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SCALE EFFICIENCY IN AUSTRALIAN DAIRY FARMS

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Abstract

Data Envelope Analysis, (DEA), a linear programming technique, provides a more consistent measure of efficiency than the commonly cited partial measures of farm efficiency. It yields a relative measure of efficiency and identifies inputs or outputs that are under utilized.

In this paper, DEA is used to assess the technical efficiency of a sample of dairy farms across all dairy regions in Australia. Regions vary in size and scale of operation and are examined to see the relationship between farm size and technical efficiency, and to see if there is justification in the move towards bigger dairy production units than currently exist, given their factor mix.

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1. Introduction

The dairy industry in Australia is currently a major growth industry in terms of value of production, employment and an important source of exports. Over the period 1980-2002, figures released by the Australian Dairy Corporation (ADC), show milk production has more than doubled in volume from 5,400m. litres to 11,300m. litre. Although the number of farms have halved from 22,000 to 11,000 over the same period, the average farm and herd size have both increased, with the national average being 285 hectares and 214 cows per farm.[1]

The rate of increase in the size of dairy farms has coincided with a period of growth in returns to dairy farming. The international market has produced high returns and with demand still high, encouragement is being given to farms to increase investment and increase the number of farms. Farmers in some of Australia's dairy regions, notable South West Victoria and S.E. South Australia are being encouraged to consider dairy farming as an alternative to other farming activities. A Dairy Conversion Conference held in Warrnambool, Victoria September 2002, was told that more than 150 farms have been converted in the past 8 years in Western Victoria.[2] Interest has also being expressed by New Zealand and European farmers, looking for an investment opportunity in Australia.

Following deregulation of the industry in July 2000, the more dynamic and competitive environment for Australian dairy farms implies efficiency and productivity will become an increasing important determinant of financial success at the farm level and of the economic viability at the sector level. Farmgate prices, in real terms are starting to decline, increasing the importance of efficiency in farm operations.[3]

The aim of this article is to examine whether the trend towards increasing dairy farm size is improving the efficiency of Australian dairy production. Using a non-parametric technique, Data Envelope Analysis, DEA,[4] the technical efficiency of a sample of dairy farms from around Australia is measured, with the relationship between farm size and efficiency examined in more detail for a select few dairy regions. DEA has been used in a number of previous papers to examine technical efficiency of dairy farms in Canada, New Zealand and Australia, e.g., (Weersink, Turvey *et al.* 1990), (Cloutier L M and Rowley 1993), (Jaforullah and Whiteman 1999), and (Fraser and Cordina 1999) respectively. In this study we employ a recently collected national survey of dairy farms to measure technical efficiency and to examine the relationship between technical efficiency and farm size.

The structure of this paper is as follows. In section 2 we provide an overview of the meaning of economic efficiency and how the DEA models are estimated. Next we describe the data set used. In section 4 we present our results. The results are divided into two parts. First, we present those

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1.Murdoch S. (2002) The Australian Dairy Industry - An Analysis. In '2002 Australian Agribusiness Forum'. The Southee Complex, Sydney Showgrounds, Homebush (2002)
2 Jackson M. (2002) Making the Big Splash. In 'The Weekly Times'. pp. 93. (Melbourne)
3 Murdoch, ibid
4 Data Envelopment Analysis (DEA), a mathematical programme technique, initially developed by Farrell (1957), is reported in Coelli T, Rao P, D.S., Battese G (1998) 'An Introduction to Efficiency and Productivity Analysis.' (Kluwer Academic Publishers: Massachusetts) .

that deal with the whole data set that is for all of Australia. Second, we present results for scale analysis for some of dairy regions in Australia. Finally, in Section 5 we present conclusions.

2. Measuring Efficiency

Beginning with the work of (Farrell 1957), a simple measure of efficiency accounting for a single output and multiple inputs was defined. Efficiency consists of both technical efficiency, which reflect the economic unit's ability to obtain maximum output from a given set of inputs, and allocative efficiency, which reflects the unit's ability to optimise on the use of its inputs, given their respective prices. Combining the two measures produces total economic efficiency.

