical differences in operating expenditure in the first three years of the period. Similarly, operating expenses in 2007, 2008, and 2010 were not statistically different, while the expenditure in 2010 was similar to that of 2011. The minimum mean expenditure was recorded in 2009, and the maximum in 2011. Table 55 presents the comparison of means for the input variable, herd size.

Table 55

Comparison of Means for the Physical Input Cows

Class	n	Cows	
2007	245	250	
2008	231	251	
2009	231	270	
2010	197	292	
2011	124		369

Herd size showed an increasing trend. However, only the last year of the period was significantly different from the rest of the years. This trend to increasing numbers of cows in the herd was accompanied by a similar tendency towards intensification, as denoted by the higher use of supplements per cow found in Table 56.

Table 56

Comparison of Means for the Physical Input Supplements per Cow

Class	n	Supplement Kg/cow	
2009	231	1128	
2010	197	1152	
2007	245	1252	1252
2008	231	1323	1323
2011	124		1370

The beginning of the period in 2007 showed a moderate use of supplements at 1,252 kg/cow on average. This was not statistically different from the supplements used in 2008, 2009, 2010, and 2011. However, there were differences between supplement feed to the cows in 2011 relative to 2009 and 2010, which were at a lower level in response to an unfavourable milk:feed price ratio.

7.3 Metafrontier across countries

The last section in this Chapter presents the metafrontier across countries, using CPI-adjusted gross farm revenue (US$) as the single output. CPI-adjusted operating expenses (US$), cows, and supplement (kg/cow) were used as inputs. Descriptive statistics for these output and inputs can be found in the previous sections.

The cross-country metafrontier addresses the research question of which country is more efficient and why. From the previous analyses, two contrasting years were chosen and metafrontier analyses conducted separately for them. These years are considered contrasting because of both price and climate: in both countries, 2008/09 and 2009 represent a poor year for New Zealand and Chile, respectively, and 2010/11 and 2011 a good year. Note that a relatively less favourable weather scenario affected the New Zealand pastoral season in 2010/11, with officially declared areas of drought across the country (MAF, 2011). Therefore, the metafrontier results must be interpreted with care. In addition, it must be remembered that the years do not refer to exactly the same period, since New Zealand uses the agricultural year (June-May), while Chile uses a calendar year (January-December). In addition, results across years are not strictly comparable since different farms made up the samples each year. Figure 21 shows the descriptive statistics for the two New Zealand years, 2008/09 and 2010/11, and their Chilean counterparts, 2009 and 2011.

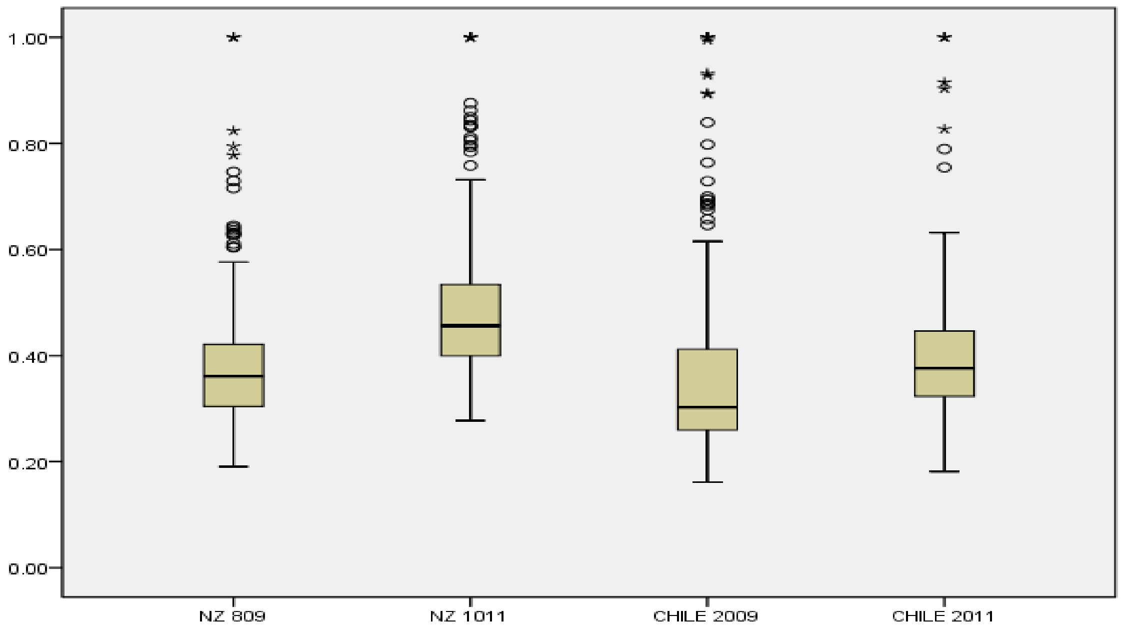

Figure 21. Boxplot of metafrontier efficiency across countries.

The horizontal lines across the boxes in the box plot represent the medians for each country–year combination. Those in the top quartile (25%) with the higher efficiency are shown by the top ‘whisker’ and dots. Dots usually represent outliers but, in this case, these are DMUs with distinctively high efficiency scores. Conversely, the bottom ‘whisker’ represents the lower quartile and, although they may occur, there were no low efficiency dots in any of the country-year combinations. The whiskers ends show the minimum values present in each subset. The poor year, 2008/09, severely affected revenue efficiency in New Zealand (mean = 0.38), which was consistently below the mean for the whole period (0.41), with a relatively low standard deviation (0.11) in a relatively large sample (n = 494). In the equivalent year in Chile (2009), the Chilean sample (n = 231) had a lower efficiency (0.37) and also greater variability (0.18) than the New Zealand sample. Differences in average efficiencies between *DairyBase* and *TodoagroBase* samples during the poor year were not significant. Table 57 presents the comparison of means for the metafrontier across countries in the selected years of interest.

Table 57

Comparison of Means for the Metafrontier across Countries

Class	n	Metafrontier efficiency		
CHILE 2009	231	0.37		
NZ 0809	494	0.38		
CHILE 2011	124		0.41	
NZ 1011	293			0.49

The good year, 2010/11 in New Zealand and 2011 in Chile, showed a recovery in efficiency for both countries. The mean efficiencies were both significantly higher than those observed in the poor year. New Zealand's mean efficiency (0.49) was also significantly higher than the Chilean mean efficiency (0.41) and, despite the smaller samples, the variability in the results was greater on average, as shown by standard deviation values of 0.13 (New Zealand) and 0.15 (Chile). The minimum metafrontier efficiency score observed in New Zealand in 2008/09 was 0.19 and in Chile in 2009, it was 0.16. The minimum estimates in the good years were 0.28 and 0.18, respectively. It is clear that in these types of years, there are Chilean observations doing very well, and also very badly, as demonstrated by standard deviations.

Means comparison were also carried out with the inputs used in the construction of the metafrontier, which were the same as those used in the country-specific metafrontier (refer to Tables 47 and 51). The significance tests showed that in the poor year, gross farm revenue was significantly lower in Chile compared to New Zealand, and both revenues were significantly lower than those observed in 2011, but not significantly different one from the other. However, in 2009, the mean expenditure was also significantly lower in Chile than the expenditure means for the other three country-year combinations (no difference between them). In addition, the use of supplements was significantly lower in New Zealand than in Chile for all the years under review

8. General Discussion.

The purpose of this study was to describe and compare key drivers of NZ and Chilean pasture-based dairy farming systems. These countries are natural benchmarking partners, since farms in both of them transform similar inputs or resources, into similar outputs or products (Bogetoft & Otto, 2011). The systems were assessed in terms of their internal resources, key performance indicators, and drivers of success. This chapter discusses the key findings presented in the results (Chapters 5, 6 and 7) and their implications. Three independent sources of data were used to assess and benchmark the NZ and Chilean pastoral systems. The International Farm Comparison Network data was used at the individual farm businesses level, while at the farming systems level, the research used longitudinal panel data from *DairyBase* from NZ and *TodoagroBase* from Chile.

The IFCN farm to farm comparison (Chapter 4) confirmed the expected international level of competitiveness and the cost advantages in both countries. The typical farms in each country were able to profitably produce milk at a lower cost than the world's average. These farms demonstrated Porter's (1980) cost efficiencies, effectively outperforming other farms in the IFCN comparison when their cost profiles were analysed, and exhibiting technically feasible input-output combinations. The cost advantages in agricultural systems are found in those countries or regions where particular climate, soil conditions, or labour supply allow more efficient farming than in other regions (Kay, Edwards & Duffy, 2012). Both countries exhibited all these characteristics in their non-mountainous territory (approximately half of the total area) which contributes to them being lower cost producers compared to the world's average.

The assumption of perfect competition was considered appropriate in the context of NZ and Chile, where farmers do not have any control over milk pay out, accept input market prices as a given, and seek to minimise expenditure in variable inputs. The NZ dairy industry in particular, has adopted a widely used strategy of cost leadership (Akoorie & Scott-Kennel, 1999; Shadbolt, 2011). The IFCN data also showed that the farms' returns for both countries were well below the world's average due to milk prices that more (NZ) or less (Chile) closely track international prices and the absence of quotas and subsidies. Efficient-scale processes and an on-going cost minimisation throughout innovation can be assumed for both countries given the farm sizes and cost profiles. According to Spulber (2004) these processes are critical in order to achieve and maintain a cost-leadership position. However, NZ and Chilean farming systems demonstrated that a good international positioning can be achieved by using a set of inputs in different quantities or by approaching the cost-leadership strategy in different ways. For instance, while expenditure in fertiliser on average is higher in NZ than in Chile, conversely, expenditure in supplementary feed on average is greater in Chile. Shadbolt (2011) explained two basic different basic approaches to the cost-leadership strategy, one is the low-input approach and the other is the high-output approach. The first one is typically associated with NZ farming systems and is self-explanatory. The latter is the Chilean approach and is based on reducing the cost per unit by producing larger amounts of product.

The comparison carried out using IFCN data confirmed that larger samples, including data recorded over several years, were needed to really assess farming systems in the respective countries. Langemeier (2010) indicated that benchmarking over several seasons was required to determine competitive advantages given the evident difficulty in consistent farming performance. Therefore, judgements about the relative performance of one or more farming systems may be better if based on large samples from different regions (Benson, 2008). In addition, individual farm performance will naturally fluctuate over time and thus, snapshots of performance can be misleading. In any year, a downturn or upturn in performance may be found, which in part could be explained by an industry-wide trend, a general economic circumstance, or weather related factors that are out of the control of the manager. According to Fleming et al. (2006) failure to identify causal relationships between performance and factors such as rainfall and input-output prices has often led analysts into interpretative errors.

In this study, the relevance of weather and market-related shocks in isolation, and in combination, was apparent depending on the magnitude of the event. For example, over the period 2006-11 there were good and poor years, climatically and economically. both in NZ and Chile. The NZ results (Chapter 5) show those years of high milk prices affected milk efficiency and especially revenue efficiency. Conversely, a poor climatic year was more likely to affect the physical efficiency than the revenue efficiency depending on the input:output price ratio. The summer 2007/08 was the driest in a century in parts of the North Island and South Island of NZ (NIWA, 2012). The following year (2008/09) was again dry: some regions in the North Island, and also the South Island had near record low annual rainfalls. The 2009/10 season was also a difficult climatic year for most regions, mainly due to a late summer/autumn drought (Dairy NZ, 2011). However, 2007/08 had exceptionally high milk prices, only comparable to the high milk price observed in 2010/11, and this helped farmers to overcome the climatic shocks. In contrast, the 2008/09 season in NZ showed how a really poor year can result from the combination of both low yields and low product prices.

DairyBase and *TodoagroBase* provided the data to characterise NZ and Chilean pasture-based dairy farming systems over the 2006/07-2010/11 period. Country-specific key metrics were identified and used as operating statistics to identify performance gaps, and the competitive position of the systems and particular groups of businesses. Before getting into this discussion, it is worth reviewing the methodology and some fundamental steps to understand and interpret these results. Motivated by the need to compare only similar (peer) farms the data in both databases were nested into several classes using country-specific classification systems. The NZ one (27 classes) included a combination of year, region and three levels of intensification, while the Chilean one (10 classes), limited by dataset size, combined just year and two levels of intensification. DEA within these classes meant that data was normalised to remove differences between seasons, regions and intensification level which were expected from reading the literature.

8.1 The Non-financial Benchmarks

The three key non-financial benchmarks identified in *DairyBase* were the milk solids production measure (kgMS/cow), the labour input measure (FTE) and a productivity of labour measure (MS/FTE). In *TodoagroBase*, the key metrics identified were a milk production measure (L/cow), the wages paid relative to production and the feed input measure, supplement feed to the cows also relative to production (grams/L). Therefore, some physical benchmarks found for NZ, and Chile where similar while others were different. The countries shared similar indicators for milk production and labour, however, labour and labour productivity were very important in NZ while in Chile supplementary feed was key in defining efficiency. Table 58 summarises the findings discussed in this section.

Table 58

Production, Labour and Feed Benchmarks

INDICATOR	NZ	CHILE	**SIMILAR**
PRODUCTION	MS/cow	L/cow	**yes**
LABOUR	FTE	Wages CLP$/L	**yes**
Paid wages	yes	yes	
Paid management	yes	no	
Family labour	yes	no	
Family management	yes	no	
Share of Operating Expenses	*20%*	*14%*	
PRODUCTIVITY OF LABOUR	MS/FTE	WAGES/L	**yes**
FEED	no	g/L	**no** [25]

[25] DairyBase data was only at level one so did not have the level two indicator KgDM eaten per Kg MS.

Table 58 presents non-financial benchmarks, except the Chilean labour indicator presented here to facilitate the comparison with the physical NZ indicator full time equivalent (FTE). All the non-financial metrics are discussed in this section while the indicator Wages/L is discussed at the beginning of the financial benchmarks section.

Since milk is both a suspension and a solution, it can be measured in either volume or weight (Draaiyer et al., 2009). In NZ, the driver for dairy production is milk solids for export, rather than fluid milk to supply the small domestic market. Therefore, the dominance of kilograms of milk solids rather than litres (which also was available in the data) in NZ was not surprising given the country-specific payment system. In NZ, farmers are rewarded for milk solids content and penalised for volume (Bates, 1998). In contrast, in Chile milk is measured and paid for in litres and, thus, this was the obvious production measure to be expected. The largely domestic market for milk, results in a payment system based on the reverse of the NZ system, rewarding volume and providing bonuses for milk composition (Prolesur, 2011). This is why milk solids content is not even recorded in *TodoagroBase*. The threshold values at which these indicators came out of the trees were between 320 and 406 kg MS/cow in NZ, and between 4,700 and 5,300 L/cow in Chile (roughly equivalent[26] to 470 and 530 kg MS). These values suggested that the production per cow in Chile was greater than in NZ. However, the difference was not as large as the observed gap between the IFCN farms (discussed earlier in Chapter 4), for which the Chilean farm has been shown here to be less typical than assumed.

The dominance of the production measure 'per cow' rather than 'per hectare', could have turned out to be a controversial factor, especially in NZ. The indicators kg MS/cow and L/cow are measures traditionally associated more with supplement intensive systems than with pastoral farming (Hansen et al., 2005). In pasture-based systems the tendency is make the most out of the first limiting factor which usually is land, to the detriment of productivity per cow. In NZ, the ratio milk solids produced per hectare has been regarded as the ultimate measure of physical performance (Holmes et al., 2002). In Chile, the Department of Agricultural Economics at the Catholic University of Chile (1991), quoted in Silva (1997), identified the most reliable indicators of efficiency for a dairy farm as being production of milk per hectare and year. Other authors, however, have challenged these traditional views about pasture-based farming systems and their ultimate production benchmark. Ferreira et al. (2010) explained that L/cow is the industry standard benchmark for efficiency in Chile because the main breed is the American Holstein and North American farm management principles predominate. Lerdon et al., (2008) and Lobos et al. (2001) do not mention productivity per hectare in the list of factors considered particularly important as determinants of results for Chilean dairy farms but included milk

[26] Based on the assumption that 10 litres of Chilean milk (3.4% Protein, 3.7% Fat) would be roughly equivalent to one kg of MS

production per cow among the measures. Neto, et al. (2012), found in the largest milk-producing region in Brazil that the productivity of the herd was more strongly correlated to return on capital than the productivity of the land. Benson (2008) suggested that relative indicators per cow, and per unit of land, were both necessary physical performance benchmarks for pasture-based farming systems regardless of the world's setting.

