Sub theme - Managing farm business

MEASURING HOW NZ DAIRY FARMERS REACT TO VOLATILE PRICES BY ANALYSING FARMER RESPONSES OVER A PERIOD OF TIME USING PANEL DATA

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Abstract

Since 2006, milk prices, on average, have increased but there has been a great deal of price volatility in global dairy trade prices as well as New Zealand farm gate milk prices. Higher milk price can lead to higher profits if New Zealand dairy farmers respond to these price changes accordingly and adjust their input costs. The prime objective of this paper is to identify how farmers react to volatile prices during this period and this can be done by analysing farmer responses over a period of time using panel data. Farms that were both technical and scale efficient did not significantly change the three inputs (land, labour, and number of cows) but these farms slightly adjusted inputs to find the optimal point of their production. The majority of farms that were only scale efficient substantially varied these three inputs irrespective of price fluctuations and sought optimal scale rather than technical efficiency. Irrespective of price fluctuations, the inefficient farms kept increasing or decreasing inputs and ended up with low technical and scale efficiency.

Keywords: New Zealand dairy farmers, panel data, DEA, technical and scale efficiency

Introduction

Since 2006, a great deal of price volatility has been observed in global dairy trade prices as shown in Figure 1 (a) and the milk price, on average, has increased (DairyNZ, 2017). A number of factors are responsible for the price fluctuations including increasing global demand, supply and demand shocks and a thinly traded market in dairy products (Shadbolt & Apparao, 2016). Supply shocks include under supply, due to an adverse climate or disease outbreaks, and over supply due to farmers responding to high prices or legislative changes such as the elimination of the EU milk quotas. Demand shocks include, for example, the trade embargo between Russia and the EU. The New Zealand milk price, on average, has increased but variation can also be observed as shown in Figure 1(b). This higher milk price can lead to higher profits if New Zealand dairy farmers respond to these price changes accordingly and adjust their input costs.

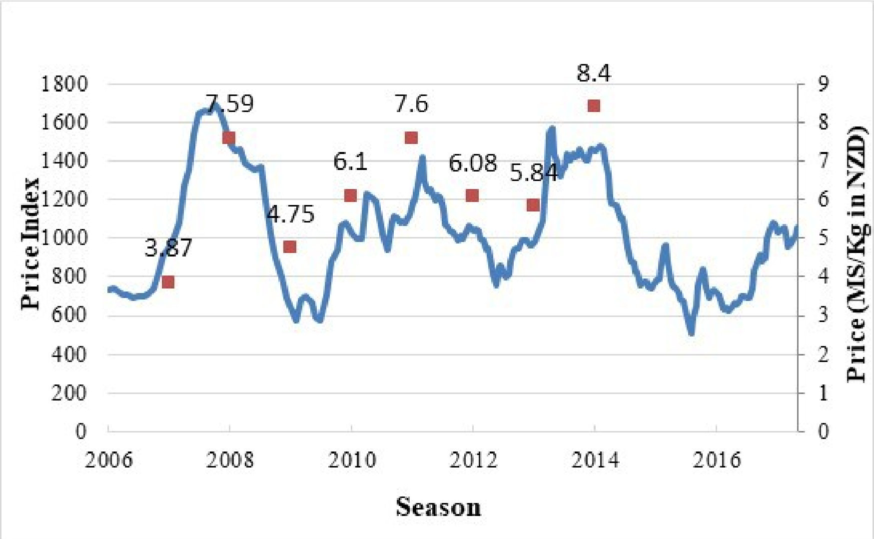

Figure 1 Global Dairy Trade Price Index (Global Dairy Trade, 2017) & NZ Domestic Dairy prices (DairyNZ, 2017)

New Zealand dairy farmers responded to the price signals through expanding or intensifying their farms, changing land, labour, cow numbers, or stocking rate (SR) to adjust production (Scarsbrook & Melland, 2015). This not only increased the average cost of production for owner operators in New Zealand but also increased the production per hectare and per cow (DairyNZ, 2016). Average operating profit per hectare have been higher, on average, since 2007-08 (DairyNZ, 2017). However this increase in milk price has been capitalised into land and dairy cattle values and intensification has also required additional capital in the form of cows, machinery, irrigation and infrastructure so the return on assets, on average, has not increased. Operating profit per hectare, therefore, is an incomplete measure of profit as all hectares are not now equal. Operating profit margin, the dairy operating profit as a percentage of dairy gross farm revenue, a measure of operating efficiency, is a useful alternative measure of profitability (Langemeier, 2010).