Efficiency measures assume that the production function, which shows the maximum output attainable from a given set of inputs, of the fully efficient economic unit is known. Farrell (1957) suggested that the function, if not known, be estimated from sample data using either a non-parametric piece-wise linear technology, resulting in the development of DEA, or a parametric function, such as the Cobb-Douglas form, resulting in the development of the stochastic frontier model. Production functions fit over data collected from economic units and the frontier will be most heavily influenced by the best performing units reflecting the technology being used. Efficiency involves a comparison between a production unit's observed and optimal values of output and input.

2.1 Data Envelopment Analysis

DEA, a linear programming technique, is used to estimate a production frontier so that from observed data, the efficiency of an economic unit can be measured. A frontier that envelops all the input-or output data is estimated, with observations lying on the frontier defined as technically efficient, and those observations that lie below the frontier considered inefficient. A relative measure, the efficiency of an economic unit relative to others in the sample is derived. The unit's performance is compared with the best actually achieved rather than with some unattainable ideal. DEA analysis can identify the efficient units and results for an inefficient unit will show by how much each input can be reduced (or output increased) to produce an efficient outcome. DEA identifies the best practice economic units to form a benchmark and calculates their relative contribution to the benchmark. The inefficient units can identify their relevant partner or peer group and emulate their better practices to eliminate sources of controllable inefficiencies and thus improve performance.

The efficiency measure can be further analyzed to determine the contribution of pure technical factors and scale, or size, factors to the overall level of efficiency. To obtain separate estimates of technical and scale efficiency, input orientated technical efficiency measures satisfying three different types of scale behaviour are specified. These are constant returns to scale, (CRS), variable returns to scale (VRS), and non-increasing returns to scale (NRS). Each linear programme exercise must be solved separately for each economic unit in the data set.[5]

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[5] In this paper the methodology of Coelli, Rao *et al.* (1998Ibid. is used to measure the technical and scale efficiency of the Australian dairy Industry.

2.1.1 Constant Returns to Scale Model (CRS)

(Charnes, Cooper *et al.* 1978; Coelli, Rao *et al.* 1998) proposed an input orientation model, with CRS. The single input and output orientated measure has been extended to accommodate multiple inputs and outputs. Efficiency is defined as the ratio of the weighted sum of outputs to the weighted sum of inputs, ($u'y_1/v'x_1$), where u is a M*1 vector of output weights and v is a K* 1 vector of input weights.

Using the duality in linear programming, an equivalent envelopment function is:

$$\begin{aligned} &\min\theta \\ &\text{st} \quad -y_{ij} + Y\lambda \geq 0 \\ &\theta x_1 - X\lambda \geq 0 \\ &\lambda \geq 0 \end{aligned} \qquad (1)$$

where θ is a scalar and λ is a N * 1 vector of constants. The value of θ will be the efficiency score of the ith economic unit. It will satisfy the condition $\theta < 1$, with a value of 1 indicating a point on the frontier and thus a technically efficient economic unit. A value less than one indicates the unit, given the existing set of observations, can improve the productivity of its inputs by forming benchmarking partnerships and emulating the best practices of its reference or peer group. To derive a set of N technical efficiency scores, the problem needs to be solved N times, once for each economic unit.

The resulting measure of technical efficiency is an overall measure with the residual including all sources of inefficiency, both the controllable and uncontrollable. In using the constant returns to scale specification, we are assuming the unit is operating at optimal scale. However, inefficiency may arise due to the size of the unit (scale), poor management, differences in soil quality, climate, animal genetics, or some other unspecified variable as well as errors in measurement. To measure inefficiencies due to size and to identify optimal scale for the economic units, two other DEA exercises are needed. These are the NRS and VRS.