In this study, milk production per cow in both countries was strongly associated with technical efficiency but milk production per hectare did not come through as a KPI in the trees. Far from being controversial, this was expected considering the research method (Chapter 3). Two factors were involved that may have had variable weight identifying these 'per cow' key benchmarks rather than 'per hectare'. Firstly, the classification system for each country may have partially removed the land and the stocking rate effects on production by nesting into year-region-intensification combinations for analysis. Once these factors were removed, the trees picked up the key variable from what was left. After the nesting, and from the literature, a similar production per hectare (within a range) was expected within the classes and major variability could only be explained by individual cow productivity. The second factor is that efficiency scores are slightly biased towards the variables used as inputs or outputs, which has been pointed out as a weakness of the second stage DEA procedures by Simar and Wilson (2007). Following their reasoning, our results would be biased towards 'cows' rather than 'hectares' (the latter was excluded from the DEA inputs to avoid multi-collinearity). However, evidence in this study suggested that the estimated efficiency scores and their ranking were highly reliable, which indicates that the first methodological factor had the greater weight in determining the results. This particular point will be addressed further at the end of this chapter where methods are reviewed and discussed.

The second important physical benchmark in NZ was total labour measured as full time equivalents (FTE), suggesting that after milk production, labour cost and labour productivity are the key drivers for efficiency in NZ. A weakness of this indicator is that despite including both paid and unpaid labour and management, it does not distinguish the quality of the input. Winkler (1999) concluded that high minimum wages might be a weakness of NZ dairy farming systems compared to lower-wages systems in developing countries. While this high labour cost may be beneficial as part of an effective social welfare policy (Bonoli, 2001) and trigger correspondingly higher labour efficiency (IFCN, 2011) than in other countries, it also threatens NZ's international competitiveness when competing against lower labour cost countries. The dairy industry repeatedly considers the labour issue when looking for options for dairy farming in NZ, with farmers adopting labour saving systems such as once-a-day milking, and investing in technology such as bigger rotary sheds, milking robots (Robertson, 2010), or looking at fence-less systems (Emerson & Rowarth, 2009).

Owner-operated family businesses have traditionally been the predominant structure in NZ farming systems, with the ownership of the assets combined with managerial control. This offers some advantages from the labour perspective. Typically in family businesses, the family provides a significant part of the labour requirements (Robbins & Wallace, 1992). A clear advantage from the labour stand point is that greater confidence in the family working team and elasticity in task allocation can be expected. This is also advantageous because what is a typically fixed cost can become a variable cost by employing family members as required. Fixed costs remain constant for a business regardless of production levels and are mutually exclusive with variable costs unless the labour agreement is flexible which is possible in family teams. However, perhaps the most positive factor relates to the cash flow advantage: reliance on family labour means that wages do not have to be paid rigidly and can be reduced in poor income years (Gersick et al., 1997). All these labour-related factors may be significant in defining the business and the labour structures that characterise the NZ dairy industry.

The importance of labour-related variables in NZ is seen by the fact that labour came out in the analyses as an absolute measure (total labour) and as a ratio (productivity per FTE). The drivers of total FTE are size of the business and intensification level. This suggested that different scales or labour intensities affect efficiency in a major way. However, there was no clear pivotal value of FTE to predict high efficiency, with the indicator appearing at different levels in several trees and exhibiting threshold values ranging from 0.58 to 12.44 total FTEs (most commonly between 1.305 and 1.705) suggesting that medium size farms were on average more efficient. However, this research found that business size was not a limitation to efficiency in NZ over the period 2006/07-2010/11. Farms employing 12.44 FTE were as efficient as those employing only 0.58 FTE. Thus, scale should not be a big concern for dairy business since what really matters is having the right combination of inputs. The farm management literature has traditionally reported the opposite, emphasising the importance of economies of scale in farming (Fox, Bergen, & Dickson, 1993; Olson & Vu, 2009; Purdy et al., 1997). This apparent contradiction may be explained by the fact that most NZ dairy farms are already large enough to display significant economies of scale. Moreover, Jiang's results (2011) show that the subsamples of dairy farms from both islands in NZ, on average, exhibited decreasing returns to scale. Earlier work by Rouse et al. (2010) found that in 2004/05 the herd size for optimum performance was around 300 cows. In our sample of dairy farms over the 2006/07-2010/11 period, the average herd size was larger than 400 cows with an associated labour input over two FTEs, or 200 cows per labour unit in most regions. National data as reported by LIC and presented in Figure 3 also demonstrates that, over the same period, herd size has increased from 340 cows to approximately 390 on average, and that more than 50% of the herds are already larger than 300 cows.

The third and last non-financial benchmark of importance in NZ was a combination of a production and a labour measure, commonly known as labour productivity, expressed as milk solids produced per labour unit (kg MS/FTE). Over the last decade, labour productivity in NZ, measured as cows per full time equivalent, has increased at an annual rate of 3.1% (Dairy NZ, 2012). The main driver for this has been the progressive trend to increase herd size, since labour in most cases behaves like an indivisible factor of production. Across NZ, efficient farms were likely to have higher production per unit of FTE than less efficient farms. Although the relevance of this indicator was found for the whole of the *DairyBase* sample, some regional differences were detected in previous efficiency analyses. Jiang (2011) looked at the regional efficiency performance of dairy farming in New Zealand over the period 1998/99 to 2006/07, and found that the different climate, soil, and farming history between the North and South Island of NZ resulted in markedly different dairy farming technologies, and that labour was relatively more important in determining technical efficiency in the North Island, while farming systems in the South Island relied more heavily on capital and fertiliser. Laca Vina (2010) suggested that given the high levels of technical efficiency of NZ farms in most regions, the industry could only expect to achieve major productivity gains through technical progress that increases labour and capital productivity. These concordant findings support the results of the present study.

In summary, to perform efficiently a dairy farm in NZ needed to produce a given amount of milk solids with as few labour units as possible. Production per cow within the range of 340 to 400 kg MS/cow, combined with a value for labour efficiency of around 45,000 kg MS/FTE, ensured high technical efficiency in producing milk solids in NZ dairy farms from 2006/07 to 2010/11. In countries such as Chile, where the level of wages is lower than in NZ, the expected importance of labour in the overall performance of a dairy farm was lower.

The second important physical benchmark identified in the *TodoagroBase* data was supplement fed to the cows measured as g/L of milk produced. The importance of supplements in defining efficiency in Chile is such that it could not be removed by the classification system. Pasture-based dairy farming systems in Chile are characterized by grazing herds with a variable percentage of the diet being supplements of various types (Smith, Moreira, & Latrille, 2002). A Chilean pastoral farm may also house cows fed on concentrates, maize or grass silage and hay over the winter period, and rely to some extent on the use of supplements all year round (Challies & Murray, 2006; Smith, et al., 2002).

All of these facts suggest that most dairy farm businesses in Chile could be classified as System 4, 5 or above using the Dairy NZ classification system, which was verified in this research. In addition, it is well reported that the feed cost was the largest proportion of the total cost in most dairy farming systems in the world, including Chile, and total cost of feed has a direct and positive relationship with the use of supplements (IFCN, 2010, 2011 and 2012). Therefore, the importance of this benchmark in Chilean farming systems is well justified and was not a surprising finding. This raises the question of whether the Chilean agricultural systems behave more like confinement systems than like typical pasture-based systems. However, this question was not considered a fundamental one since the answer depends on how relaxed the criteria used to define 'pasture-based farming systems' are.

The Chilean indicator, grams of supplement fed to the cows per litre of milk produced, allows for the calculation of response to the use of supplements. Milk production responses of grazing cows offered supplements reported in the literature are positive, and quadratic, varying between 30 and 150 g of milk solids per kg of dry matter intake (Auldist et al., 2013). Given this large variability and the cost of supplementary feed in NZ, it may be important to consider the relevance of the Chilean indicator, grams used per unit of output, at high intensification levels (farming systems 4 and 5).

8.2 The Financial Benchmarks

Fleming et al. (2006) warned that the use of partial benchmarks would not provide an accurate picture of whole-farm performance unless these are contextualised adequately. Whole farm measures would be valid indicators of economic performance while partial measures would not. The tree analyses showed that to predict an efficiency class, in most cases, physical indicators needed to be assisted by financial benchmarks. Two exceptions to this rule were MS/cow alone, and in combination with MS/FTE, as shown in Figure 13. Thereafter, non-physical benchmarks which include expense and revenue measures will be referred to as financial benchmarks. The NZ trees revealed five financial benchmarks: return on assets (ROA), operating profit (OpP/ha), operating profit margin (OPM), operating expenses (OpEx/kgMS), and asset turnover (ATR). The Chilean trees also revealed five benchmarks as follows: gross farm revenue (GFR/cow), wages (CLP$/L), production costs (CLP$/L), and operating profit (CLP$/cow).

Given that there are some similarities between the physical NZ benchmark 'FTE' and the Chilean benchmark for labour, 'wages CLP$/L' (Table 57) will be discussed first. The literature showed conflicting opinions about the relevance of this indicator. Neto et al., (2012) found that regardless of the operating scale, labour, and labour productivity, were only weakly correlated with return on capital in Brazilian dairy farms where most labour is provided on low wages similar to Chile (IFCN, 2011, 2012). In contrast, labour cost per litre of milk has been regarded as an important indicator in Chile (Bywater, 2010). Along with this our findings show that labour input was also a very important indicator for Chilean farming systems. As in NZ, the Chilean pasture-based dairy farm is usually family owned but the concepts discussed earlier about the family labour input are not particularly relevant to the Chilean context. Since the wages are low, the Chilean family farm frequently has absentee land lords and thus, it is not owner-operated (Anrique & Latrille, 1999). For the same reason, in the majority of the cases the contribution of the children and/or the partner is negligible.

The lack of a physical measure for labour in *TodoagroBase* makes the cost of 'wages' the only recorded measure of labour input. According to the IFCN (2011) the family input as a percentage of total labour input on a typical Chilean dairy farm would be 7%, and thus, wages would be a sound approximation to total labour input. In this research, *TodoagroBase* revealed that the average share of wages in the direct cost of production was 16%, and in total cost only 14%. Although this is not a high proportion, this variable was second in relative importance after feed cost (41% of total cost on average including concentrate and pasture cost). Therefore, the one indicator that was not to appear in the Chilean sample was necessary in explaining an important part of the total variability in efficiency as it did with the NZ sample. Table 59 summarises the findings discussed in this section.

Table 59

Financial Benchmarks and Similarities Across Countries

INDICATOR	NZ	CHILE	**SIMILAR**
PROFITABILITY	ROA OPM Operating Profit/ha per unit input	no ATR** Operating profit/cow per unit input	**no** **no** **yes**
EXPENDITURE	Opex/kgMS per unit output	Production cost/L per unit output	**yes**
REVENUE	no	GFR/cow per unit input	**no**

** Fifth Chilean tree refer to Appendix five

Dairy return on assets was the most important financial benchmark revealed by the NZ trees which concurs with the dairy industry view of the farm business (DairyBase, 2009). Other research in NZ has indicated that the most important measure of profit is ROE, which according to the Du Pont model, is fundamentally similar and closely linked to ROA (Shadbolt, 2011). In this research it was shown that ROA was the closest to an efficiency measure of all the financial indicators (including ROE) because it has a relatively high focus on the capital used for production, and captures multiple inputs and outputs in the same way that DEA did. Note that this benchmark was highly correlated with both milk and revenue efficiency, and consistently came through with the threshold value of 4.5% in the trees. The partitioning into the left and right branches where ROA acted as a root variable (Figures 14 and 15) suggested that most NZ dairy farms are in a strong to medium position related to ROA[27]. ROA is widely used across many industries and types of businesses, and is recommended as the leading indicator of the earning capacity of the asset (Boehlje, 1994; Doehring, 2001). If assets are valued at market value, ROA can be looked at as the opportunity cost of farming relative to alternate investments (Olson, 2010). In NZ, its calculation uses the value of opening assets, while in Chile annual averaged values are used following American farm management principles (Ferreira et al., 2010). The most common concern associated with the ROA measure is its reliance on asset valuations. However, this is not an issue in NZ since the asset value is defined using market values and there is confidence in the valuation of the properties.

The results presented in Chapter 5 also indicated that ROA, at the pivotal value of 4.5%, interacted with physical indicators such as MS/cow and MS/FTE to create efficiency classes, as well as with other financial ratios such as rent and interest paid, and equity. ROA also interacted strongly with the operating expenses ratio at a critical value of NZ$ 4.39/kg MS. For instance, in Figure 14, more than one-fifth of the *DairyBase* sample (582 observations) were found to be virtually efficient at producing milk (DEA efficiency score 0.96) following the pathway of ROA > 4.5% and relatively low operating expenses (< $4.39/kg MS). All these interactions were logical, as was the fact that ROA came through as a key performance indicator closely linked to efficiency. Two major strengths of ROA are firstly that it is a comprehensive indicator in which cash and non-cash expenses are truly represented, and secondly that it allows for comparison of farms which pay family wages with those than do not, or the comparison of farms which own run-offs to those that do not (DairyBase, 2009).

Operating profit per hectare was the second financial benchmark of importance revealed by the NZ trees. This indicator was not completely normalised by the classification system (as it happened with the kg MS/ha) which could suggest that it was stronger at defining efficiency than milk production per hectare (kg MS/ha). Its use is not as widely spread as the use of ROA or net farm income, but in NZ it has been postulated as being critical for dairy farming systems (DairyBase, 2009). In NZ, the use of relative measures expressed on a per kilogram of milk solids, per cow or per hectare basis is encouraged to make comparisons between different sized businesses possible. Operating profit is a very comprehensive indicator, calculated after several adjustments have been made to the net farm income including depreciation. The presence of

[27] Based on Kohl and Wilson (1997) where strong > 5% when assets are mostly owned and > 12% if assets are leased; weak < 1% and < 3% respectively.

Operating Profit/ha among the key performance indicators suggests that it is strongly correlated with technical efficiency, and more precisely, with revenue efficiency. However, it has been stated that although operating profit is undoubtedly a measure of business performance, it is not always an indicator of operating efficiency (Shadbolt & Gardner, 2005).

Operating profit margin was the third benchmark of importance revealed by the NZ trees. It is one of four major indicators recommended in NZ for measuring profitability in farming (along with net farm income, ROA, and return on equity) (DairyBase, 2009). OPM measures the firm's ability to generate revenues and control costs. Since its major drivers are operating profit and gross farm revenue, OPM becomes the most comprehensive expression of the input/output ratio. When leasing costs are not deducted, OPM is an accurate indicator of the business's operating efficiency in producing profit from its revenue (Shadbolt, 2011). In this research, OPM was strongly associated with kg MS/cow suggesting that farmers who get the most out of their cows are also financially more efficient. The pivotal values in the trees for OPM were between 22.5% and 26.5%, indicating a strong to stable position[28] for most NZ farms through the 2006/07-2010/11 period. For each dollar of revenue earned, most NZ dairy farmers were above the pivotal values, and thus retained more than one fifth of returns as profit with the rest being expenses.

Operating expenses ratio per kilogram of milk solids was the fourth benchmark to come through in the NZ trees. The importance of a cost measure was not unexpected. The importance of assessing costs as well as production and income to optimise profit has been well highlighted in the literature (Anderson & Ridler, 2010). A strong to stable position in OPM indicated an ability to control costs effectively, and also suggested a clear cost control focus. In general, information on farm production cost and detailed information about expenditure may be valuable for all farming systems. However, the importance of detailed expenditure may become higher at increasing intensification levels, scale and complexity of the business.

The predominance of operating expenses (OpEx) over farm working expenses (FWE) was not a surprise after the importance shown by labour in determining efficiency. OpEx is a more comprehensive measure than FEW, and may include unpaid labour, if relevant, in a manner similar to total economic costs, which is the indicator suggested as the leading indicator of a sector's ability to compete, adapt and expand since it includes all resource input costs, including family labour, equity capital and owned land (Dillon et al., 2008; Lobos et al., 2001). Both FWE and OpEx are, nonetheless, leading indicators of farm expenditure in the NZ dairy industry (DairyBase, 2009; Shadbolt & Gardner, 2009). OpEx and FWE can be both expressed in

[28] Kohl and Wilson (1997) indicated the reference for OPM reflecting a strong (0.25), stable (0.10-0.25) or weak position (<10%).

absolute terms ($), or as ratios per unit of output such as FWE/kg MS or unit of input such as dairy grazing area, for example OpEx/ha. Fingleton (1995) and Thorne and Fingleton (2006), in examining the competitiveness of Irish milk producers, opted for expenses relative to kilograms of milk solids rather than area, to allow for differences in the potential of the land for milk production.

Asset turnover ratio was the fifth and last benchmark revealed in the NZ trees. This came through twice, in two different trees (Figures 14 and 15), at the threshold values of 25% and 15%. In general, asset value has an inverse relationship with the ATR and ROA value, and a direct relationship with operating profit margin. Some authors suggest that a low profit margin can be tolerated if there is a high asset turnover ratio (Kohl & Wilson, 1997). This supports our findings in Chapter 5, where it was shown that a dairy farm in NZ may have high operating expenses and still be very efficient, simply by making better use of the assets as indicated by the interaction with Assets Turnover ratio (ATR) at a threshold value of 25%. This would be the case with irrigated, supplement-intensive farms in the South Island of NZ where the land is less expensive than in most NZ regions. However, when a lower ATR value was combined with a low profit margin, a low efficiency operation was always identified. Therefore, the pivotal value for ATR which defines a strong, stable or weak position strongly depended on the type of operation, and whether assets were owned or leased. A key point to note from the results in this study is that there was no one pathway to efficient performance, and that many variable combinations of good practices could result in high and very high efficiency scores. Also, these results demonstrate that strong, stable and weak threshold levels of measures cannot be taken as general truths.