Earlier research into the resilience of New Zealand dairy farmers (Shadbolt *et al.* 2016) identified operating profit margin as a key distinguishing factor between farms. They assumed this meant those farms with a higher operating profit margin optimally adjusted the use of inputs in response to price changes each year as suggested by economic theory (Chambers, 1988) and delivered higher average profits over time. Those farmers had statistically higher operating profit margins, double those of their peers over a six-year period, with commensurate higher return on assets and return on equity. This work identified operating profit margin as a key resilience metric as was milk production per hectare. Both were efficiency metrics, the former measuring financial efficiency, and the latter technical efficiency.

It is critical to know how farmers react to volatile prices and this can be done by analysing farmer responses over a period of time using panel data. This will help identify farmers according to how they have responded to milk price changes and to identify key characteristics of profit maximizers in the farming population. Earlier work by Shadbolt, Rutsito & Gray (2011), grouped farmers by those who did best when prices increased as well as those who mitigated best when prices decreased; no one farmer was in both groups. The objectives of this study are to work with more statistical accuracy than previously by using the DEA approach to estimate technical (TE) and scale (SE) efficiencies of 54 farms using a balanced panel data over eight years and to compare and analyse the behaviour of these farms based on their TE and SE.

Methodology

Data envelopment analysis (DEA) is a non-parametric technique that has been widely used to measure technical efficiency (TE) in a range of industries (Banker, Conrad, & Strauss, 1986; Bulla et al., 2000; Vassiloglou & Giokas, 1990). It involves the construction of a piece-wise linear surface or 'frontier' over the data, so that the efficiency of each producer can be measured relative to the "most efficient" producers in the sample. Allocative efficiency can also be assessed using data envelopment techniques if price, as well as production information is available (Coelli et al., 2005). To measure cost efficiency, a minimum cost frontier is estimated, and the efficiency of the firm is calculated by comparing observed costs to an estimated minimum cost. Analogous procedures are available for profit and revenue maximization.

Researchers can choose input- or output-oriented models depending on the production process characterizing the firm (i.e. minimize the use of inputs to produce a given level of output or maximize the level of output with given levels of the inputs). The majority of empirical applications of DEA in the dairy industry have been based on output-oriented models (Stokes, Tozer, & Hyde, 2007; Tauer, 1993; Weersink, Turvey, & Godah, 1990). With output-oriented DEA, the model is configured to determine a firm's potential output given its inputs if it operated as efficiently as firms along the best practice frontier. The resulting efficiency measures give an indication of how efficient each farm is, relative to empirically estimated best practice in the sample used in the study.

Efficiency measures are then calculated relative to this surface (Coelli et al., 2005). Charnes, Cooper and Rhodes (CCR) (1978) proposed a model that had an input orientation and assumed constant returns to scale (CRS). Subsequent research considered alterative sets of assumptions, such as Fare, Grosskopf and Logan (1983), and Banker, Charnes and Cooper (BCC) (1984), in which variable returns to scale (VRS) models are proposed.

The DEA model implemented to examine dairy farm technical and scale efficiency was the Charnes, Cooper, Rhodes (1978) model with an input orientation. According to Coelli et al. (2005) to obtain estimates of technical and scale efficiency, three models with different returns to scale behaviour are required, namely the constant return to scale (CRS) model, the variable return to scale (VRS) model and the scale efficient (SE) and non-increasing return to scale model. SE measures can be obtained for each dairy farm by estimating a CRS model and a VRS model. If there is a difference in the CRS and VRS TE scores for a particular farm, then this indicates that scale inefficiency is present (Coelli et al., 2005). SE is measured as the ratio of CRS efficiency and VRS efficiency scores and expresses how close the farm is to the optimal scale size: the larger the SE, the closer the farm is to optimal scale (Bogetoft, 2013; Cooper, 2013).

One shortcoming of this SE measure is that it does not specify whether the farm is operating in the increasing or decreasing returns to scale portion of the production frontier (Carter, 2000). There arises a need to estimate non-increasing returns to scale (NIRS) TE in order to determine whether the farm should increase or decrease scale.