2.1.2 The Variable Returns to Scale Model (VRS)

Market imperfections may prevent optimal size from being achieved and thus any measure of technical efficiency will include scale efficiencies as well as other factors. If environmental conditions (for example, soil quality, climate, animal genetics, in dairy farming) are the same and there is no measurement error, pure technical inefficiency represents departures from best practice management. Incorporating variable returns to scale (VRS) into the model, allows technical efficiency (TE), to be calculated without the influence of scale efficiencies.

The programming problem *(1)*, above, needs to have the convexity constraint, $N1'\lambda$, added so that the frontier will envelope the data points more closely. The resulting efficiency scores are equal to or greater than those obtained with the CRS model. The convexity constraint ensures that an inefficient unit will only be compared against units of similar size.

$$\begin{aligned} &\min\theta \\ &\text{st} \quad -y_{ij} + Y\lambda \geq 0 \\ &\theta\, x_1 - X\lambda \geq 0 \\ &\lambda \geq 0 \\ &N1'\lambda = 1 \qquad (2) \end{aligned}$$

Where N1 is an N * 1 vector of ones.

If DEA's are conducted for both CRS and VRS, and if there is a difference between the technical efficiency scores this indicates scale inefficiency exists. Scale inefficiency, (SE), can be calculated from the difference between the VRS and the CRS technical efficiency scores. To determine if the unit is operating in the area of increasing or decreasing returns to scale, an additional DEA is required whereby non-increasing returns to scale is assumed, (NIRS). The restriction $N1'\lambda=1$, needs to be replaced with $N1'\lambda<1$ in the programming problem *(2)* above.

If inefficiency exists, (ratio less than unity) and to determine if increasing or decreasing returns to scale is responsible, the NIRS TE is compared to the VRS TE score. If the two are unequal, then DEA results suggest inefficiency is due to increasing returns to scale. If the economic units increased their size of operations, inputs can be used more productively. If the two are equal„ DEA results suggest scale inefficiency is due to decreasing returns to scale. The size of operations needs to be reduced to increase productivity and decrease unit costs.

3. Data Source

As part of the Dairying For Tomorrow project, a nationwide survey of dairy farm management practices and productivity was conducted by an independent research organisation, IRIS Research, on behalf of the Dairy Research and Development Corporation, (DRDC) in 2000. A 30 minute telephone survey to over 1800 farmers throughout Australia, over a six month period, had a response rate of eighty-four per cent. The results of this survey, made available by DRDC, are used in this paper to examine the level of efficiency in the industry. Of the 1826 farmers interviewed 84, or 4.6%, have been deleted from the analysis, due to incomplete data relating to either milk production, amount spent on fertilizer, purchased feed or the capital value of their property

The data is analysed in several ways. We examine the whole of data set (i.e., all Australia) and various sub sets of the data (i.e., specific dairy regions). Australia's dairy industry is divided into eight regions, grouped according to the DRDC's regional development programs, (RDPs) which have been established in all major dairying areas of Australia, and twenty sub-regions. The eight RDPs are the Sub Tropical Dairy region in eastern Queensland, DIDCO in the central coastal area of NSW, Murray Dairy in the River Murray region of Victoria and NSW, GippsDairy in eastern Victoria, and WestVic Dairy in south west Victoria and the south east of South Australia. In Tasmania there is one region, DairyTas, one in South Australia, DairySA, and Western Dairy in SW Western Australia.

Dairy farm production can be measured in terms of litres of milk, or kilograms of butter fat. Measures of butter fat was converted into a common output measure of litres of milk. Thus, in this analysis, the output measure used is litres of milk, and it is matched with inputs to reflect size of operation, plus important inputs of water, fertiliser and purchased feed. A measure of capital is also included. The choice of variables was constrained by the available data and the need to avoid including too many variables in the model specification. If too many variables are used, the proportion of efficient farms will increase. (Chambers, Fare et al. 1998) suggest that any farm level DEA should be based on a sample that has at least three times as many farms as there are inputs. Appropriate and measurable variables, whether input or output based, to properly characterise the farming system, need to be used. The selected variables need to capture all the salient features of the farm. Of particular importance is the flow of services from capital investment.