The relationship between ATR and OPM also relates to the competitive strategy. In this study, farms following the low-cost strategy are likely to have lower ATR and ROA, and a higher OPM. More intensive farms such those found in Chile and some in NZ, however, are likely to behave in the opposite manner. For example, the efficiency literature in NZ consistently found that technical efficiency was, on average, higher in the South Island than in the North Island, which was also found in this research. Without exception, all efficiency analyses have included land capital as an input. We found that North Island farms were able to be as efficient as South Island farms through having a lower ROA but higher OPM. Therefore, when facing the dilemma of whether to look at overall efficiency (ROA) or operating efficiency (OPM) in choosing just one indicator, the answer would be that it depends on the values and goals in the farming business.

The Chilean trees revealed three financial benchmarks, as shown in Table 59: gross farm revenue per cow (GFR CLP$/cow), production costs per litre (PC CLP$/L), and operating profit per cow (OpP CLP$/cow). GFR per cow was highly correlated with net milk sales per cow, and thus, it is ultimately correlated with physical milk production. The importance of this benchmark suggested that Chilean farmers are revenue maximising. This assumption has been found in the literature for those situations where the level of inputs, especially land, operator and family labour, is considered fixed in the short run (Olson & Vu, 2009). Both the literature reviewed and the evidence in this study all indicated that an important driver for milk production in all countries is milk price. This is perhaps more clear in Chile, where farmers may be more reactive to milk price information than a NZ farmer. The reason for the strong influence of this variable is because it is easily quantifiable, resulting in a direct incentive to improve production and increase revenue when milk price is high, or to reduce costs per unit of output when the price is low. This ability to respond rapidly to milk price is a fundamental difference between pastoral and supplement intensive farming systems. In this respect, Chilean farming systems are more likely to behave like confinement systems than like pasture-based systems.

Lerdon et al., (2008) studied the interactions between different social, productive, economic and financial variables in dairy farms in Chile during two consecutive years, 2000 and 2001. They found a strong correlation between milk production and milk price in both periods, explaining more than 60% of the variation in milk production. The authors also found that milk price was of higher importance in planning and decision making than profitability and cost per litre. The physical information contained in *DairyBase* and *TodoagroBase*, and used in this study, clearly indicated that farmers responded to price information by feeding more supplements to the herd, which led to farming systems shifting towards greater use of imported feed in years of higher prices.

In both countries, a price crisis would produce discontent and then uncertainty, which may stimulate variable cost reduction. This is likely to negatively affect production in the same way that a high milk price will stimulate production. However, only in Chile would a price crisis encourage the search for new alternatives by diversifying the production portfolio. The literature reports that one basic difference between NZ and Chilean dairy farming systems is that NZ farmers have long opted for specialisation in dairying, while Chilean farmers have opted for diversification. For most specialized farming systems, any change from dairy to beef production is a long-term decision, however, for the Chilean dairy systems it can be either a long or a short-term decision (Winkler, 1999). Chilean dairy farms often allocate land to a variety of agricultural activities such as beef or cropping. These non-dairying activities generally occupy more than 50% of the total land area (Anrique et al., 2004; Lerdon, Munoz & Moreira, 2010). In particular the beef and the dairy markets are negatively correlated, mutually influencing the decision-making process. While this can be advantageous for the farmer, it becomes a serious disadvantage for the Chilean dairy industry because it increases both price and volume instability.

In Chile, milk price was strongly related to physical milk production (L/cow), and this to gross farm revenue per cow and farm efficiency. The second financial benchmark to emerge from the trees was production costs which is closely linked to the other benchmark yet to be discussed that is operating profit per cow. Production cost per litre of milk produced was 90% on average of the total production cost averaged in the *TodoagroBase* data over the 2007-2011 period. The structure of the Chilean trees was similar to the NZ trees, in that production, labour, cost and profit variables came out in almost the same order as in the NZ trees. Operating profit per cow was a variable created as part of this study to test whether or not this NZ-specific variable was relevant for Chilean farming systems. No literature exists suggesting that this might be the situation. In this particular case, the farmers' focus on Operating profit per cow can be discarded as a causal agent of the measure being so relevant. Therefore, the strong association between operating profit (per hectare and per cow) and technical efficiency revealed by the trees for both countries was reinforced. The fact that in Chile it is expressed as a relative measure on a per cow basis is also compatible with the industry view, where the preference is for cow rather than per hectare measures in Chile.

8.3 The Benchmark Sets Applied to Different Performance Groups

The corresponding benchmarks for each country were used to comprehensively describe the five-year NZ and Chilean samples, which were divided into three sub-groups according to their efficiency scores. The ability to have an efficiency score of one in producing both milk, and revenue, for three or more years, as explained in Chapters 5 and 6 was recognised as resilient efficiency. Top performers were described as 'resilient' which implies robustness and the capability to adapt to alterations in the environment and to take advantage of opportunities, while maintaining productive capacity despite variability in financial, market and production related factors (Shadbolt, Rutsito & Gray, 2011). Aven (2011) pointed out that a key difference between robustness and resilience is that the first relates to a fixed threat, whereas resilience is relevant to any type of potential shock and uncertainties given a certain environment. This is why the term 'resilience' was preferred over 'robustness'. Scholz, Blumer, and Brand (2012) pointed out that resilience is linked to risk and vulnerability; it incorporates the capability of a system to cope with the adverse effects or risks that a system has been exposed to.

The percentage of resilient farms in Chile (4.3% extracted from Table 40) was lower than in NZ (5.6% extracted from Table 26). This may be more likely explained by a higher percentage of the farms being in the NZ database for three or more years, as the criterion for defining resilient farms indicated, or/and by a better overall management among NZ dairy farmers than among

Chilean farmers. In Chile, along with a higher use of supplements there is a lower dependence on rainfall and pasture production to feed the herds. This may have the effect of increasing resilience since supplements are well known as a way to, simultaneously, improve milk yields and reduce the climatic risk associated with pasture-based systems (Edwards & Parker, 1994). According to the IFCN criteria (2011) presented in Table 9, and recent research by Anderson and Ridler (2010), due to climatic risk NZ farms have a more risky profile than Chilean farms. Therefore, if resilience refers to the capability of a system to cope with risks, under comparable scenarios the 'natural' resilience of NZ dairy farms would be more challenged than under other less risky situations.

Rodriguez, deVoil, Power, Cox, Crimp and Meinke (2011) claimed that flexible farming systems express greater resilience than more rigid farming systems. Research suggests that this flexibility is an important attribute for farming systems, likewise ecologists have long identified that phenotypic plasticity as a key element in the functioning of organisms (DeWitt & Schneider, 2004). Rodriguez et al. (2011) explained that where farm management is highly contingent on, for instance, environmental conditions, farm managers often vary crops and inputs based on the availability of limited and variable resources (land, water, finances, labour, machinery), and signals from its operating environment (rainfall, markets), with the objective of achieving a number of often competing objectives, such as reduce risk or increase profits. This is similar to what the Chilean farmers do with their diversification strategy by considering beef and cropping as complements but also as alternatives to dairying. Therefore, farmers in Chile with a higher proportion of variable costs may be more responsive to changing market conditions than NZ farmers. This is what is likely to be expected from a supplement intensive farming systems versus a pasture-based system. However, given the current environment it may be advisable for NZ farming systems to find mechanisms to be more responsive to changing conditions in general and to milk price in particular.

In NZ, the observed frequency of resilient farms in the 2010/11 season was significantly higher than the expected value. Similarly, the Otago-Southland region, farming system number five, irrigated farms, and dairy farms larger than 600 cows dairy farms showed a higher frequency of resilient farms (Appendix 8). In Chile there was no difference between the observed and expected frequency of resilient farms by year and farming system (identified by use of supplements) but there were differences in region and scale. The observed frequency of resilient farms was significantly higher in the Bio-Bio region, and in farms larger than 600 cows (Appendix 8).

Interestingly, for many of the analysed variables in NZ and Chile, consistent top farms showed greater variability than poorer performers. This suggests that in both countries, the overall ability to perform well consistently did not depend on the size of the business. This reinforces the discussion about economies of scale in NZ presented earlier. This finding has not been noted yet for Chilean dairy farming systems; on the contrary the opposite was found by authors in several studies. Although traditionally Chilean dairy farming systems have shown considerable variability in efficiency, profitability, and other variables (Aichele, 1979; Campos et al., 1995; Silva, 1997), generally increasing returns to scale have been found (Diaz & Williamson, 1998; Moreira 1999; Schilder and Bravo-Ureta, 1994). The long time gap between these results and the findings presented in this research makes it believable that the norm has changed for pasture-based dairy farms over this period.

In NZ and Chile, top performers, on average, produced the same or more output per cow than the other groups. The resilient top performers in NZ produced about 391 kg MS/cow on average, with a minimum of 213 kg MS/cow and a maximum of 650 kg MS/cow. The labour productivity of resilient farms was in the order of 60,000 kg MS/FTE, which means that variable herd productivity needed to be accompanied by very high labour productivity to consolidate resilient farm efficiency. Labour productivity was crucial and showed a mean significant difference in the order of 15% between resilient and poorer performers. In Chile, a resilient farm could also produce a very similar output per cow compared to an average farm (about 5,300 L/cow), but would do this with higher efficiency in the use of supplements.

Supplement fed to the cows was the key defining efficiency and resilience among Chilean dairy farms. Resilient performers used less supplement than the mean (215 grams per litre), with some not using supplements at all to achieve resilient efficiency. In contrast, the poorer performers all used supplements and most were heavy users. Under Chilean conditions, and with Chilean dairy breeds and strains, dry matter intake of pasture may often be insufficient for the high genetic merit cows to meet their potential, and therefore supplements are needed (Kolver & Muller, 1998). This implies dependence on the use of supplements which can result in inefficient farmers being cost-inefficient if the milk:feed prices ratio is unfavourable. On average, the resilient performers used 22.4% less supplement per cow than the poorer performers. Milk production responses of grazing cows offered supplements varied and positive quadratic responses to increasing amounts of supplement have been observed for yield of milk (Auldist et al., Wales, 2013). The resilient farms, may be achieving higher responses to supplement in milk production than poorer performers. They may also be more flexible in adjusting to unfavourable milk:feed prices ratio by using breeds and strains more suited to a pasture-based feeding strategy, or by better grazing management .

Interestingly, despite lower reliance on supplements, the direct cost of production expressed in CLP$/L achieved by the resilient performers in Chile on average was not significantly different from that achieved by the non-resilient observations. Most Chilean farmers may be maintaining a relatively low-cost status by reducing cost per unit through the denominator effect by producing larger volumes of milk. However, resilient farms on average had significantly higher profitability per cow with the lowest variability, and also had wages per litre of milk produced which were significantly lower than the inefficient performers. This is consistent with the fact that generally higher intensification levels (exhibited by inefficient observations) require higher labour input.

In NZ, resilient farms were consistently more profitable than non-resilient farms, exhibiting 10% lower operating expenses per kilogram of milk solids on average, and better use of assets, as reflected by dairy ROA and ATR results. Profitability per hectare was also markedly higher among resilient performers, and OPM in absolute and statistical terms was also higher, indicating that these generate more profit from their revenue by effectively controlling costs. Shadbolt, Rutsito and Gray (2011) proposed that efficiency measured as profitability could be equated to resistance, one desirable attribute clearly exhibited by resilient farms in this study. In NZ and Chile, resilient performers remain production- and cost-focussed simultaneously, achieving greater profitability than non-resilient performers no matter what milk price, feed price or rainfall received. Resilient farms are flexible enough to take advantage of upside risk and cope with downside risk.

8.4 The Metafrontier Analyses

The purpose of the metafrontier analyses within countries was to compare efficiencies scores across a number of years, regions and farming systems in NZ and Chile, separately. In addition, the metafrontier analysis across countries compared efficiencies of dairy farms across countries for two selected years of interest.

The country-specific analyses found that the countries benefited from high technical efficiencies relative to their own frontiers, with efficiency estimates averaging around 0.90. Thus, in each country there were a number of farms operating relatively close to the technical efficiency frontier. However, when compared to a metafrontier, broadly representing the pasture-based technology set shared by both countries averages showed very low technical efficiency scores. This reinforces the idea that within each country, a range of diverse and sometimes contrasting farming systems can coexist.

All metafrontier analyses used herd size (cows), supplements (kg/cow) and CPI adjusted operating expenses expressed in US$ as inputs. The selection of inputs was reduced to the reliable variables present in both databases that were reliable, with the set chosen to keep consistency with the previous efficiency analyses. Assets were deliberately excluded from the metafrontier analyses because of the unreliability of the backwards calculation of return on assets in the *TodoagroBase*. The default output in this type of technical efficiency analyses is 'milk', expressed either in kilogram of milk solids or in litres. However, the metafrontier output was CPI adjusted gross farm revenue, also expressed in US$. The use of this variable affected by production and milk price was the straightforward option given the lack of information about milk solids content in the *TodoagroBase*.

The fact that some inputs and outputs are expressed in US$ (because physical measures were recorded in different units in *DairyBase* and *TodoagroBase*), deflated by average price indices per country may introduce problems in comparison between countries. In addition to issues related to relative prices, the movements of the respective exchange rate can affect the conclusions (Sharples, 1990). Real movements in exchange rates tend to be associated with changes in the competitive position of a country. In particular, real appreciation of local currency means, *ceteris paribus*, that the goods produced are comparatively more expensive domestically, which is a situation associated with a loss of competitiveness (Harrison & Kennedy, 1997). For example, the NZ$ has appreciated against the US$ following an increasing trend since 1998, reaching its historical maximum value in 2011 (Figure 6) while the Chilean peso has been erratic behaviour over the same period (Figure 7). This might mean data limitations might have weakened the metafrontier results, and therefore, some interpretative caution is required.

The NZ metafrontier used all the observations, across all years, a total of 2,588 DMUs. Not surprisingly, the years with lower efficiencies had lower milk price, and conversely, the higher efficiency years had higher milk prices. Overall, efficiency tracked fluctuations in GFR which suggests a similar consumption of inputs throughout the period. Operating expenditure on average was only statistically different in 2006/07 from the rest of the period. It is interesting to note that even when facing an average milk price scenario in 2009/10, expenses were not significantly lower than in other more favourable years. This suggests a high fixed costs proportion in total expenses in NZ. In 2008/09 expenses were not significantly different from other more favourable milk price years because milk price dropped half way through the season when the majority of the costs were already locked in.

Throughout the period, there were no significant differences between years in the average herd size or in the use of supplement per cow. These suggest that NZ dairy farming systems may benefit from being more reactive to milk:feed prices ratio which could be achieved by increasing or decreasing expenditure per unit of output as a function of the price received for milk. Despite feed being more expensive in NZ than the world's average, it would make sense to have higher use of supplements at higher milk prices. This may be very challenging for isolated farmers, but may possibly be achieved by using a complete systems approach involving the entire value chain, encouraging more cropping under contract and other arrangements that make more feed available to farmers.

The Chilean metafrontier used the observations across all years, totalling 1,028 DMUs. Through the period there were highs and lows alternatively, which may reflect the influence of weather and price shocks. The metafrontier efficiency in 2009 was significantly lower than the rest of the period, explained by an observed milk price well below the expectations that farmers had at the beginning of the production year. Average years, such as 2010 and 2007, showed intermediate mean efficiencies, while the years 2011 and 2008, had noticeably higher mean efficiencies due to record high milk prices. Overall, NZ and Chile behaved in a similar way; the NZ 2008/09 season can be compared to the Chilean 2009 year, even if it was not exactly the same time period. Correspondingly, the NZ 2010/11 season can be compared to the Chilean 2011 year.

In both countries, the changes in efficiency were smoother than the fluctuations observed in mean gross farm revenue. In Chile, the greatest difference between maximum and minimum mean efficiencies were in the order of 32%, while the maximum mean revenue was almost double the minimum. From 2007 to 2011, despite fluctuations there was an overall trend in increasing operating expenses over time. The minimum mean expenditure was recorded in 2009, and the maximum recorded in 2011. This suggests that Chilean farmers are milk price focused and react to it by increasing or decreasing variable costs. Herd size showed an increasing trend over the period, but only the last year of the period was significantly different from the rest of the years. This trend to increase numbers of cows in the herd was accompanied by a similar tendency towards intensification, as denoted by the higher use of supplements per cow. The beginning of the period (2007) had a moderate use of supplements of 1,252 kg/cow on average. This was not statistically different from the supplement used in 2008, 2009, 2010 and 2011. However, there were differences between supplement fed to the cows in 2011, relative to 2009 and 2010, in response to more favourable milk: feed ratio.