By comparing the results obtained under CRS and VRS, the location of a particular dairy farm on the production frontier can be determined. If $SE<1$ and $TE_{CRS} = TE_{\mathbf{N}}$, then scale inefficiency is due to increasing returns to scale. On the contrary, if $SE<1$ but $TE_{CRS} < TE_{\mathbf{N}}$, then scale inefficiency is due to decreasing returns to scale.

Output DEA produces measures of each farm's overall TE, pure TE, SE and identification of its benchmarks. Additionally, the analysis identifies specific benchmark peers, of similar scale, for farms that are technically inefficient.

Results and Discussion

The panel of 54 farms each with data over a period of 8 years was analysed using the Benchmarking package in R. The efficiency model was estimated for each of the eight years for all farms and summary of efficiencies is attached in appendix A. For each year, TE and SE farms along with mean TE and SE of the 54 farms are estimated and the number

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of technical and scale efficient farms are shown in Table 1.

Table 1: Technical and scale Efficient Farms (n = 54)

Year Number	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
TE Farms	7	6	8	10	5	5	8	6
SE Farms	4	3	4	2	3	1	5	4

Which farms were efficient in each year is shown in Table 2, few farms were efficient in all years. For example, farm 22 was TE in all the years except 2013-14, similarly, farm 10 was TE for 6 years, and 3 farms (34, 40, and 45) were TE for 5 years each. Some farms (3, 5, 8, 17, 19, 38, and 46) were TE for just one year in the eight years of data studied. Likewise, few farms were SE in all years, for example, farm 22 was SE for 5 years, farm 34 for 4 years and farm 10 for 3 years as seen in Table 2.

Table 2: Technical and scale Efficient Farms

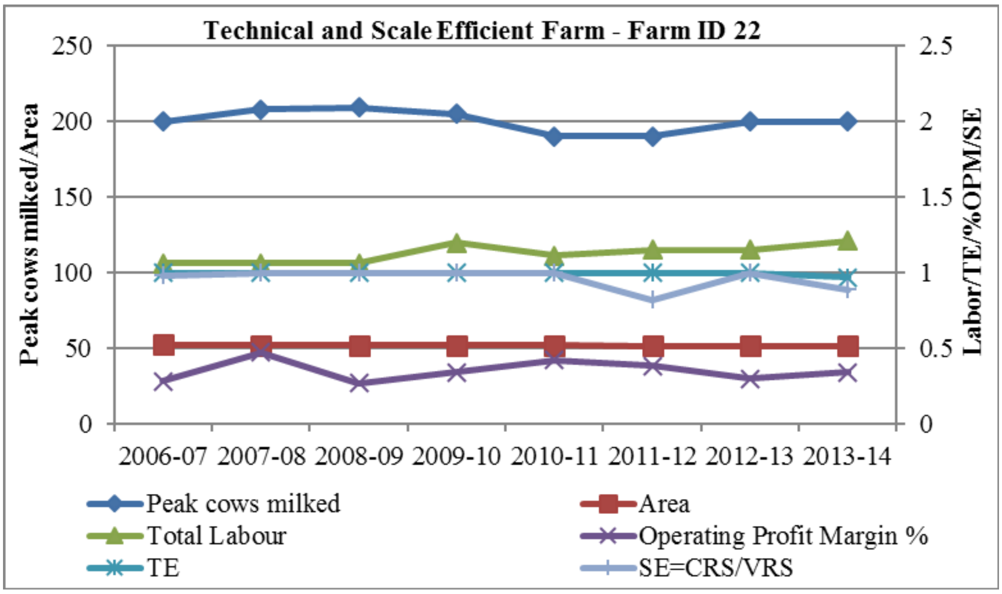
Year Number	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
TE Farms	2, 15, 19, 22, 34, 40, 45	3, 9, 11, 22, 34, 40	7, 10, 11, 22, 34, 38, 40, 45	5, 6, 7, 9, 10, 11, 15, 22, 34, 45	2, 6, 10, 22, 34	7, 10, 22, 31, 40	6, 8, 10, 17, 22, 31, 40, 45	6, 7, 10, 31, 45, 46
SE Farms	19, 34, 40, 45	22, 34, 40	7, 22, 34, 38	7, 22	10, 22, 34	10	6, 22, 31, 45	6, 10, 31, 46

A few farms (6, 7, 10, 19, 22, 34, 40) were both technical and scale efficient in the same year but then they changed their scale by altering their inputs and became scale inefficient. Some few farms (2, 11, 15, 17) were just TE in some years and never attained t scale efficiency. The results revealed that these farms followed price changes closely and increased their production by changing all the three inputs in higher milk price years and vice versa. These farms attained the TE by this strategy, however, by operating at different scales in alternate years, never attained the scale efficiency.