The size of the farm was gauged from the size of the milking area, in hectares, plus the number of milking cows. As a measure of water use, data relating to irrigation was examined. Many of the farms using irrigation did not give details on the number of megalitres used. To gain a larger response rate, the data relating to area of the farm irrigated, in hectares, was used. This refers to the area to which irrigation water was applied, thus excluding rainfall and re-use systems. The survey included a number of questions on the use of different types of fertilizers and how decisions on the application of fertilizers were made. However, no actual figure was given on the amount used. Categorical variables were used in giving expenditure on fertilisers in aggregate, and for this analysis, the mid point in each category was used as an indicator of the amount spent on fertilizer. The total cost of purchased feed was derived from the information on the total feed purchased per cow, and as a measure of the capital input, the level of debt was used. Again, the mid point of the categorical variable was applied.

One limitation of the data set is that it did not contain any data relating to labour. Many of the farms would rely on hired as well as family labour. However, no data is available regarding this input and thus it its not considered in this analysis. The exclusion of this result will bias our results and needs to be borne in mind when interpreting the findings presented.

Individual dairy regions differ not only in terms of quantity of milk output but also in production technology and best management practices in terms of the various inputs used, as shown in Table 1. In terms of the average megalitres of milk output, Western region is just ahead of WestVic and South Australia. Sub Tropical region had the lowest average milk output, a reflection of the low cow numbers but not farm size. The average farm size varied from a low of 98 hectares in GippsDairy to 206.5 hectares in Western. Cow numbers were more consistent, with 5 regions having an average of more than two hundred cows. The higher irrigation regions, namely Murray Dairy, Dairy South Australia and Sub Tropical all had lower fertilizer expenditure compared to the other regions. By contrast, Western Dairy Tasmania and WestVic Dairy, all spent on average more than $24,000 per annum on fertilizers.

The use of supplementary feed was significant for all regions, except Dairy Tasmania where an average of only $0.49 per cow was spent. Feed is perhaps not so essential an input in this region where farms use both irrigation and fertilizer to promote feed growth. Climatic differences between the regions in terms of promoting pasture growth would also be significant in terms of input use.

The level of debt varied across the regions, from a high of $1,587,766 in Western Dairy to $810,056 in Tasmania.

Table 1: Farm Characteristics by Region

	South Australia	Tasmania	DIDCO	Gippsland	Murray	Sub-Tropical	Western	WestVic
Number of farms	130	179	191	295	308	265	94	280
Milk Output (megalitres)								
--mean	1,029,283	896,115	806,999	876,393	993,795	578,436	1,190,731	1,168,427
--min	70,000	102,564	114,830	118,475	80,600	80,000	314,459	90,000
--max	5,000,000	4,300,000	4,000,000	5,500,000	9,000,000	2,200,000	4,500,000	7,500,000
Hectares								
--mean	147.1	112.3	103.2	98.1	116.5	140.8	206.5	145.8
--min	12	20	20	20	16	16	51	30
--max	1497	465	486	526	607	898	800	1300
Cow Numbers								
--mean	182	219	156	200	204	138	207	237
--min	22	32	40	36	38	30	60	30
--max	730	250	750	1150	1600	600	800	1300
Feed ($per cow)								
--mean	2.06	0.49	1.67	0.83	1.38	1.32	1.61	1.2
--min	0	0	0	0	0	0	0	0
--max	12.5	5.78	8.0	5.78	5.56	12.6	8.3	5.05
Irrigation (hectares)								
--mean	43.28	44.3	41	70.3	92.3	28.8	43.34	44.1
--min	2	4	4	4	4	4	12	2
--max	263	243	162	405	668	243	101	280
%farms	67	61	54	35.6	86	61.5	37	34.6
Fertilizer($)								
--mean	14,883	24,943	17,037	17,398	14,983	13,898	25,957	24,504
Capital ($)								
--mean	1,021,154	815,643	1,078,947	844,915	901,466	822,642	1,587,766	991,964