8.5 The Metafrontier Across Countries

The metafrontier across countries for two selected years of interest addressed the research question 'What country is more technically efficient regarding dairy farming and why?' From the previous analyses, two contrasting years were identified by both price and climate. A 'good' year was represented by 2010/11 in NZ and 2011 in Chile, while the contrasting 'poor' year was 2008/09 in NZ and 2009 in Chile. Metafrontier analyses were conducted separately for those years. Note that a relatively less favourable weather scenario affected the NZ pastoral season in 2010/11, with officially declared areas of drought across the territory (MAF, 2011). In addition, it must be remembered that the years do not refer to the same period, since NZ uses the agricultural year (June-May) while Chile uses a calendar year (January-December). It also is worth noting that results across years within countries are not strictly comparable since different farms made up the samples each year.

Significance tests showed that in the poor year, gross farm revenue was significantly lower in Chile compared to NZ. Both countries' poor year's revenues were significantly lower than those observed in 2011, but were not significantly different from each other. In contrast, mean expenditure for Chile in 2009 was also significantly lower than the expenditure means for the rest of the country-year combinations (but not significantly different between them). The use of supplements was significantly lower in NZ than in Chile for both years under review. In both countries, efficiency was highly affected by input/output prices and climate. Highly correlated world market prices for milk, feed and oil, as well as rainfall, are important drivers of efficiency of milk production in both NZ and Chile. Particularly for milk price, exceptionally high values occurred at the end of 2007 and the beginning of 2011, while low values were observed in June 2009 and 2012 (IFCN, 2012).

The low milk price and poor climatic year, 2008/09, severely affected revenue efficiency in NZ (mean = 0.38), which was consistently below the mean for the whole period (0.41). The equivalent year for the Chilean sample (2009) demonstrated a lower efficiency (0.37), and also greater variability (0.18), than the NZ sample. However, differences on average efficiencies between *DairyBase* and *TodoagroBase* samples for the poor year were not significant. The IFCN (2012) and Tozer, Bargo, and Muller (2003) both remark that a low milk:feed prices ratio, as observed in 2008/09 (below 1.5), may benefit low input farming systems with moderate milk yield levels. In NZ, the same pattern was found by Jensen, Clark, and Macdonald (2005) who analysed different levels of intensification within pasture-based systems. At a higher milk payout (NZ$4.5/kg MS), the higher input systems showed higher profitability. The metafrontier showed that in NZ and Chile, a good year (2010/11 in NZ and 2011 in Chile) allowed for a recovery in efficiency. The mean efficiencies in both countries were significantly higher than those observed in 2009. The difference between NZ mean efficiency (0.49) and the Chilean mean efficiency (0.41) was also significant.

The metafrontier across countries results indicated that there is a very large variability within countries, and even larger variability between them. To the best of our knowledge, this is the only possible explanation for the fact that the metafrontier scores were very low compared to the class-specific scores. The metafrontier across countries also suggests that both NZ and Chilean samples had similar mean efficiency during the poor year, but differences were expressed in the good 2011 year. This would suggest that NZ farmers had greater ability to capitalise a high milk price as revenue, by using fewer inputs that their Chilean counterparts.

8.6 Review of Method

This section provides a review of data envelopment analysis with recursive partitioning as a second stage approach. Despite criticism of DEA models applied to agriculture, this research relied to a large extent on DEA estimates of efficiency. Major criticism has been that DEA does not account for random errors, is sensitive to nesting and input/output selection, and it usually ignores undesirable outputs (Coelli et al., 2005).

Random factors that affect production, such as rainfall, can have a large impact and are particularly important in pasture-based farming systems. These random factors can affect the relative performance scores calculated by DEA, which attributes all movement away from the frontier of the scores to inefficiency rather than providing some allowance for random effects. Typically, operating conditions, and environmental and contextual variables such as climate or land attributes, are assumed to be non-discretionary inputs and are rarely included in a given dataset. If the environmental impact component can be identified, its separation from managerial inefficiency is advised. Otherwise the DMUs can be penalised for the uncontrollable conditions they face. Several efforts to include non-discretionary inputs in the DEA are testament not only to their importance, but also to the difficulty of satisfactorily incorporating their impact in any evaluation of performance.

In this research, this limitation was addressed and its undesirable effect reduced through the country-specific classification system. Nesting DMUs is one way researchers have attempted to adjust for heterogeneity in operating conditions when estimating DEA efficiency scores, since the discriminatory power of DEA, and to some extent its validity, relate to the homogeneity of the sample (Semoneiko & Osei-Bryson, 2008). However, DEA typically has a high level focus, and the use of aggregated information is actually one of its strengths (Rouse, Harrison & Turner, 2011). When there are multiple ways to nest the observations, DEA can yield very different results which is undesirable. This study found heterogeneity within the *DairyBase* and *TodoagroBase* data rather than homogeneity, and used a nesting process to group naturally occurring peers based on the literature, normalising the sample against the larger sources of heterogeneity. This was done at the year, region and feeding system levels. This disaggregation proved to be of benefit in estimating efficiency scores and was the most important step in the process because all the successive steps relied on it.

DEA is known to be sensitive to the selection of inputs, outputs and to the presence of outliers. In this research, we determined the relative importance of competing explanatory factors without a built-in test based on their appropriateness and reliability and avoiding multi-collinearity. This is an issue when inputs are highly collinear, which can lead DEA into the second error type. In contrast, when inputs have very low correlations, DEA is more likely to view each DMU as being unique, and therefore fully efficient, especially when there are limited observations resulting in the loss of discriminatory power. Moreover, the flexibility of the envelope underlying normal DEA may be a cause of upward bias, especially for limited sample sizes (Pedraja-Chaparro et al., 1997). This research acknowledged this limitation and tested the robustness of DEA estimates for the benefit of this discussion, evaluating the influence of including the input 'hectares', rather than 'cows', in the DEA applied to the largest class in the study 'Rest of North Island' (n = 189; NZ, season 2006/07). The influence of this on the efficiency scores was minor as reflected on a Spearman correlation coefficient of 0.884, significant at the 0.001. A second test evaluated the impact of including hectares and cows simultaneously in the same NZ class. The impact of this on the efficiency scores was also negligible, as reflected by a Spearman correlation coefficient of 0.968, significant at the 0.001. These mean that the reliability of efficiency estimators calculated in the first place was high, as was the validity of our results.

Another major limitation of DEA is the existence of undesirable outcomes, often not measured or included in the databases, and therefore, excluded from the analyses. Lack of information about undesirable outputs in this study may have led to a misclassification of a DMU as efficient when it is actually inefficient because it may produce large quantities of undesirable outcomes. According to Seiford and Zhu (2002), these undesirable outcomes should be included as outputs when performing efficiency analyses. Frequently ignored undesirable outputs could include pollutants and wastes. However, these are often difficult to quantify which is why they are not included. For instance, FAO (2006) attributed to agriculture 18% of the world's total anthropogenic greenhouse gases, and the IFCN (2012) estimated that dairy farming systems worldwide have on average a carbon footprint of 1.36 kg CO_2 equivalent per kg of energy corrected milk. In the last few years, there has been an increasing tendency for people to be more conscious of undesirable outputs and other issues derived from agricultural activities. This trend should help to increase work in this area, which, in the near future may generate measures and identify techniques to quantify undesirable outputs, making the information more available for the debate on how to deal with them.

In this research bias was expected to vary between the classes within the country-specific classification systems. It was expected to be lower in larger classes where there were enough efficient or near-efficient observations to delineate the frontier adequately, and to be higher when the class had fewer DMUs. Banker (1993) pointed out that in DEA two possible types of error may occur: firstly, falsely classifying an efficient unit as inefficient, and secondly, falsely classifying an inefficient unit as efficient. At smaller sample sizes, the frontier is thinly populated and DEA is particularly liable to fall into the latter error (Banker, 1993). This means that the frontier estimator is biased below the theoretical frontier for a finite sample size and that the bias approaches zero for large samples. Kittelsen (1995) addressed the problem of bias in DEA and concluded that even though bias may be an intrinsic limitation of the methodology, it is at least predictable such that it increases with dimensionality and decreases at higher average efficiency, sample size, and concentration of observations adjacent to the frontier. Hawley (2010) in contrast, suggested that the use of a large sample would not necessarily prevent bias, which is an intrinsic property of, and a limitation, in DEA. In this research, bias was not only expected, but also tolerated, as is the measurement error in the explanatory variables.

This research explicitly ignored other potential applications of DEA, such as slacks, peers or scale efficiency scores. These, although acknowledged valuable information, were out of the scope of this study. For time constraint reasons, individual farm analyses were not feasible, while peer information using DEA efficient DMUs was neither analysed and nor taken into account. DEA provides a formal method of performance measurement that addresses some of the problems encountered in the use of conventional accounting methods of such measurement. In particular, it enables comparisons to be made of relative performance where multiple performance measures exist, but the appropriate weightings to be applied to those measures are not known or cannot be agreed upon (that is, where the production function is unknown), and where nonfinancial, as well as financial, measures are important.

Finally, second stage DEA in general, including the analysis presented in this study using regression trees, has many supporters, but also critics, because of its limitations. Many authors have used DEA efficiency scores in a two-stage analysis for various purposes (Banker & Natarajan, 2008; Olson & Vu, 2009; Simar & Wilson, 2007). The first, and stronger, argument against the second stage DEA approach states that if the variables in the second stage were expected to affect the performance, they should have been included in the original DEA model (Grosskopf, 1996). Grosskopf also draws attention to the likelihood of bias and inconsistency in the second stage due to the correlation with the factors included from the first stage. Other detractors of this approach also claim that efficiency scores are inevitably biased, and often strongly correlated with the variables used as inputs or outputs (Siman & Wilson, 2007). For example, peak cows milked was used in DEA as an input, rather than the effective dairy area (ha), and both were expected to affect performance since they both represent dairy farm size and have a very high correlation, so one had to be discarded. The second stage revealed that the ratio per cow was in fact dominant over the ratio per hectare, although it is uncertain how much of this is due to the nesting process or to the correlation between DEA inputs and the trees' results. We also addressed this limitation by applying RPT to *DairyBase* and *TodoagroBase* using the first split variables ROA and GFR/cow, respectively, as response variables to re-test consistency and relevance of the respective benchmark sets. These trees, which are briefly discussed in the appendices, showed the desired consistency and relevance. These regression trees could be used as prediction tool for ROA without the need to estimate efficiency scores with similar results.

In addition, and related to the recursive partitioning trees (RPT), Strobl et al., (2009) explain that an undesirable side effect of the trees is that an entire tree structure could be altered if the root variable or its cut-off point was chosen differently because of a small change in the dataset. A solution to this instability problem was also provided by these authors, who suggest the use of a series of trees instead of a single tree, where there are reliability concerns that could affect the consistency of the results. In this research, this limitation was addressed by using multiple trees for each country, and only selecting the benchmarks that were consistent across the trees.

9. Conclusions.

This research focused on New Zealand and Chilean dairy farming systems and particularly on the interactions between inputs, outputs, and the macro-environment. It was in response to the need for greater understanding of the farming systems and demand for information-sharing, triggered by both globalisation and increased market risk.

In New Zealand, well-delineated pastoral systems following the cost-leadership strategy were confirmed regardless of the intensification level. Herd and labour productivity played key roles in defining efficiency. The operating cost per kilogram of milk solids, return on assets, operating profit margin, operating profit per hectare, and asset turnover, joined the production measures in the final set of KPIs that adequately described and explained the variability in efficiency in New Zealand farming systems. In Chile, supplement-intensive systems based on pasture were identified. Herd productivity and supplement fed to the cows played the most important roles in defining efficiency. Chile benefits from temperate grasslands just like New Zealand, and has the advantage of a low cost labour supply and land, both of which place Chile in a very good competitive position internationally as a milk producer. The absence of return on assets in Chile was noticeable, but may be justified by the fact that the main asset, land, is not actively marketed since land belongs to families for sucesive generations and there is little chance in disinvesting from farming to invest in any other activity. From these findings, it may be concluded that operating profit should be included as an indicator in Chile since it was the only profitability indicator that came out from the regression trees (operating profit was not originally available in *TodoagroBase*). Similarly, in New Zealand it may be interesting to study the relevance of including a similar KPI to that found in Chile (g supplement/L milk produced), to evaluate performance in the use of supplements in Farming systems 4 and 5.

The fact that different KPIs were identified for each country indicates that metrics should not be used to benchmark across systems without a previous evaluation. It has been proven here that system-specific benchmarks can objectively be identified. Other conclusions also extracted from this work are that New Zealand farming systems are more dependent on weather-related factors and may have a riskier profile than Chilean farming systems due to higher stocking rates and greater reliance on pasture as feed. Furthermore, New Zealand farmers may be technologically more advanced at managing pasture, while Chilean farmers may be better at managing supplements since they have traditionally used them more intensively. Chilean farmers are more revenue focused and respond to milk:feed ratio and response to the use of supplement, while New Zealand farmers are profitability and cost-focused looking at both the OPM and capital invested. This suggests a greater orientation towards entrepreneurship in New Zealand than in Chile, as well as differences in values and goals.

New Zealand and Chile are natural benchmarking partners for pasture-based dairy systems since they produce similar outputs, trade under similar market conditions, and consume similar inputs although in different proportions, and efficiently and profitably produce milk at a lower cost than the world's average. Their systems are also evolving in similar ways through efficient-scale processes, innovation, and gradual increases in average intensification levels and specialisation. Other similarities are that, despite being heterogeneous groups, the consistent top performers in both countries were more likely to be bigger, to produce on average the same or more output per cow, and to have higher labour productivity than poorer performers. Interestingly, the consistently top performers in Chile, on average, used significantly less supplements per litre of milk produced than the poorer performers. Similarly, New Zealand's top performing farmers had significantly lower operating expenses ratios than the other groups. They also used assets better, and had higher operating profit margins and profitability per hectare. This is important in terms of sustainability because dairy farms with a higher profitability have a lower risk of being unsuccessful when faced with a turbulent environment.

Benchmarking has been criticised as being 'just' backward looking. The innovative second stage DEA and RPT approach could be used as a prediction tool in each country using actual pivotal values found in this research. For extension and education purposes RPT may be also useful to graphically show relationships between key variables of interest rather than using the standard multivariate regression method.

A natural follow up for this research could be further exploring the outcomes of this study. Peers and slacks from the data envelopment analyses, surrogate splits from the trees and metatechnology ratios from the metafrontier results which were out of the scope of this work, could be used to gain more insight into the studied farming systems and the virtues of the method. Another direction for future investigation based on this work would be qualitative research both in New Zealand and Chile, to identify the key management factors and the different pathways that lead to consistent efficiency.

The identification of a few KPIs among all the measures currently available may permit a better focus on the really key metrics. This is important for at least two reasons. Firstly, because all the measures and available information at times might be overwhelming and secondly, because a better focus on just few KPIs could allow time and resources to identify and measure other variables needed for improved farming systems such as undesirable outputs that threaten sustainability and resilience. If that were possible the differences in results when undesirable outputs, such us greenhouse gases or soil degradation, would need to be included in future estimations of efficiency in agriculture.