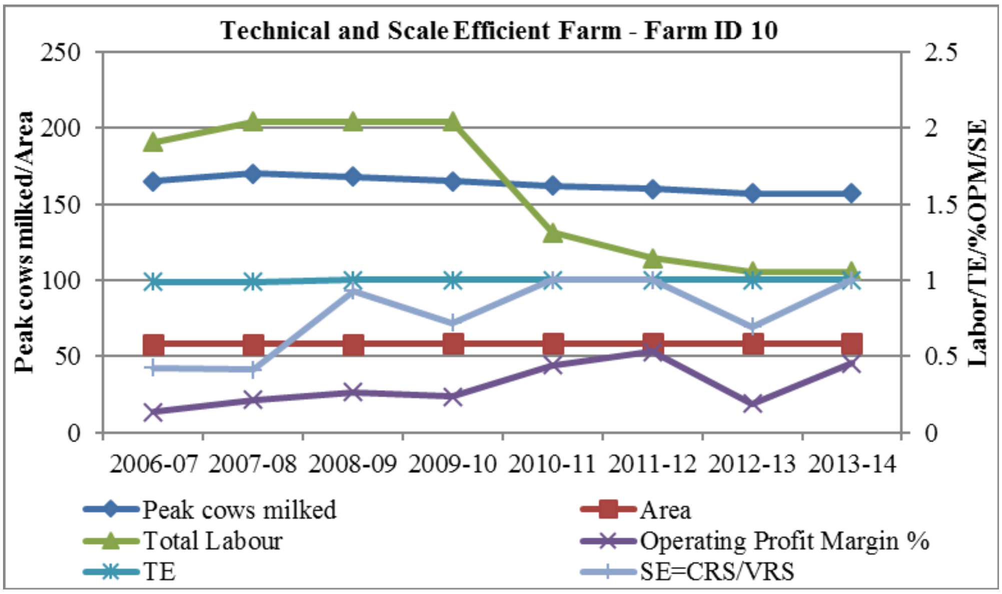
Farm 22 maintained both TE and SE for 7 years and 5 years, respectively, but did not respond significantly to milk price fluctuations by changing major inputs. It was consistent in its operation and slightly flexed within the system by adjusting the three inputs as shown in Figure 2 (a). Mean TE for farm 22 was 99.6% with CV of 1.15%, minimum TE of 96.7% and maximum 100%, average SE was 96% with CV of 7%, and minimum SE was 82% and maximum 100%. This farm employed more paid labour during high milk price years and less paid labour in low milk price years. Minimum operating profit margin was 28% while the maximum was 47%.

Figure 2: Technical and Scale Efficient Farms

(a)



(b)



Similarly, Farm 10 was TE and SE for 6 years and 3 years, respectively, but again did not respond significantly to milk price fluctuations. It was consistent in its operations and slightly flexed within the system by adjusting the three inputs as shown in Figure 2 (b). However, this farm gradually decreased the amount of paid labour and substituted less unpaid family and management labour to reduce the cash cost of the farm and increase the production per unit of FTE. Mean TE was 99.7% with CV of 0.5% shows the highest consistency in its operation, with minimum TE of 98.85 and maximum of 100%. The average SE was 77% with CV of 32.4%, and minimum SE was 41% and maximum of 100%. This variation in SE was associated with changes in cows and labour inputs. It was interesting to note that this farm achieved technical and scale efficiency by optimizing its scale of production in 2010-11, 2011-12 and 2013-14. The minimum operating profit margin was 13% while maximum was 45% for that particular farm.

Farm 34 was TE and SE for 5 and 4 consecutive years respectively, was consistent in its operations, and did not react significantly to price variations. The farm had maximum TE and SE until 2011-12. In the 2012-13 the farm increased labour and peak cows and TE dropped to 61% and SE to 69%. Reducing the number of cows back to the 2011-12 level in 2013-14, stopped TE decreasing and SE increased to 88%. Mean TE was 89.7% with 20.5% CV, minimum TE was 58% and maximum 100%. Minimum operating profit margin was 21% while the maximum was 59% for that particular farm.