4. Results

Our results are presented in the following order. We begin by presenting technical efficiency estimates for the whole data set as well as the various regions. We then estimate technical efficiency for the various regions independently. This allows us to examine the impact of aggregating the data across the whole survey. (Zhang and Bartels 1998) point out that the technical efficiency estimated using DEA, will decrease as the number of units included in the analysis increases. Increasing the sample size increases the chances of having units close to the frontier, and therefore the frontier constructed by DEA approaches the true frontier. In addition, performance evaluation of DMU over all Australia brings in many variables that differ considerably over the nation. Climatic conditions differ widely and produce different reliance on, for example, the need to irrigate, or the need to introduce supplementary feeding. Best management practices may vary from one region to another, as shown in Table 1 and discussed above. Individual regional analysis gives recognition to differences between regions. By eliminating much of the variables outside the control of the farmer, a more valid comparison is possible.

4.1 All Australia

Combining the sample data for Australia's eight dairy regions and employing a constant return to scale specification in the DEA, 63, or 3.6%, of dairy farms were regarded as technically efficient. The resultant distribution, (Fig.1, Appendix 1), reflects a near perfect distribution with the majority of farms ranging from 0.47 to 0.69 efficiency. Table 2 summarizes the performance of each dairy region. The best performing regions, those with mean efficiency was above the Australian mean of 0.59, were Gipps Dairy, and WestVic Dairy regions in Victoria, Dairy Tasmania, Dairy South Australia, and Western Dairy in SW Western Australia. Dairy SA and Dairy Tasmania both had 10% of their farms with an efficiency score in the top decile. However the performance of the remaining 90% of farms in the Dairy Tasmania region was much poorer, reflected in the second lowest medium score of 0.557. WestVic Dairy had 7.1% of farms in the top decile but only 3.2% fully efficient. Western Dairy, although the stronger performer overall, with a mean of 0.627, did not have so many units fully, or near fully efficient, as did the other regions. The remaining three regions, namely Sub-Tropical, Murray Dairy, and DIDCO, although having a reasonable number of fully efficient farms, were the poorer performers with means of 0.52, 0.576 and 0.573 respectively. Each of these regions had between approximately one third and one half of their farms operating at less than 0.5 efficiency. The least efficient farm, with 0.13 efficiency, was located in the Murray Dairy region.[6]

Table 2: Statistical Summary: Technical Efficiency Australia and Regions

Region	Aust.	Dairy SA	Dairy Tas	DIDCO	Gipps Dairy	Murray Dairy	Sub Trop Dairy	Western Dairy	West Vic Dairy
No.	1742	130	179	191	295	308	265	94	280
Mean	0.589	0.622	0.603	0.573	0.614	0.578	0.521	0.625	0.614
Min.	0.131	0.17	0.252	0.228	0.221	0.131	0.148	0.253	0.215
Median	0.577	0.618	0.557	0.581	0.606	0.563	0.502	0.625	0.601
Fully Effic.	63	7	12	6	3	13	12	1	9

[6] Results for each dairy region can be obtained from the first author.

4.2 Individual Dairy Region Analysis

Table 3 gives the statistical summary of the DEA analysis conducted for each individual dairy region when analyzed using the same inputs but with no reference to the other regions. Tables 2 and 3 show that the ranking of the top regions, when analyzed on their own, does not vary much from their ranking when analyzed as part of Australia. The degree of efficiency increased and was less spread as a result of analyzing a smaller group and comparing farms only to farms operating under similar physical conditions, that is, all in the same region. The Sub Tropical region, with a mean efficiency of 0.638, is once again ranked last and now contains the poorest performing farm with an efficiency of 0.152. Gipps Dairy, with a mean of 0.705, ranked seventh, well below its equal third ranking in the all Australia analysis. By contrast, the ranking of the DIDCO region improved.