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APPENDICES

Appendix One: *DairyBase* variables and ratios

(Source: DairyBase handbook)

Table A-1

List of Variables DairyBase Analyses

DairyBase	**Variable status**
ACC	ORIGINAL
All Dairy Sheds	ORIGINAL
Animal Health	ORIGINAL
Asseturnover	ORIGINAL
BREED	ORIGINAL
Breeding & Herd Testing	ORIGINAL
Business profit before tax	ORIGINAL
CalfRearing(Excluding Labour)	ORIGINAL
Calving Season	ORIGINAL
Cash Operating Surplus	ORIGINAL
Cash surplus/deficit	ORIGINAL
Change in Dairy Livestock Value	ORIGINAL
Change in Non-dairy livestock Value	ORIGINAL
ChangeDairyLivestock	ORIGINAL
Close Liabilities.kg MS	ORIGINAL
Closing Dairy Investments	ORIGINAL
Closing.Equity	ORIGINAL
ClosingDairy Livestock value	ORIGINAL
ClosingDairyAssets	ORIGINAL
ClosingDairyLandBuildings	ORIGINAL
ClosingTotalAssets$	ORIGINAL
Cows.ha	ORIGINAL
CowsMilked.FTE	ORIGINAL
Dairy Gross Farm Revenue	ORIGINAL
Dairy Operating Profit	ORIGINAL
DairyreturnAssets	ORIGINAL
DebttoAsset % BM	ORIGINAL
Decision making unit (Farm ID+Season)	ORIGINAL
Discretiory cash	ORIGINAL
Drawings	ORIGINAL
EffDAIRYArea (Ha)	ORIGINAL
Effective Area : Non-Dairy (Ha)	ORIGINAL
Effective Area : Run-off Area (Ha)	ORIGINAL
EFs introduced funds	ORIGINAL
EFS: Dairy Operating Profit (EFS)	ORIGINAL
EqGrowthCapital	ORIGINAL
EqGrowthProfit	ORIGINAL
Equity Growth from Profit	ORIGINAL
Estimated $.kg MS	ORIGINAL
Extraordiry expenses	ORIGINAL
Farm ID	ORIGINAL
Farm System	ORIGINAL
Farm Working Expenses	ORIGINAL

FarmDairyExpenses	ORIGINAL
Feed Inventory Adjustment	ORIGINAL
FeedInvAdj	ORIGINAL
Fertiliser	ORIGINAL
FEW	ORIGINAL
FEW.kg MS	ORIGINAL
FreightgeneralFWE	ORIGINAL
Fuel & Oil	ORIGINAL
GFR.ha	ORIGINAL
GFR/kg MS	ORIGINAL
Grazing and Run-off Expenses	ORIGINAL
GrowthEquity	ORIGINAL
GrowthEquity %	ORIGINAL
IL	CREATED
Income Equalisation	ORIGINAL
Interest	ORIGINAL
Interest & Rent.GFR	ORIGINAL
Interest & Rent.kg MS	ORIGINAL
IRRIGATION	ORIGINAL
LabAdj-Management	ORIGINAL
LabAdj-Non-paid	ORIGINAL
Labour Adjustment	ORIGINAL
Labour Expenses (adjusted)	ORIGINAL
Liabilities.kg MS	ORIGINAL
Milk Fat composition	ORIGINAL
Milk fat/cow	ORIGINAL
Milk fat/ha	ORIGINAL
Milk litres/cow	ORIGINAL
Milk litres/ha	ORIGINAL
Milking interval	ORIGINAL
MS.cow	ORIGINAL
MS.FTE	ORIGINAL
MS.ha	ORIGINAL
MSComposition	ORIGINAL
Net Adjustments	ORIGINAL
Net Capital Expenditure	ORIGINAL
Net Cash Income	ORIGINAL
Net cost of leased runoff land	ORIGINAL
Net Debt	ORIGINAL
Net heifer/General grazing	ORIGINAL
Net Livestock (adjusted)	ORIGINAL
Net Milk Sales	ORIGINAL
Net Non-Dairy Cash Income	ORIGINAL
Net Off-farm income	ORIGINAL
Net revenue from dairy livestock	ORIGINAL
Net winter grazing	ORIGINAL
NetMilkSales	ORIGINAL
NetRDairyLivestock	ORIGINAL
Nitrogen	ORIGINAL
Non-Dairy (Ha)	ORIGINAL
Non-dairy operating profit	ORIGINAL

Non-DairyCashIncome	ORIGINAL
Non-DairyOpEx	ORIGINAL
Non-dairyOpProfit	ORIGINAL
Number of replacement calves reared	ORIGINAL
Off Farm Income	ORIGINAL
Opening Dairy Investments	ORIGINAL
OpeningDairyLandBuildings	ORIGINAL
OpeningDairyLivestockValue	ORIGINAL
OpeningTotalAssets	ORIGINAL
OpEquity	ORIGINAL
OpEx.ha	ORIGINAL
OpEx.kg MS	ORIGINAL
OpProfit(EFS).ha	ORIGINAL
OpProfit(EFS).kg MS	ORIGINAL
OpProfitMargin	ORIGINAL
Overheads	ORIGINAL
Owned Run-off Adjustment	ORIGINAL
Owned Run-off Adjustment	ORIGINAL
Paid FTEs	ORIGINAL
PEAKCOWS	ORIGINAL
Protein Composition	ORIGINAL
Protein/cow	ORIGINAL
Protein/ha	ORIGINAL
RatesLandwater	ORIGINAL
Region	ORIGINAL
Rent	ORIGINAL
Repairsmaintenance	ORIGINAL
repairsmaintenanceLand&Buildings	ORIGINAL
ReturnEquity	ORIGINAL
Run-off (Ha)	ORIGINAL
Season	ORIGINAL
suppl.ha	ORIGINAL
Suppl.PurchasedMadeCropped	ORIGINAL
Supplementary Feed Expenses	ORIGINAL
Tax	ORIGINAL
Tax/ha	ORIGINAL
TotAdmEx	ORIGINAL
Total Area : Milking Platform (Ha)	ORIGINAL
Total Dairy Operating Expenses	ORIGINAL
Total Depreciation	ORIGINAL
Total fat for KPIs	ORIGINAL
Total FTEs	ORIGINAL
Total Grazing & Run Off Expenses	ORIGINAL
Total milk for KPIs	ORIGINAL
Total Other Dairy Farm cash revenue	ORIGINAL
Total Other Working Expenses	ORIGINAL
Total Overheads	ORIGINAL
Total protein for KPIs	ORIGINAL
Total Stock Expenses	ORIGINAL
Total Supplement Expenses	ORIGINAL
TotalArea (Ha)	ORIGINAL

TotalFixedAssetsClosing	ORIGINAL
TotalMSProduced	ORIGINAL
TotalrrigationEx	ORIGINAL
TotCostPastureRenovation	ORIGINAL
TotCurrentAssetsClosing	ORIGINAL
TotCurrentLiabilitiesClosing	ORIGINAL
TotDairyOpEx	ORIGINAL
TotDepreciation	ORIGINAL
TotFarmElectricity	ORIGINAL
TotFarmInsurance	ORIGINAL
TotFarmVehExexcludingfuel	ORIGINAL
TotFeedEx	ORIGINAL
TotFixedAssets-Opening	ORIGINAL
TotGraz&RunOffEx	ORIGINAL
TotLabExpenses	ORIGINAL
TotOpEx	ORIGINAL
TOTOpPROFIT	ORIGINAL
TotOtherDairyFarmcashR	ORIGINAL
TotOtherFWE	ORIGINAL
TotOverheads	ORIGINAL
TotreturnAssets	ORIGINAL
TotreturnEquity	ORIGINAL
TotStockExpenses	ORIGINAL
TotSupplExpenses	ORIGINAL
TotTerm LiabilitiesClosing	ORIGINAL
Ungrazeable area	ORIGINAL
UnpFamilyLabour	ORIGINAL
UnpFamilyManag	ORIGINAL
Wages (incl ACC, less subsidies)	ORIGINAL
Wages(inclACClesssubsidies)	ORIGINAL
Weed and Pest	ORIGINAL
Winter milk	ORIGINAL
Youngstock area	ORIGINAL

Production System: The type of production system as defined by the amount of imported feed and/or off farm dry cow grazing (irrespective of young stock grazing).

Calving Season: The calving season for the herd. 1 Spring only. 2 Autumn only. 3 Spring and Autumn. 4 Other, including year round and extended lactation.

Milking Interval: Describes milking frequency: 1 TAD Twice a day milking for majority of milking season. 2 OAD Once a day milking for majority of milking season. 3 Mixed – OAD for between 16 and 30 weeks of milking season. 4 Other eg 3 times in 48 hours for majority of milking season.

Winter Milk: Describes whether the herd is milked during the winter months of June and July.

Region: DairyBase has 8 regions across the country: 1 Northland. 2 Waikato. 3 Bay of Plenty. 4 Taranaki. 5 Lower North Island. 6 West Coast-Tasman. 7 Marlborough-Canterbury. 8 Otago-Southland (refer to the website www.dairybase.co.nz for a map showing regions).

% Milking Area Irrigated: Describes the proportion of the Milking Area (C31) that is irrigated. 1 No irrigation. 2 Some irrigation – but less than 30% of the Milking Area is irrigated. 3 More than 30% of the Milking Area is irrigated.

Farm Dairy Type: The farm dairy type followed by the number of sets of cups. H = Herringbone R = Rotary. O = Other

Predominant Dairy Breed: The main (predominant) breed of the herd. 1 Friesian. 2 Crossbred. (Under 70% of 1 specific breed). 3 Jersey. 4 Other (Ayrshire, Brown Swiss, Guernsey, Milking Shorthorn etc.)

Peak Cows Milked: The highest number of cows milked at any time during the season.

Stocking Rate (Cows/ha): The number of Peak Cows Milked divided by Milking area.

Replacement Calves Reared: The total number of heifer calves reared as herd replacements for the year.

Non-replacement Calves Reared: The total number of beef (non-replacement) calves reared in both the spring and autumn (includes dairy heifers raised for sale).

Full Time paid labour Equivalents: 1 FTE = 2,400 hours of work a year. All paid farm employees hours as a proportion of the working year (2,400 hours). Includes labour for calf rearing, relief milking and casual workers as well as paid farm managers. Excludes any specific contract work such as cultivation or fencing etc which is attributed to another category.

Full Time unpaid labour Equivalents: 1 FTE = 2,400 hours of work a year. All unpaid (usually family labour) farm labour hours as a proportion of theworking year (2,400 hours). Includes unpaid labour for calf rearing and relief milking. A maximum of 0.5 FTEs will be added to unpaid labour from unpaid management due to different treatments to calculator labour adjustment.

FTE unpaid Management: 1 FTE = 2,400 hours of work a year. The Full Time Equivalent (FTE) of all unpaid (usually family) farm management. The number of FTEs displayed for unpaid management could be up to a maximum of 1.0. Management FTEs over 1.0 will be added to unpaid labour (C23) up to a maximum of 0.5 FTEs. Note: it is possible to have less than 1.0 FTE unpaid management.

Total FTEs: Total paid and unpaid labour hours as a proportion of the working year (2,400 hours).

Total Dairy area: Total surveyed dairy farm area (freehold and leasehold) excluding run-off.

Ungrazeable area: The area on the Total Farm that can not be grazed. This includes waste areas, waterways, races, fences, drains, buildings and forestry.

Effective Dairy area: Total Dairy area less Ungrazeable area. Essentially this is the area available for grazing and/or cropping.

Defined Young Stock area: The Effective area assigned to young stock over 3 months of age. (based on a 25% replacement rate). For young stock raised to 10 months; 4% of Effective area For young stock raised from 10 to 22 months, 11% of Effective area. For young stock raised from 3 to 22 months, 15% of Effective area

Milking area: Effective area less Defined Young Stock area. It is the pasture and/or cropping area available for milking cows. This figure is used to calculate per ha KPI's.

Dairy Run-off effective area: Effective run-off area (freehold and leasehold) used to support the milking area. Note: this does not include the area used for non-dairy related production.

Non-dairy effective area: Any effective run-off area (freehold and leasehold) not used for the dairy cows within the business. Include: Effective area used for grazing non-dairying livestock, grazing dairy stock on a contract basis, forestry, horticulture, viticulture and cash cropping,

Total – Total for the farm

Per ha – Total divided by Milking area

Per cow – Total divided by Peak Cows Milked

Composition – Kg of milk solids (fat, protein, total MS) divided by Milk Litres. This shows the milk composition proportion per litre of milk supplied

Milk litres: Total volume of milk supplied to dairy company plus milk fed to non-replacement calves.

Fat Kg: Total milk fat supplied to dairy company plus milk fat fed to non-replacement calves.

Protein Kg: Total milk protein supplied to dairy company plus milk protein fed to non-replacement calves.

Financial year - Milk solids Kg: Total Fat Kg produced plus total Protein Kg produced Total milk solids supplied to dairy company plus milk solids fed to non-replacement calves. This is for the financial year e.g. May June. This figure is used to calculate per Kg Milk solid KPI's in the financial reports

Non-replacement Calf Milk (litres): Milk (excluding colostrum) from the vat fed to non-replacement calves.

Non-replacement Calf Milk (Kg): Milk litres for Non-Replacement Calves converted to Kgs MS using the total Kg MS supplied to the dairy company for the season divided by total litres supplied to the dairy company for the season.

Stocking Rate: Peak Cows Milked divided by Milking area.

Kg Milk solids/ha: Milk solids Kg divided by Milking area.

Kg Milk solids/cow: Milk solids Kg divided by Peak Cows Milked

Cows/FTE: Peak Cows Milked divided by Total FTEs

Kg MS/FTE: Total Milk solids Kg produced divided by Total FTEs.

Gross Farm Revenue/ha: Dairy Gross Farm Revenue (GFR) - cash and non cash from net milk, net livestock (adjusted) and other dairy farm related revenue divided by milking area.

Operating Expenses/ha: Total Dairy Operating Expenses (E29) - cash and non cash- divided by Milking area.

Operating Profit (EFS)/ha: Dairy Gross Farm Revenue per ha (K06) less Total Dairy Operating Expenses per ha.

Gross Farm Revenue/Kg MS: Dairy GFR divided by Milk solids Kg.

Operating Expenses/Kg MS: Total Dairy Operating Expenses - cash and non cash divided by Milk solids Kg.

Operating Profit (EFS)/Kg MS: Dairy Gross Farm Revenue per Kg MS less Total Dairy Operating Expenses per Kg Ms.

FWE/Kg MS: Farm Working Expenses divided by Milk solids Kg.

Operating Profit Margin %: Dairy Operating Profit as a percentage of Dairy Gross Farm Revenue. This measures how well a farm generates profit from its revenue.

Asset Turnover %: Dairy Gross Farm Revenue as a percentage of Opening Dairy Assets. Note: Opening assets are Closing assets from the previous year. The rate of asset turnover measures how well a farm generates dairy revenue from its assets.

Operating Return on Dairy Assets %: Dairy Operating Profit plus owned run-off adjustment less rent as a percentage of Opening Dairy Assets. Note: Opening Dairy Assets are Closing Dairy Assets from the previous year . The RoDA measures the profit generated from the dairy assets employed

Interest and Rent/Total Revenue: Interest and Rent (excluding run-off rent) paid as a percentage of Total Revenue: Total GFR + Net off-farm income.

Interest and Rent/Kg MS: Interest and Rent (excluding run-off rent) paid divided by Milk solids Kg.

Total Return on Assets %: Total Operating Profit plus owned run-off adjustment less rent plus change in capital value divided by Opening Total Assets. Note: Opening Total Assets are Closing Total Assets from the previous year. The TRoA is the profit generated by the assets employed plus capital gains and losses. It measures the overall financial performance of the business.

Change in Capital Value: Closing Total Assets less Opening Total Assets less Net Capital Purchases less Value of Change in Dairy Livestock. Note: Opening Total Assets are Closing Total Assets from the previous year

Return on Equity % (excluding change in capital value): Total Operating Profit plus owned run-off adjustment plus net off-farm income less rent less interest as a percentage of Opening Equity. Note: Opening Equity is Closing Equity from the previous year. The RoE measures the return on the funds of the owner but does not include the change in capital value.

Total Return on Equity %: Operating Profit plus owned run-off adjustment plus net off farm income less rent less interest plus change in capital value as a percentage of Opening Equity. Note: Opening Equity is Closing Equity from the previous year (Y-1). The TRoE measures the return on thefunds of the owner including the change in capital value.

Net Cash Income: Net Cash income from milk sales; net (sales-purchases) dairy livestock sales and other dairy farm related revenue. Note: this is net cash income from dairy operations only and does not include the value of the change in dairy livestock numbers.

Farm Working Expenses: Total dairy farm cash expenditure, including labour, stock, feed, other working expenses and overheads.

Cash Operating Surplus: Net Cash Income less Farm Working Expenses. It is the cash available from dairying after paying for farm working expenses.

Discretionary Cash: This is the cash available from dairy, non-dairy and off-farm operations to meet capital purchases, debt repayments, drawings, and extraordinary expenses (discretionary items). The calculation is Cash Operating Surplus less rent, interest and tax plus net non-dairy cash income, change in income equalisation and net off-farm income.

Cash Surplus/Deficit: The cash surplus from dairy, non-dairy and off-farm operations over the year. It is measured by total discretionary cash plus introduced funds less net capital purchases, net change in debt, drawings and extraordinary expenses.

Closing Dairy Assets $: The value of all dairy related assets at close of the financial year. 1 Closing land and buildings (includes all improvements used for dairying eg fences, races, dairy shed and the house value) valued at current market value by applying an adjustment based on Quotable Value sales to the latest Rateable Capital Value. Alternatively an assessed market value can be entered for open and close. 2 plus plant, machinery and vehicles at book value, 3 plus dairy livestock valued at NAMV, 4 plus any dairy related farm investments eg dairy company shares and shares in dairying related companies eg fertiliser, meat, animal breeding and trading companies) at market value. Note: Closing Dairy Assets does not include current assets eg bank, savings accounts, sundry debtors.

Closing Total Assets $: The total value of all business assets at closen Closing Dairy Assets 2 plus any non-dairy farm land and buildings 3 plus the book value of any plant, machinery and vehicles not included in Dairy Assets, 4 plus all non-dairy livestock valued at NAMV, 5 plus the market value of any off-farm assets and investments eg off-farm houses, commercial buildings, boats, aeroplanes Note: Closing Total Assets does not include current assets eg bank, savings accounts, sundry debtors.

Closing Total Liabilities $: Closing long-term liabilities + (current liabilities – current assets). Note: debt to family is included in liabilities if there is an expectation that it will be repaid. A long-term liability is one where the term for repayment is longer than 1 year. This also includes hire purchases for more than 1 year.

Closing Total Equity $: This is sometimes referred to as Net Worth as it is the value of the owner's share of the assets. Closing Assets–Closing Liabilities.