In order to look at how different farms behaved through these eight years of price volatility, the best way was to analyse each farm over eight years. Therefore, each farm was grouped and studied chronologically based on its TE and SE for the eight years.

For the purpose of explanation, farms with higher than 60% technical and scale efficiencies were considered as efficient farms whereas farms with 100% efficiency were "efficient" as per previous discussion. According to this criterion, results from the panel data of 54 farms in all the eight years revealed;

- 15 farms that were both technical and scale efficient
- 22 scale efficient only farms
- 5 technically efficient only farms, and
- 12 inefficient farms.

Farms that were both technical and scale efficient shared some common characteristics. There was no dramatic change in the three inputs (land, labour, and number of cows) and these farms slightly adjusted their inputs to find optimal point of their production. Also, these farms did not significantly respond to price fluctuations and operated at a near constant level of production. Operating profit margins rose up to 59% in a high milk price year and dropped as low as 11% in a low milk price year. Most of these farms attained high efficiencies by replacing paid labour with less unpaid family labour in low milk price years. However, a few farms achieved high efficiency when they replaced family labour with paid labour in high milk price years. The opportunity cost of unpaid family labour and management in included in DairyBase so these results are more about the hours worked than the value of those hours.

The majority of farms that were only scale efficient suddenly increased or decreased these three inputs irrespective of price fluctuations. Usually a trend of increasing peak cows milked and land can be seen in these farms, however, several farmers also decreased these inputs. The operating profit margins rose to 61% in a high milk price year, but it declined to negative in a low milk price year. By increasing size (land or cows), these farms became scale efficient but using more inputs without considering prices, cost also increased and TE declined.

The farms that were only technically efficient did not respond significantly to price changes but flexed within the system by slightly changing the inputs. None of the farms drastically changed their production system or inputs. Operating profit margins were as high as 54% in a high milk price year and as low as 46% in a low milk price year. These farms optimized their inputs with given prices but failed to operate at optimal scale of production and this was reflected by low SE values. Irrespective of price fluctuations, inefficient farms kept increasing or decreasing inputs and ended up with low technical and scale efficiency.

Conclusion

In an effort to maximise profits, dairy farmers responded to high milk prices by expanding or intensifying their farms with only one of the three major inputs (land, labour, number of cows) or a combination of these. However, during this process most of the dairy farms had disturbed the optimal level of production and became technical and/or scale inefficient. The farms who were scale inefficient before intensification achieved SE but had lost TE by increasing the amount of inputs. However, low TE was the issue for nearly all farms before and after intensification. The farms that slightly adjusted major inputs instead of moving their scale of production were profitable. This is also supported by the results where all farms that were technical and scale efficient only slightly flexed within their production system and mainly adjusted labour during high and low milk price years.

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Appendix A: Description of Variables used in DairyBase

DairyBase Variables	Description
Cows/ha	Peak Cows Milked divided by Milking area
KgMS/ha	Kilograms of milksolids divided by Milking area
KgMS/cow	Kilograms of Milksolids divided by Peak Cows Milked
Cows/FTE	Peak Cows Milked divided by Total Full Time Equivalent labour units (FTEs)
KgMS/FTE	Total Milksolids Kg produced divided by Total FTEs
Net Cash Income $/ha	Net Cash income from milk sales; net (sales-purchases) dairy livestock sales and other dairy farm related revenue. This value is divided by Milking area
Op.Exp. $/ha	Total Dairy Operating Expenses: (FWE plus depreciation, feed inventory adjustment, value of unpaid family labour, owned run- off adjustment) divided by Milking area.
FWE $/Kg MS	Farm Working Expenses divided by Milksolids Kg
Op.Exp. $/KgMS	Total Dairy Operating Expenses divided by Milksolids Kg.
Op.Profit $/KgMS	Operating Profit divided by Milksolids Kg.
Op.Profit Margin %	Operating Profit Margin (Dairy Operating Profit as a percentage of Dairy GFR) as a %.
Asset T/O %	Asset Turnover (Dairy GFR as a percentage of Opening Dairy Assets).
Dairy Return on Assets %	(Operating Profit plus owned run-off adjustment less rent) as a percentage of Opening Dairy Assets.
Total return on asset	Total Operating Profit plus owned run-off adjustment less rent plus change in capital value divided by Opening Total Assets.
Return on equity	(Total Operating Profit plus owned run-off adjustment plus net off-farm income less rent less interest as a percentage of Opening Equity