Table 3: Statistical Summaries: Efficiency Analysis of Individual Dairy Regions

	Dairy South Aust.	Dairy Tas.	DIDCO	Gipps Dairy	Murray Dairy	Sub Trop.	Western Dairy	WestVic Dairy
No. of farms	130	179	191	295	308	265	94	280
Mean	0.794	0.722	0.729	0.705	0.729	0.638	0.822	0.737
Minimum	0.236	0.299	0.278	0.274	0.226	0.152	0.394	0.253
No. Fully Efficient	33	32	28	32	37	35	20	39

An examination of the dairy regions raises the question of what is the appropriate scale (size). Table 1 shows considerable variation in terms of size of operation and the quantities of inputs used. Inefficiencies may arise from pure technical factors representing departure from best farming practices and management or inefficiencies may be due to scale, or size, factors.

4.2.1 Optimal Scale of Production

By conducting a VRS DEA in all regions, farms operating at constant, increasing and decreasing returns to scale are identified and if matched with cow numbers, the optimal scale of production in each region can be determined. Table 4 summarizes this analysis for all regions.

Table 4: Optimal Scale of Production (CRS) and Herd Size

Dairy Region	% farms CRS	%Farms IRS	%farms DRS	Mean Herd size CRS farms	Herd increase (all farms)
South Australia	26.2	69.9	3.9	224	42
Tasmania	22.4	68.1	9.5	268	49
DIDCO	15.7	76.4	7.9	211	81
Gippsland	15.3	76.6	8.1	271	71
Murray	14.3	65.6	20.1	241	37
Sub-Tropical	14.3	78.5	7.2	204	66
Western	22.3	69.2	8.5	286	79
WestVic	17.8	73.2	8.9	272	35

Increasing returns are experienced by at least two thirds of farms in all regions. Few farms in any region are too big. Less than 10% of farms in any region, with the exception of Murray Dairy, experience DRS. The level of efficiency could be improved by farms increasing in scale in terms of land or herd size. Using herd size as a measure of scale, the optimal scale of production for each region is determined.

Dairy South Australia, with over one quarter of farms achieving optimal scale, is once again the strongest performer. Average herd size is 182 cows and if this was increased 19% to 224 cows, optimal scale of production would be achieved for the 70% of farms currently experiencing IRS. (Table 4) Only 4% of the farms need to decrease their herds to improve their efficiency. Dairy Tasmania and the Western Regions both have 22% of their farms at optimal scale. Average farm sizes in both regions are greater than farms in the South Australia region, but they too need to increase their herd size to achieve optimal scale of operations. Farms in the Dairy Tasmania region need to increase their herds on average by 22% to achieve 268 cows, while farms in the Western region need a bigger increase of 38% to achieve a herd size of 286, the largest optimal herd size in any of the regions. Just under 10% of farms in both regions need to reduce their herds. Sub Tropical and Murray Dairy regions both have only 14% of their farms operating at optimal scale. Farms in Subtropical need to increase herds 32% to achieve optimal scale. In Murray Dairy, the two thirds of farms experiencing IRS need an 18% increase in herd size, while the 20% of farms experiencing DRS need to reduce their herd size.

DEA implies different optimal sizes for farms with different input-output combinations. Thus each region has different optimal herd sizes but the analysis does suggest two distinct groupings of dairy regions – those whose optimal scale of production requires around 200-220 cows, and those which require much larger herds of around 270 to achieve optimal scale of production. Murray Dairy is left in the middle with an optimal herd size of 240 cows.