Growth in Equity $: The change in owner's equity during the year.Closing Equity – Opening Equity. Note: Opening Equity is Closing Equity from the previous year.

Equity Growth from Profit $: Dairy operating profit plus the adjustment for non-paid family labour and management plus the adjustment for owned run-off, plus non dairy operating profit plus net off-farm income less extraordinary expenses, rent (excluding run-off), interest, drawings and tax.

Growth from Capital $: Growth in Equity less Growth from Profit. It includes capital gain and introduced funds.

Growth in Equity %: Closing Equity – Opening Equity as a percentage of Opening Equity. Note: Opening Equity is Closing Equity from the previous year.

Debt to Assets %: Closing Total Liabilities as a percentage of Closing Total Assets. This measures the proportion of the business value that is borrowed by the owners. Note: the Equity to Asset ratio is the inverse of the Debt to asset ratio and thus the 2 measures sum to 100%.

Liabilities per Kg MS: Opening: Total Liabilities divided by Milk solids Kg. Note: Opening Total Liabilities is Closing Total Liabilities from the previous year (Y-1).

Appendix Two: *TodoagroBase* variables and ratios

Table A-2

List of Variables TodoagroBase Analyses

TodoagroBase	Variable status
Adm, freights, others US$	CREATED
Administration, freights and others	ORIGINAL
Animal health CLP$	CREATED
Animal health CLP$.L	ORIGINAL
Arriendo $.L	ORIGINAL
Assets CLP$	CREATED
AssetsUSD	CREATED
AssetsUSD.ha	CREATED
ATR	CREATED
Cash I.ha US$	CREATED
Cash income CLP$	CREATED
Cash income CLP$.L	ORIGINAL
Cash Income.ha	ORIGINAL
Cash Op Surplus US$	CREATED
Cash Op Surplus.ha US$	CREATED
Cash operating surplus	CREATED
CL$/US$	CREATED
Contribuciones CLP$.L	ORIGINAL
Contribution CLP$	CREATED
Cow.ha	CREATED
Cows	ORIGINAL
Decision making unit (Farm ID+Year)	CREATED
Depreciation	CREATED
Depreciation $.L	ORIGINAL
Discretionary cash plus tax	CREATED
Effdairy area (ha)	ORIGINAL
Electricity CLP$	CREATED
Electricity CLP$.L	ORIGINAL
Farm ID	ORIGINAL
FEW (PROD+ADM-DEPR)	CREATED
FEW US$	CREATED
FEW.Cow	CREATED
FEW.cow US$	CREATED
FEW.ha	CREATED
FEW.ha US$	CREATED
Fuel & oil CLP$.L	ORIGINAL
Fuel & oil CLP$	CREATED
Gastosadmin $.L	ORIGINAL
Gastosfinancieros	CREATED

GFR CLP$	ORIGINAL
GFR CLP$.cow	ORIGINAL
GFR US$	CREATED
GFR. US$ cow	CREATED
GFR.ha US$	CREATED
Inseminación	CREATED
Insemination $.L	ORIGINAL
L.cow	ORIGINAL
L.ha	ORIGINAL
L.milked cow	ORIGINAL
Livestock sold (heads)	ORIGINAL
MantencionCosts CLP$	CREATED
Margen Neto CLP$	ORIGINAL
Meat price CLP$/kg	ORIGINAL
Milk control CLP$	CREATED
Milk control CLP$.L	ORIGINAL
Milk price (CLP$/L)	ORIGINAL
Milk price (US$/L)	CREATED
Milk:Feed prices ratio	CREATED
Milked cow/Total cow	ORIGINAL
Milked cows	ORIGINAL
Net milk sales CLP$	ORIGINAL
Net MS US$	CREATED
Net MS US$.ha	CREATED
Off farm forage	ORIGINAL
Operating Profit $	CREATED
Operating Profit US$	CREATED
OpEx (Total-Int-Rent)	CREATED
OpEX US$	CREATED
OpEX US$.ha	CREATED
OpProf Margin	CREATED
OpProfit $.Cow	CREATED
OpProfit $.ha	CREATED
OpProfit.cow US$	CREATED
OpProfit.ha US$	CREATED
Pasture renov.&others CLP$	CREATED
Pasture renov.&others CLP$.L	ORIGINAL
Prod+Aminsitration $	CREATED
Production cost CLP$.L	ORIGINAL
Profitability %	ORIGINAL
Region	ORIGINAL
Rent CLP$	CREATED
Resultado CLP$.L	ORIGINAL
ROA %	CREATED
SubTotCostprodGastosAdmin $.L	ORIGINAL
SubTotMantencion CLP$.L	ORIGINAL

Supplement (g.L)	ORIGINAL
Supplement CLP$/kg	ORIGINAL
Supplement kg/cow	ORIGINAL
Supplements CLP$	CREATED
Supplements CLP$.L	ORIGINAL
Total Cost $	CREATED
Total cost CLP$.L	ORIGINAL
Total Interest CLP$	CREATED
Total production cost $	CREATED
TotProd US$	CREATED
TotProd US$.L	ORIGINAL
UAxHa	ORIGINAL
Wages CLP$	CREATED
Wages CLP$.L	ORIGINAL
Year	ORIGINAL

Season: period between the 1st of January each year until the 31st of December.

Dairy Area (ha): indicates the area under dairy, including run-off and crops.

Milk production (L): milk produced annually by each farm.

Cows: the average obtained between beginning and ending inventory of dairy cows (heads) per year.

Annual production per cow (L/cow): milk production in the period in relation to the mass number of cows.

Annual production per milked cow (L/milked cow): milk produced per cow milked.

Milk equivalent (L): Milk plus the meat produced in the Dairy area "converted" to L of milk. Meat is obtained from the sum of income from meat (calves and cull cows sold or transferred to fattening area, inventory difference, and new born calves). This is converted to 'milk' by dividing into the average price received per L of milk. 'Litres' resulting from this calculation are added to the milk produced on the farm.

Milk per hectare (L/ha): is equivalent milk production divided by dairy area.

Stocking (AU/ha): is the number of cows (expressed in animal unit (AU)) for the Dairy area.

Use of concentrate: variable measured by the consumption of concentrate per cow (kg concentrate/cow) and also by the grams of concentrate used per liter of milk produced (g of concentrate/L of milk).

Production costs (CLP$/L): includes wages, energy (electricity, fuels and lubricants), contributions and leases, maintenance (machinery, buildings, parlor, fences, roads and other), grassland and fodder at (fertilizers, chemicals, seeds, forage conservation, among others), concentrates and forages external health and milk control, insemination, replacement and purchase of cows, depreciation and administration and expenditure item general, which includes overhead, personal retreats, compensation manager, freight and sales commissions of animals;

Direct Costs (CLP$/L): involves costs related to the management of the herd, such as animal health, inputs to the parlour, insemination, own fodder production, fodder and concentrates bought, taxes, rent and labor costs, which involve direct wages and social security;

Indirect Costs (CLP$/L): includes energy costs as defined above, indirect wages, water, telephone, repairs of buildings and machinery of the property, depreciation, overheads, freight and commissions sold animals, administration and personal retreats (two criteria were used for allocating indirect costs: a) sales allowance, which is to distribute indirect costs according to the relative importance of dairy item sales in relation to total sales of the company, b) animal unit allowance assigns the relative costs of the item dairy animal units, relative to the total units of the venture animals.

Gross Farm Revenue (CLP$): product sales plus the value of milk consumed by calves plus inventory variation.

Total Capital (CLP$): is the total value of investments in land, machinery, equipment, buildings, animals and working capital (only considers the investment in pastures).

Net income: revenue less production costs and administrative expenses including bank interest payments as the debt level of the producers is not related to production efficiency.

Profitability (%): Different from return on assets. This indicator is obtained by dividing net income between total assets (land, machinery, equipment, buildings, animals and operating capital)

(Source: Lerdon, Baez & Azocar, 2008)

Appendix Three: R codes

*Data Envelopment Analysis (*requires lpSolve package to be installed).*

```
source("CRS.r")

source("VRSInput.r")

source("VRSOutput.r")

source("Additive.r")

Data = read.csv("EXAMPLE.csv",sep=",",header=T)

Outputs= Data[,1]

Inputs = Data[,2:6]

EXAMPLECRS  = CRS(InputMat = Inputs, OutputMat = Outputs, ResultsFilename = "EXAMPLEResultsCRS", ResultsFileType="csv")

EXAMPLEVRSI  = VRSInput(InputMat = Inputs, OutputMat = Outputs, ResultsFilename = "EXAMPLEVRSI", ResultsFileType="csv")

EXAMPLEVRSO = VRSOutput(InputMat = Inputs, OutputMat = Outputs, ResultsFilename = "EXAMPLEVRSO", ResultsFileType="csv")

EXAMPLEAdd = Additive(InputMat = Inputs, OutputMat = Outputs, ResultsFilename = "EXAMPLEResultsAdd", ResultsFileType="csv")
```

Recursive Partitioning Trees (requires the rpart package to be installed).

```
Data = read.csv("EXAMPLE.csv",sep=",",header=T)

str(Data)

library(rpart)

Model = rpart(RESPONSE VARIABLE ~.,data=Data,control=c(minbucket=50))

sink("RPartOutput.txt",append = FALSE)

print(Model)

summary(Model)

sink()
```

Appendix Four: The NZ classification system, an iterative process

This section describes the iterative process leading to the final classification system in NZ, which in turn, guided the selection of the Chilean classification system. After reviewing the literature it was evident that a combined approach was required. To split the sample according to year was the first straightforward decision. Some particular, very responsive variables were certainly likely to show both intra and inter-annual variation. Examples of these are pasture growth and use of imported feed both highly responsive to rainfall which shows high variability in inter-annual comparisons. Issues around categorisation by DairyNZ farming systems were that previous empirical work has been done where differences between systems in efficiency terms were not recognized. The sample was split into three intensification levels (IL), created by re-coding DairyNZ farming systems such that farming systems 1 and 2 composed LOW, farming system 3 represented MEDIUM and farming systems 4 and 5 composed HIGH.

A preliminar analysis was conducted to evaluate the variability across regions. The regional analysis included the whole dataset, which comprises 2,614 observations across the period 2006 to 2011. The dataset was highly unbalanced in the size of sample per region as it is shown in Table 1 by the n value. The variables analysed were herd size, stocking rate, FTEs, MS/ha, MS/cow, Operating expenses and Operating profit per hectare. A second preliminar analysis was then conducted to evaluate variability across seasons. The seasonal analysis included the whole dataset or pooled sample (n=2614). Data was available for seasons 2006/07, 2007/08, 2008/09, 2009/10 and 2010/11. A third preliminar analysis was conducted to evaluate whether or not the DairyNZ's farming systems approach based on the use of imported feed was relevant. The analysis included the whole dataset, which comprises n observations across all regions and seasons (n = 2611). More than 65% of the sample was composed of Farming systems 2 and 3.

Table A-3: *Descriptive Regional Analysis of Selected KPIs*

Descriptives

		N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Peak cows milked	1	268	349.0	218.2	13.3	84.0	1850.0
	2	864	384.4	280.7	9.5	55.0	3100.0
	3	215	357.3	162.6	11.1	99.0	1030.0
	4	292	295.2	138.1	8.1	93.0	1160.0
	5	182	394.0	254.8	18.9	106.0	1800.0
	6	226	392.7	247.5	16.5	114.0	1710.0
	7	324	819.5	455.1	25.3	155.0	2966.0
	8	243	527.2	264.8	17.0	126.0	1989.0
	Total	2614	437.2	317.4	6.2	55.0	3100.0
Cows/ha	1	268	2.5	.5	.0	1.3	4.1
	2	864	3.0	.5	.0	1.5	5.3
	3	215	3.0	.5	.0	1.7	5.3
	4	292	2.9	.5	.0	1.8	4.8
	5	182	2.9	.4	.0	1.9	4.5
	6	226	2.5	.6	.0	1.2	3.8
	7	324	3.5	.5	.0	2.2	6.3
	8	243	2.8	.4	.0	1.6	4.2
	Total	2614	2.9	.6	.0	1.2	6.3
FTEs including Unpaid Labour	1	268	2.7	1.4	.1	.6	9.7
	2	864	2.6	1.5	.1	.4	13.2
	3	215	2.5	1.1	.1	.7	7.7
	4	292	2.3	1.0	.1	.7	6.0
	5	182	2.7	1.5	.1	.8	9.8
	6	226	3.0	1.6	.1	.9	12.4
	7	324	5.0	2.5	.1	1.5	17.6
	8	243	3.4	1.5	.1	.7	11.2
	Total	2614	3.0	1.8	.0	.4	17.6
Milksolids/ ha Production year	1	268	773.9	211.5	12.9	341.7	1631.0
	2	864	1025.7	295.6	10.1	348.8	2888.8
	3	215	1026.9	237.7	16.2	523.6	2195.7
	4	292	981.8	239.8	14.0	7.7	1743.1
	5	182	1006.3	287.1	21.3	275.8	2239.6
	6	226	867.9	225.0	15.0	9.6	1634.6
	7	324	1443.6	294.3	16.3	6.1	3028.2
	8	243	1123.0	208.0	13.3	513.3	1760.0
	Total	2614	1040.9	316.9	6.2	6.1	3028.2
Milksolids/ cow Production year	1	268	309.5	50.9	3.1	183.0	451.8
	2	864	334.4	59.1	2.0	178.1	649.5
	3	215	344.1	41.8	2.9	200.3	472.2
	4	292	338.0	49.1	2.9	2.8	563.9
	5	182	349.0	70.2	5.2	118.2	603.4
	6	226	348.7	54.2	3.6	4.2	507.8
	7	324	408.7	54.4	3.0	2.0	539.5
	8	243	398.4	52.1	3.3	222.2	550.9
	Total	2614	350.4	62.9	1.2	2.0	649.5
Operating Expenses/ ha	1	268	3936.9	1258.8	76.9	1515.0	8852.1
	2	864	4599.2	1631.3	55.5	1259.1	15354.4
	3	215	4652.3	1498.2	102.2	1815.0	13854.3
	4	292	4246.5	1174.7	68.7	1818.5	9321.7
	5	182	4530.9	1536.4	113.9	1774.8	11379.5
	6	226	4083.7	1451.7	96.6	1463.8	9873.4
	7	324	6441.3	1647.8	91.5	3291.7	14871.1
	8	243	4762.6	1408.0	90.3	1979.9	13650.7
	Total	2614	4690.5	1655.3	32.4	1259.1	15354.4
Operating Profit (EFS)/ha	1	268	1186.8	1270.1	77.6	-1463.2	5258.6
	2	864	1904.4	1350.8	46.0	-2491.7	9794.0
	3	215	2016.7	1276.1	87.0	-1096.5	6067.6
	4	292	2017.5	1317.4	77.1	-1487.6	6725.8
	5	182	1876.2	1406.5	104.3	-1295.0	6920.1
	6	226	1398.2	1148.5	76.4	-1282.2	4598.6
	7	324	2972.7	2167.6	120.4	-2345.8	8319.3
	8	243	2287.7	1502.1	96.4	-1258.2	6912.6
	Total	2614	1975.0	1536.9	30.1	-2491.7	9794.0

Beyond the differences in the absolute value of the variables presented in Table 1, the regional analysis of means using one way ANOVA and Schaffe tests, showed statistical differences between the majority of the regions in every studied variable. Herd size presented significant differences in 16 out of the 28 pairs compared. Stocking rate and MS/ha was significantly different for 21 out of the same 28 pairs. FTEs and Operating profit/ha presented statistical differences in 19 out of 28, while Operating Expenses/ha were significantly different in 18 out of 28 paired comparisons. Interestingly, Regions 2 and 3 performed statistically equal in all analysed variables, while region 3 and 5 statistically performed identical. Similarly, Region 3 showed to have similarities with 4, which did not present significant differences for all variables except for OpEx/ha that was significant different and higher in Region 3 than in 4. Regions 1 and 6 performed not significantly different in five out of seven variables. The variables that did show differences were related to MS production; both per hectare and cow, demonstrated to be statistically different and higher in Region 6. In contrast, Regions 7 and 8 proved to be unique performing different in all variables and paired comparisons.

When efficiency scores were studied, Region 2 performed with the minimum efficiency and it showed to be different from all other regions. The higher efficiencies were shown by Regions 3, 4, 7 and 8 and proved to have not significant differences. Region 1 was found to be different to all Regions except for number 5. Regions 1 and 5 behaved somewhere in between close to the averaged efficiency for all region and the whole period. Region 6 proved to be different from regions 1, 2, 3, 7 and 8.

Table A-4

Descriptive Seasonal Analysis of Selected KPIs

Descriptives							
		N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Peak cows milked	67	625.00	408.28	280.98	11.24	99.00	2800.00
	78	628.00	424.51	308.83	12.32	60.00	2966.00
	89	497.00	458.91	353.11	15.84	60.00	2894.00
	910	567.00	460.60	317.99	13.35	55.00	2800.00
	1011	297.00	443.51	338.11	19.62	87.00	3100.00
	Total	2614.00	437.16	317.35	6.21	55.00	3100.00
Cows/ha	67	625.00	2.90	0.56	0.02	1.20	5.32
	78	628.00	2.94	0.57	0.02	1.30	5.27
	89	497.00	2.96	0.58	0.03	1.25	5.22
	910	567.00	2.96	0.58	0.02	1.43	6.25
	1011	297.00	2.98	0.59	0.03	1.50	5.13
	Total	2614.00	2.94	0.58	0.01	1.20	6.25
FTEs including Unpaid Labour	67	625.00	2.85	1.71	0.07	0.69	17.56
	78	628.00	2.90	1.73	0.07	0.38	15.16
	89	497.00	3.10	1.96	0.09	0.69	15.53
	910	567.00	3.13	1.76	0.07	0.58	13.75
	1011	297.00	3.01	1.75	0.10	0.77	13.24
	Total	2614.00	2.99	1.78	0.03	0.38	17.56
Milksolids/ha Production year	67	625.00	1056.21	287.56	11.50	341.67	2385.71
	78	628.00	999.76	317.04	12.65	275.84	2888.85
	89	497.00	1052.12	306.56	13.75	375.00	2362.24
	910	567.00	1031.89	339.91	14.27	6.10	3028.21
	1011	297.00	1094.37	337.25	19.57	434.41	2494.45
	Total	2614.00	1040.93	316.93	6.20	6.10	3028.21
Milksolids/cow Production year	67	625.00	361.26	54.49	2.18	181.67	591.55
	78	628.00	336.58	63.22	2.52	118.22	649.50
	89	497.00	353.17	57.93	2.60	190.21	593.21
	910	567.00	344.51	71.32	2.99	2.01	603.38
	1011	297.00	363.67	62.63	3.63	220.36	578.39
	Total	2614.00	350.43	62.88	1.23	2.01	649.50
Operating Expenses/ha	67	625.00	3754.47	1085.29	43.41	1259.08	8612.31
	78	628.00	4866.05	1660.82	66.27	1699.92	14469.50
	89	497.00	5119.70	1793.74	80.46	1604.97	15354.37
	910	567.00	4801.93	1546.98	64.97	1514.97	14871.10
	1011	297.00	5357.71	1788.52	103.78	2269.00	13910.59
	Total	2614.00	4690.46	1655.28	32.38	1259.08	15354.37
Operating Profit (EFS)/ha	67	625.00	1117.59	711.51	28.46	-1283.22	3459.02
	78	628.00	3156.67	1523.31	60.79	-792.85	9793.97
	89	497.00	781.06	1016.46	45.59	-2491.72	4173.01
	910	567.00	2002.72	1209.85	50.81	-1237.95	6595.95
	1011	297.00	3225.77	1363.97	79.15	-315.60	6725.77
	Total	2614.00	1975.01	1536.94	30.06	-2491.72	9793.97

Unbalance is clearly reflected in the following: firstly the last season comprises only 217 DMU's while previous years' numbers were between 497 and 628 and secondly, just 39 firms are present across all seasons. The latter in particular prevents from truly meaningful comparison between seasons. There are minimum absolute differences in herd size across the period reflected in few significant differences when pairs where tested. The 06/07 season presented differences when compared to season 08/09 and 09/10. Stocking rate was not affected, without significant differences across the period. Similarly, Labour did not vary much and showed just minor differences in absolute value only being significantly different when season 06/07 was matched to season 09/10.

The comparison of means yielded four out of 10 pairs of seasons that behaved statistically different from each other when Milk solids, both per hectare and per cow, were analysed. Season 06/07 was significantly different from 07/08, which showed differences when compared to 08/09 and 10/11. Season 09/10 was also different from 10/11. Despite of these, differences did exist for 90% of the pairs when Operating Expenses and Operating profit as ratios were considered. Efficiency was also calculated on a seasonal basis using DEA. Results showed that mean efficiency for dairy farms across all New Zealand were statistically not different in season 06/07, 08/09 and 10/11. In addition, season 07/08 was not significantly different from 09/10. In contrast, mean efficiency scores for season 06/07 proved to be different from seasons 07/08 and 09/10. Similarly, season 07/08 also demonstrate differences with season 08/09 and 10/11, which were both different from seasons 09/10.

Table A-5

Descriptive Farming System Analysis of Selected KPIs

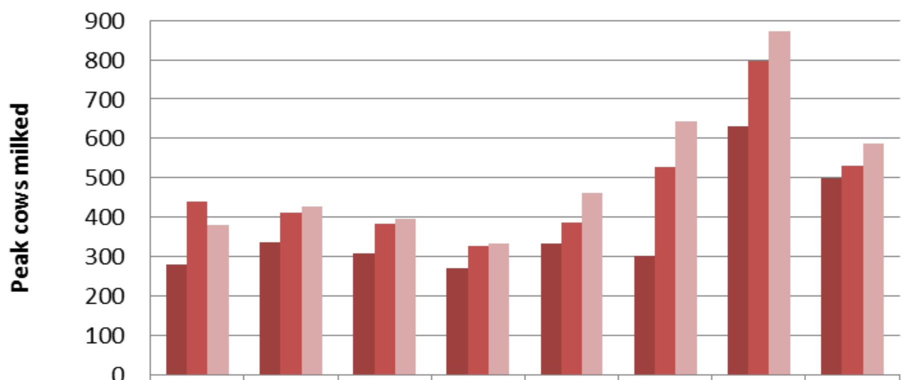
Descriptives

		N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Peak cows milked	1	270	279.85	138.65	8.44	55.00	980.00
	2	803	354.50	202.96	7.16	93.00	1620.00
	3	921	481.26	347.01	11.43	87.00	3100.00
	4	476	561.88	393.79	18.05	76.00	2966.00
	5	141	499.54	363.61	30.62	128.00	2800.00
	Total	2611	437.13	317.48	6.21	55.00	3100.00
Cows/ha	1	270	2.56	.48	.03	1.25	4.45
	2	803	2.76	.49	.02	1.20	4.40
	3	921	2.99	.52	.02	1.47	5.16
	4	476	3.21	.53	.02	1.59	5.27
	5	141	3.56	.72	.06	2.21	6.25
	Total	2611	2.94	.58	.01	1.20	6.25
Milksolids/ ha Production year	1	270	813.37	217.86	13.26	7.73	1764.51
	2	803	919.89	213.06	7.52	352.33	1626.00
	3	921	1053.88	280.89	9.26	9.57	2494.45
	4	476	1225.71	294.89	13.52	411.47	2361.89
	5	141	1453.82	485.21	40.86	6.10	3028.21
	Total	2611	1040.72	316.96	6.20	6.10	3028.21
Milksolids/ cow Production year	1	270	317.10	56.20	3.42	2.83	469.80
	2	803	334.05	53.07	1.87	182.86	525.00
	3	921	350.54	57.47	1.89	4.23	550.68
	4	476	380.69	58.11	2.66	205.74	550.87
	5	141	403.69	93.45	7.87	2.01	649.50
	Total	2611	350.38	62.90	1.23	2.01	649.50
Operating Expenses/ ha	1	270	3523.66	1032.91	62.86	1259.08	7585.96
	2	803	3970.78	1043.36	36.82	1463.83	9886.88
	3	921	4787.19	1378.57	45.43	1774.83	13910.59
	4	476	5659.44	1627.04	74.58	1979.87	13854.28
	5	141	7099.48	2560.50	215.63	2256.47	15354.37
	Total	2611	4689.33	1654.10	32.37	1259.08	15354.37
Operating Profit (EFS)/ha	1	270	1632.56	1230.95	74.91	-1237.95	5593.53
	2	803	1753.87	1262.42	44.55	-1463.19	6721.47
	3	921	1995.23	1533.73	50.54	-2007.98	7541.46
	4	476	2336.89	1781.27	81.64	-2345.84	8319.31
	5	141	2525.90	2129.26	179.32	-2491.72	9793.97
	Total	2611	1974.44	1537.30	30.09	-2491.72	9793.97

Herd size's means showed not significant differences when FS 5 was compared to 3 and 4 although statistical differences between 3 and 4 did exist. Operating Profit/ha proved to be significantly not different for FS 1 and 2; equally, FS 4 proved to behave similarly than FS 5. When efficiency scores were studied, FS 5 presented the highest averaged efficiency score and it was found to be different to all FS except for number 4. FS 4 performed with the second best mean efficiency and it showed to be different from FS 2 and 3 which showed the lowest averaged efficiency scores. Interestingly, FS 1 showed not significant differences with FS 4 despite of being somehow contrasting farming systems.

These results are essentially different to those found by Dake, Shadbolt and Dooley (2011 unpublished) who analysed all five farming systems in the Waikato and the Canterbury regions for the 2010/11 season. They found all systems performed similarly in terms of efficiency scores, estimated using DEA under VRS. Differences can be explained by sample size, regional distribution, the use of a pooled sample including five seasons instead of one and the inclusion of different inputs.

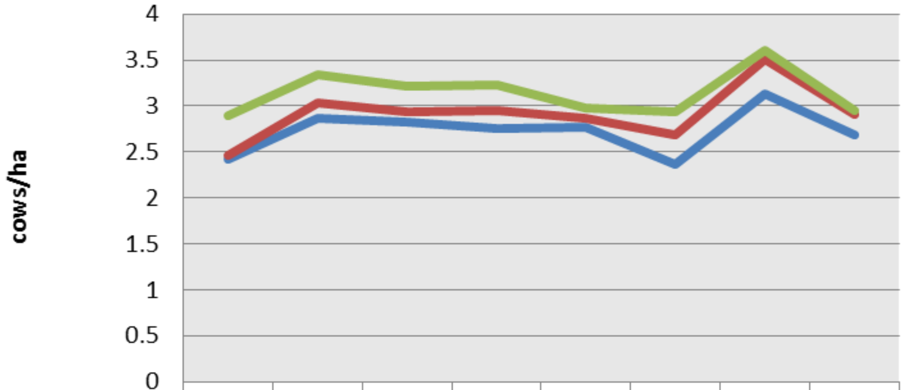
A combination of region (1 to 8) and intensification level (LOW, MEDIUM, HIGH) based on the DairyNZ's farming systems' classification was evaluated. This yielded 2614 observations classified in 27 groups. The variables analysed were herd size, stocking rate, FTEs, MS/ha, MS/cow, Operating expenses, Operating profit per hectare, *Operating profit margin*. There is a clear trend relating to level of intensification (LI) and herd size as shown in Graph 1.



	1	2	3	4	5	6	7	8
LOW	280	337	308	270	333	303	631	498
MEDIUM	441	411	383	326	385	528	797	531
HIG	379	427	397	334	461	642	872	588

Figure A-1: Herd size by region and intensification level

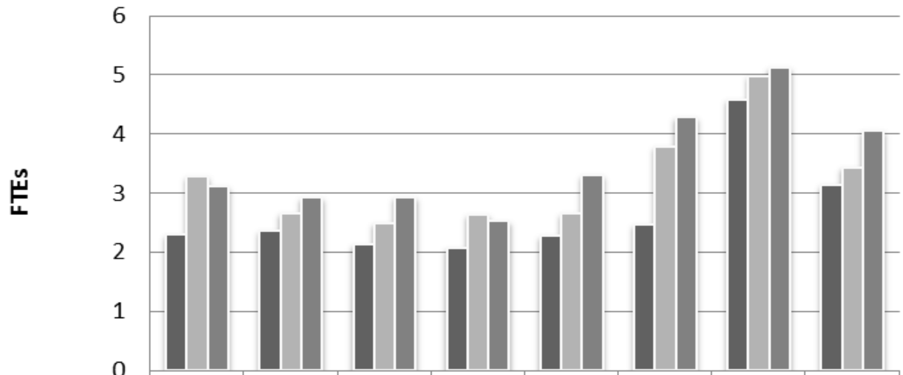
LI tends to increase with herd size or the other way round, at increased herd size, the use of imported feed increase. Region 1 shows the exception to this rule among all other regions explained by the existence of outliers. The variable stocking rate measured in cows/ha consistently responds to intensification level in all regions as presented in Graph 2.



	1	2	3	4	5	6	7	8
LOW	2.42	2.87	2.83	2.76	2.77	2.36	3.13	2.69
MEDIUM	2.46	3.04	2.94	2.95	2.86	2.69	3.51	2.91
HIG	2.9	3.34	3.22	3.23	2.98	2.93	3.6	2.95

Figure A-2: Stocking rate by region and intensification level

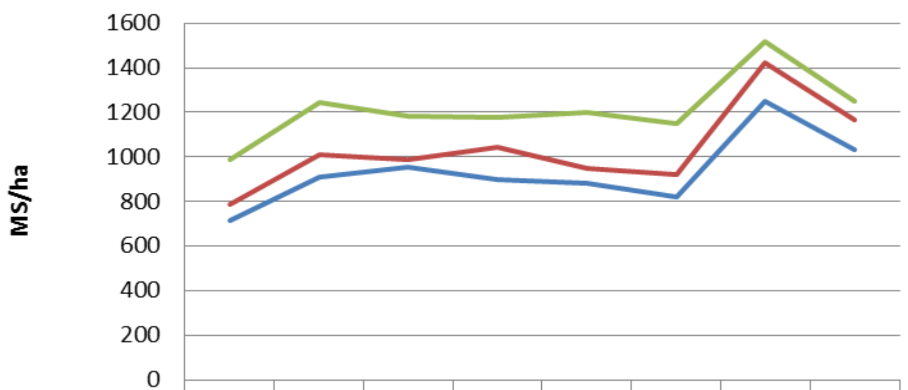
The lowest values are exhibited by regions 1 and 6 while region 7 shows the highest mean and the maximum value for a particular observation: 6.25 cows/ha at 7-HIGH. There is an observable trend between input labour and intensification level as shown in Graph 3.



	1	2	3	4	5	6	7	8
LOW	2.29	2.36	2.13	2.07	2.27	2.47	4.58	3.14
MEDIUM	3.28	2.66	2.49	2.63	2.65	3.78	4.98	3.43
HIG	3.11	2.92	2.93	2.52	3.3	4.28	5.12	4.05

Figure A-3: FTEs per hectare by region and intensification level

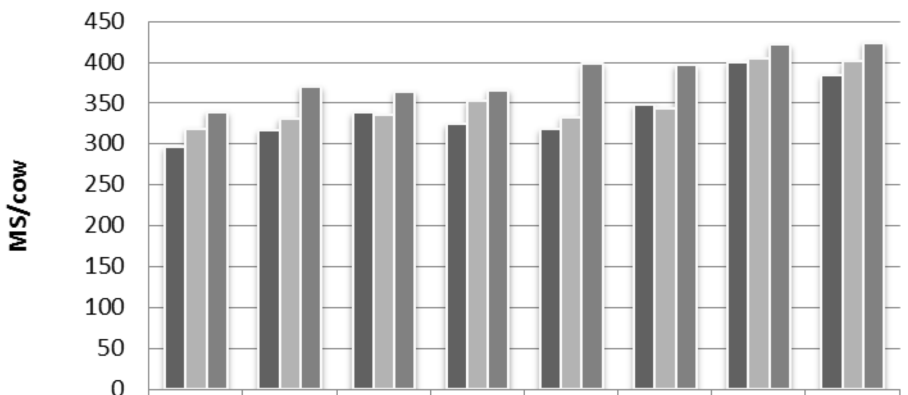
However, Regions 1 and 4 escape to the rule showing maximum labour input at MEDIUM levels of intensification. The highest, both mean and individual, observations are found at 7-HIGH. This is consistent with the high correlation observed in the same dataset, between stocking rate and FTEs. Production measured in MS/ha consistently responds to intensification level in all regions as presented in Graph 4. The response shows a very similar shape than the variable stocking rate, consistent with the high correlation between these two variables.



	1	2	3	4	5	6	7	8
LOW	717	911	954	899	879	819	1247	1032
MEDIUM	785	1011	988	1044	947	920	1423	1165
HIG	985	1246	1182	1177	1200	1150	1515	1252

Figure A-4: Milk solids per hectare by region and intensification level.

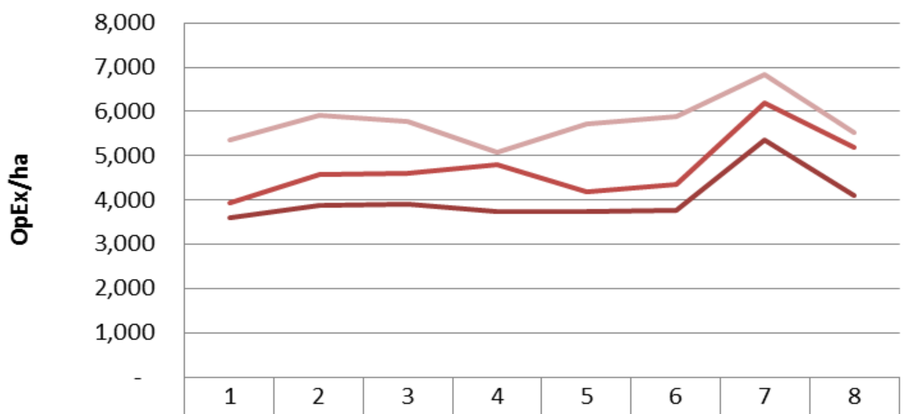
Production measured in MS/cow also responds to intensification level in all regions but some differences are not significant. Regions 3,5, 6 and 7 show very similar means when levels LOW and MEDIUM are compared.