Weersink et.al (1990), in his study of Canadian dairy farms, found overall efficiency increased with herd size, but that scale efficient farms existed under a variety of herd sizes. He concluded that competitive pressure might continue the trend towards larger farms although the variation in optimal scale between herd sizes implies a range of farm sizes will continue to exist, provided appropriate technology for the scale of production is chosen. Jaforullah and Whiteman (1999) concluded from their study of New Zealand dairy farms, that the trend towards larger farms should be encouraged to increase the productive efficiency of the farms. Fraser and Cordina (1999) also found in their study of irrigated dairy farms in Northern Victoria over the period 1994/5 and 1995/6, a significant number exhibited IRS. In addition, they found the larger farms, farms with over 200 cows, exhibited DRS, a factor they attributed to the particular farming system used in the region.

The analysis here does suggest that, as in Canada, a variety of herd sizes will continue to exist between regions, and emphasis must focus on selecting the appropriate technology for the region, to achieve maximum efficiency. A more detailed examination of each region can be undertaken to determine how it might improve its efficiency. Two regions are examined here to illustrate the type of analysis that could be conducted for all regions.

4.2.2 Dairy South Australia

In the region served by Dairy SA, a consistent performer in all analysis, of the 130 farms surveyed, 33 or 25.4% were fully efficient and all except one achieved efficiency levels of more than 0.5. Table 5 presents a more detailed breakdown on the levels of efficiency achieved. The mean efficiency is 0.79, and ranges from less than 30%, (at 24%) to 100%, with a quarter of the sample exhibiting full efficiency. Conducting a VRS DEA, the contribution of pure technical factors and improper scale of operation to the 21% inefficiency was determined. The average level of pure technical efficiency is greater than the average level of scale efficiency (0.925 compared to 0.86), which suggests that farms are combining resources reasonably well but need to increase size of operation. Pure technical inefficiency accounts for approximately 7% and scale inefficiency 14% of the overall 21% technical inefficiency. On the average, farms could decrease inputs by up to 21% by operating at optimal scale and eliminating pure technical inefficiency through the adoption of best practices of the efficient dairy farms.

Table 5: Frequency Distribution of technical efficiency estimates for Dairy South Australia

	Overall Technical Efficiency (TE)		Pure Technical Efficiency (PE)		Scale (SE)	
Efficiency Interval (%)	Frequency	Distribution (%)	Frequency	Distribution (%)	Frequency	Distribution (%)
100	33	25.4	71	54.7	34	26.2
90-99	13	10.0	21	16.1	41	31.5
80-89	25	19.2	21	16.15	19	14.6
70-79	20	15.4	8	6.15	10	7.7
60-69	16	12.3	6	4.6	11	8.5
50-59	16	12.3	3	2.3	9	6.9
40-49	6	4.6	0	0	6	4.6
30-39	0	0	0	0	0	0
<30	1	0.8	0	0	0	0
Total	130	100.0	130	100.0	130	100.0
Mean Efficiency	0.7936		0.9249		0.8597	
Medium Efficiency	0.814		1		0.9375	

Scale efficiency and herd size is examined and reported in Tables 6-8. The variability in efficiency appears to be inversely related to herd size up to herds of around 230. A possible explanation for this may be the existence of more homogeneous management practices and technology on larger farms (Weersink et.al (1990). The mean technical efficiency increases with herd size up to around 233 cows. Beyond this size, efficiency starts to decline.

Just under half (61or 47%) of the farms operate small herds, that is less than 133 cows, the majority of which experience increasing returns to scale (Table 7). Increasing returns exist in herds of up to 233, although 11% of all farms were efficient with small herds.

Decreasing returns exist in only 5 farms and these are ones with large herds, although there was 1 with the medium size herd. Analysis does support increasing herd size to increase the level of efficiency in this region, but other factors that may affect technical efficiency –other inputs, management skills, production practices – also need to be examined before advocating increasing the herd size.