	1	2	3	4	5	6	7	8
LOW	296	317	338	324	318	348	400	384
MEDIUM	319	331	335	353	333	344	404	401
HIG	339	370	364	366	398	396	421	424

Figure A-5: Milk solis per cow by region and intensification level.

Operating Expenses per hectare consistently responds to intensification level in all regions as revealed by Graph 5.

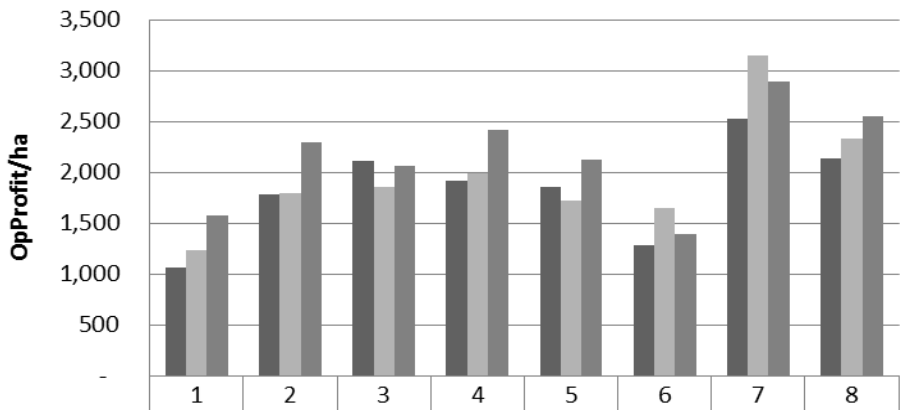


	1	2	3	4	5	6	7	8
LOW	3,612	3,865	3,917	3,753	3,738	3,754	5,368	4,093
MEDIUM	3,925	4,570	4,607	4,801	4,196	4,366	6,205	5,176
HIG	5,360	5,920	5,786	5,064	5,713	5,890	6,836	5,535

Figure A-6: Operating expenses per hectare by region and intensification level.

The lowest mean is found in region 1 closely followed by mean OpEx/ha in region 4, 5, and 6 at the LOW intensification level. Region 2 shows the minimum and maximum individual observations at the LOW and HIGH level respectively, and thus the greatest standard deviation as a region.

There is an observable trend between Operating profit per hectare and IL as shown in Graph 6, where the OpP/ha increases with intensification.

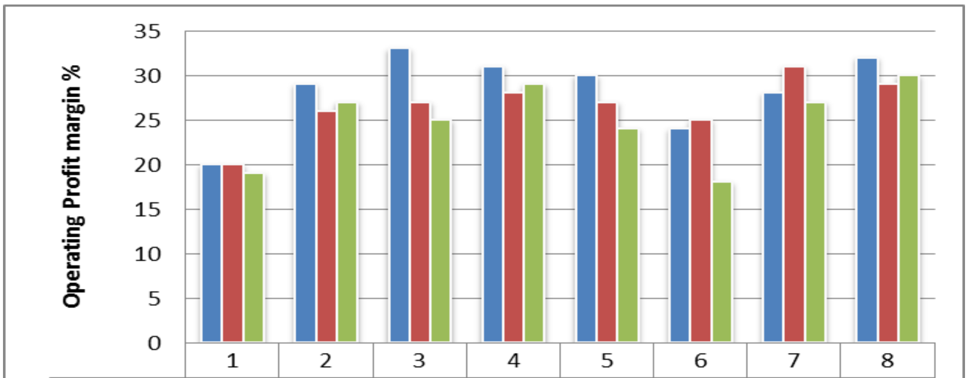


	1	2	3	4	5	6	7	8
LOW	1,067	1,780	2,114	1,912	1,850	1,286	2,526	2,138
MEDIUM	1,228	1,789	1,861	1,988	1,718	1,645	3,145	2,335
HIG	1,581	2,296	2,068	2,413	2,124	1,388	2,896	2,547

Figure A-7: Operating profit per hectare by region and intensification level.

However, regions 3, 5, 6 and 7 present mixed results as shown in Graph. In region 3 the highest likelihood to maximise the result is found at the LOW IL. In regions 6 and 7 maximum values appear associated to MEDIUM IL.

There is another observable but opposed trend between Operating profit margin and IL as shown in Graph 7.



	1	2	3	4	5	6	7	8
LOW	20	29	33	31	30	24	28	32
MEDIUM	20	26	27	28	27	25	31	29
HIG	19	27	25	29	24	18	27	30

Figure A-8: Operating profit margin (%) by region and intensification level.

Differences in operating profit margin are not significant between IL in region 1. Otherwise, the consistent trend is to observe lower margin at the higher intensification levels. The highest mean is found in region 3-LOW and the lowest is found at 6-HIGH. JUSTIFICATION FOR USING MILKSOLIDS AS AN OUTPUT There is little divergence in the use of outputs in the DEA literature. Candidate outputs are usually GFR, Dairy and non-dairy cash income, Milk solids or financial performance measures. This research proposes the use of physical output in the form of MS/ha to keep the milk price effect out. To be consistent, whenever possible, inputs such as labour are also expressed in physical units.

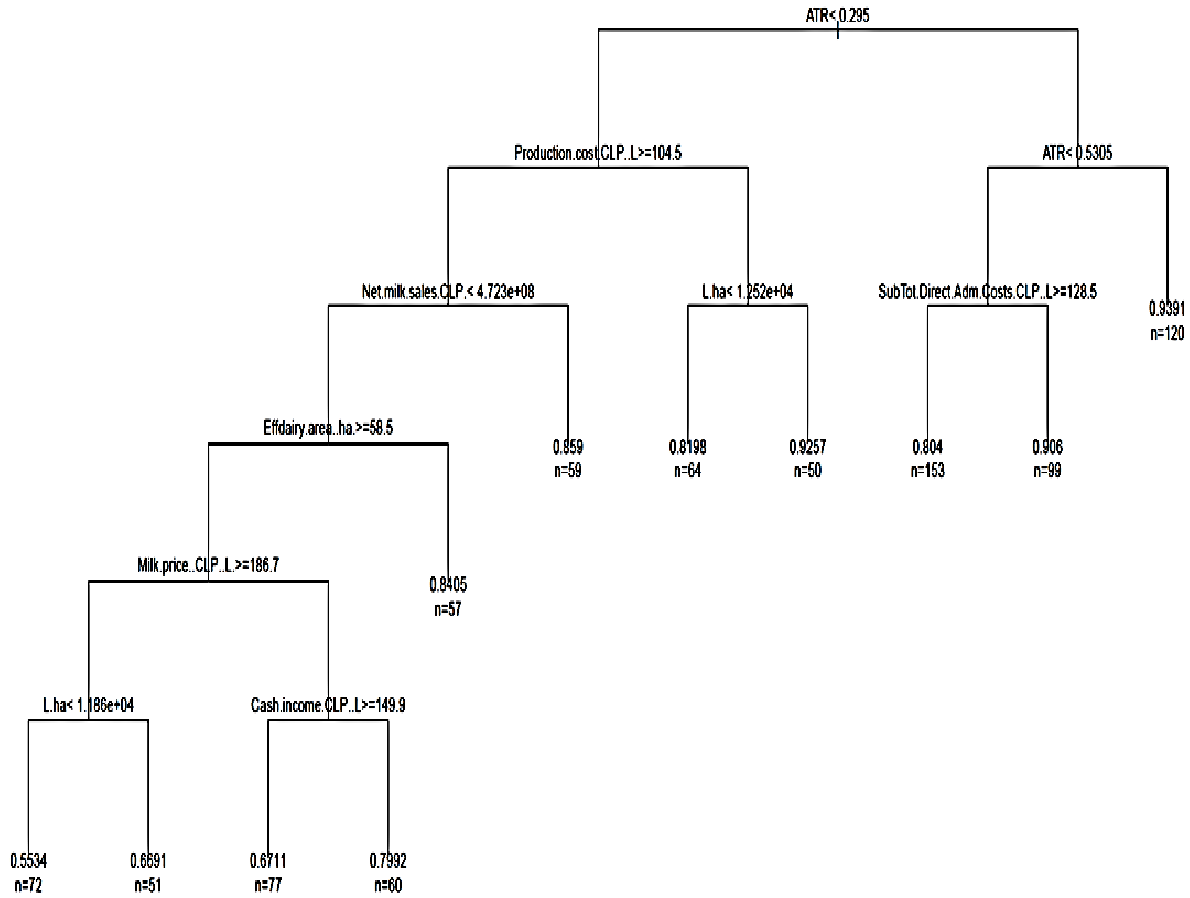
Appendix Five: IFCN results

Table A-6

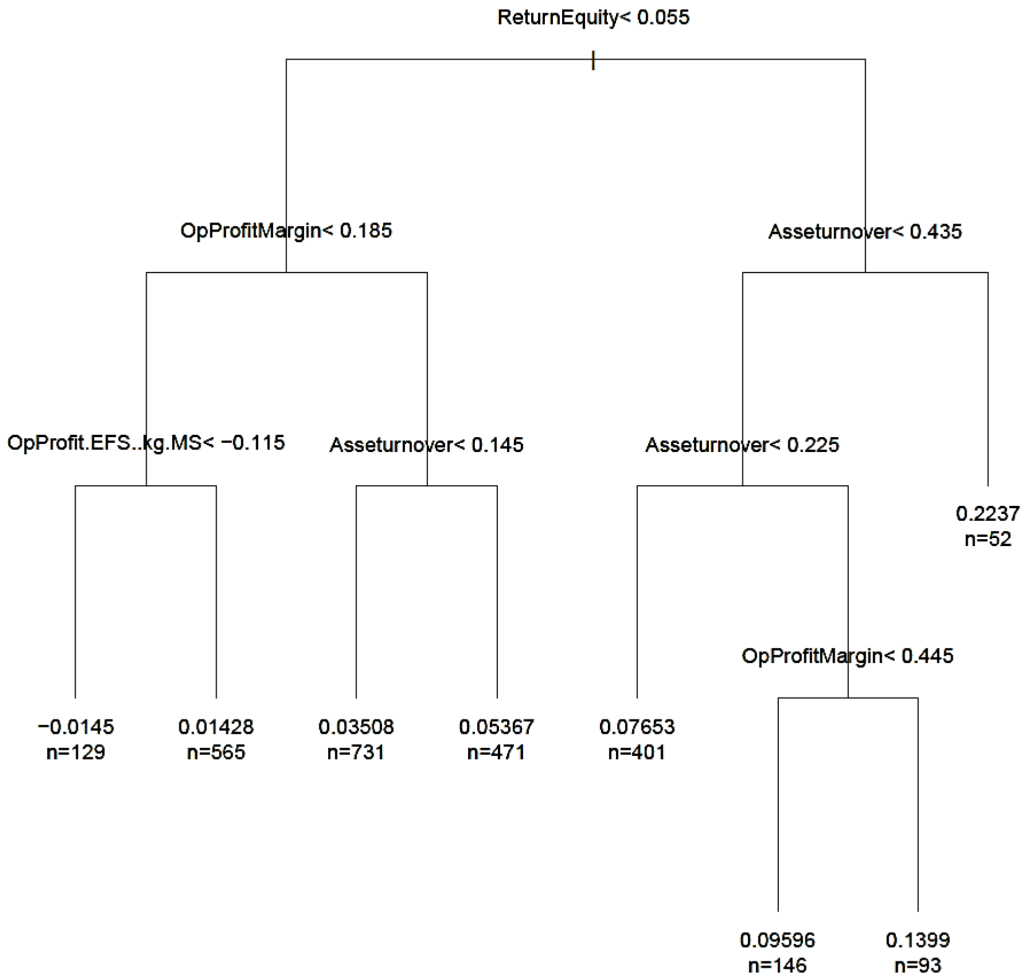
IFCN Approach New Zealand Versus Chile

Farm description	204	160	Difference
	NZ-348	CL-421	
	DR-2011	DR-2011	
No. cows	348	421	21%
Milk output in t ECM	1515	3944	160%
Returns (per 100 kg milk ECM)			
Milk returns	34.1	35.0	3%
Cattle returns	1.6	2.5	56%
Coupled direct payments, subsidies	0.0	0.0	
Decoupled direct payments, subsidies	0.0	0.0	
VAT Balance (if positive)	0.0	0.0	
Other returns	0.5	0.0	-100%
Total returns	**36.2**	**37.5**	**4%**
Costs (per 100 kg milk ECM)			
Animal purchases	0.0	0.0	
Feed (purchase feed, fertiliser, seed, pesticides)	9.9	8.9	-9%
Machinery (maintenance, depreciation, contracter)	2.7	3.4	26%
Fuel, energy, lubricants, water	0.7	1.6	114%
Buildings (maintenance, depreciation)	1.5	1.0	-31%
Vet & medicine, insemination	2.0	1.3	-35%
Insurance Taxes	1.1	0.3	-71%
Other inputs dairy enterprise	0.3	1.1	312%
Other inputs	1.0	0.7	-26%
VAT Balance (if negative)	0.0	0.0	
Costs for means of production	**19.1**	**18.3**	**-4%**
Total land costs	8.0	4.4	-45%
Total labour costs	6.1	6.0	-2%
Total capital costs	3.2	0.8	-75%
Costs for production factors	17.3	11.2	-35%
Total costs (excl. quota costs)	**36.5**	**29.5**	**-19%**
Additional costs for quota (per/100 kg milk ECM)			
Costs for rent of quota	0.0	0.0	
Opportunity costs for own quota (given + purchased)	0.0	0.0	
Results of the dairy enterprise			
Family farm income			
per farm in 1000	161.4	552.3	242%
per 100 kg milk ECM	**10.7**	**14.0**	**31%**
Entrepreneurs profit			
per farm in 1000	-4.5	312.6	-7064%
per 100 kg milk ECM	**-35.9**	**-29.5**	**-18%**
Return on labour input (per h)			
per total hours (without decoupled payments)	16.8	13.7	-19%
Decoupled payments per hour	0.0	0.0	
Return on investment			
ROI - Market values on all assets	4%	9%	105%

Appendix Six: 5th Chilean tree including assets (input variable)



Appendix Seven: 5th NZ tree using ROA as response variable



Appendix Eight: Frequency of consistently efficient farms

Table A-7

Frequency of Consistently Efficient Farms Across Years, Region, Farming systems, Irrigation and Size

DAIRYBASE			
YEAR	TOTAL	RESILIENT NUMBER	RESILIENT FREQUENCY
2008/09	496	102	0.21
2009/10	564	124	0.22
2007/08	614	118	0.19
2006/07	618	113	0.18
2010/11	295	93	0.32
REGION	TOTAL	RESILIENT NUMBER	RESILIENT FREQUENCY
Bay of Plenty	214	40	0.19
Lower North Island	178	43	0.24
Marl-Canterbury	322	77	0.24
Northland	268	49	0.18
Otago-Southland	240	70	0.29
Taranaki	289	43	0.15
Waikato	853	172	0.20
West Coast-Tasman	224	55	0.25
FARMING SYSTEM	TOTAL	RESILIENT NUMBER	RESILIENT FREQUENCY
1	268	52	0.19
2	796	152	0.19
3	910	191	0.21
4	474	109	0.23
5	140	47	0.34
IRRIGATION	TOTAL	RESILIENT NUMBER	RESILIENT FREQUENCY
< 30%	58	10	0.17
>30%	446	112	0.25
NOT IRRIGATED	2084	429	0.21
PEAKCOWS	TOTAL	RESILIENT NUMBER	RESILIENT FREQUENCY
< 300	1040	250	0.24
300-600	1030	143	0.14
> 600	518	158	0.31

TODOAGROBASE			
YEAR	TOTAL	RESILIENT NUMBER	RESILIENT FREQUENCY
2007	245	68	0.28
2008	231	68	0.29
2009	231	55	0.24
2010	197	51	0.26
2011	124	35	0.28
REGION	TOTAL	RESILIENT NUMBER	RESILIENT FREQUENCY
Llano Central Sur	379	99	0.26
Ribera de los Lagos	299	78	0.26
Litoral Sur	73	16	0.22
IX Sur and XIV Norte	215	53	0.25
Los Angeles-Angol	59	28	0.47
COWS	TOTAL	RESILIENT NUMBER	RESILIENT FREQUENCY
< 300	673	187	0.28
300-600	299	59	0.20
> 600	56	30	0.54
SUPPLEMENT kg/Cow	TOTAL	RESILIENT NUMBER	RESILIENT FREQUENCY
< 1300	555	146	0.26
> 1300	473	130	0.27