Table 6: Frequency Distribution of overall technical efficiency by herd size in Dairy South Australia

	Herd Size <130		Herd Size 130-230		Herd Size >230		Total number of farms	
Effic. Interval	Freq.	Dist.(%)	Freq.	Dist (%)	Freq.	Dist.(%)	Freq.	Dist.(%)
100	14	23	9	20	10	41.7	33	25.4
90-99	3	4.9	8	17.8	2	8.3	13	10
80-89	6	9.8	15	33.3	4	16.7	25	19.2
70-79	11	18.0	8	17.8	1	4.2	20	15.4
60-69	8	13.1	4	8.9	4	16.7	16	12.3
50-59	12	19.7	1	2.2	3	12.5	16	12.3
40-49	6	9.8	0	0	0	0	6	4.6
30-39	0	0	0	0	0	0	0	0
20-29	1	1.6	0	0	0	0	1	0.8
Total	61	100	45	100	24	100	130	100.0
Mean	0.734		0.849		0.841		0.794	
Medium	0.715		0.842		0.906		0.794	

Table 7: Returns to Scale Distribution by Herd Size, Dairy South Australia

	Farms Exhibiting Increasing Returns to scale		Constant returns to scale		Decreasing returns to scale		Total Number of farms	
Herd Size	Freq.	Dist. (%)	Freq.	Dist. (%)	Freq.	Dist (%)	Freq.	Dist. (%)
<130	47	36	14	10.8	-		61	47
130-230	35	27	9	6.9	1	3.1	45	35
>230	9	6.9	11	8.5	4	3.9	24	18
Total	91	69.9	34	26.2	5	3.9	130	100
Av. Herd Size	151		224		447		182	
Medium	130		188		500		145	

4.2.3 WestVic Dairy Region

A growing dairy region, WestVic, with a larger sample of 280 farms, and overall efficiency at 0.615, was the third most efficient region within the Australian dairy regions. Examining the region on its own, efficiency ranged from a low of 0.25 to those farms that were fully efficient, giving an average efficiency of 0.737. However, there were many farms not far from being regarded as fully efficient. Table 8 reports thirty-nine, 13.9%, of the farms were fully efficient, while another 14 had efficiency of 0.95 or better and a further 10 farms were more than 0.9 efficient. Overall, just under one quarter, 22.5%, of the farms in this region had greater than 0.9 efficiency. Only 28 farms, 10%, were less than 0.5 efficient

While this performance is good, farms operating in both the Dairy South Australia and Western Dairy regions outperform the farms in this region. Dairy South Australia had over one third of its farms, 35.4%, operating with between 0.9and 100% efficiency, and under 6 percent operating with less than 0.5 efficiency.

The inefficiency in this region, as reported in Table 8 below, reflects almost equally inefficiency due to scale of operation (12%), and inefficiency due to pure technical inefficiency (15%), whereas in other regions, notable, Dairy South Australia, approximately two thirds of the inefficiency was due to scale factors. Pure technical efficiency at 0.85 is more spread and lower compared to farms in the South Australian region. In the South Australia region, all farms achieved more than 0.5 pure technical efficiency, and 71% achieved more than 0.9. Only 46% of farms in the WestVic region achieved more than 0.9 pure technical efficiency, and 2.2% achieved less than 0.5. The scale of operation is then not the only factor to consider when attempting to increase the efficiency of the farms in this region.

Table 8: Frequency Distribution of technical efficiency estimates for West Vic Dairy Region

	Overall Technical Efficiency (TE)		Pure Technical Efficiency (PE)		Scale (SE)	
Efficiency Interval (%)	Frequency	Distribution (%)	Frequency	Distribution (%)	Frequency	Distribution (%)
100	39	13.9	104	37.1	50	17.9
90-99	24	8.6	26	9.3	135	48.2
80-89	46	16.4	50	17.9	32	11.4
70-79	47	16.8	39	13.9	15	5.3
60-69	57	20.4	39	13.9	17	6.1
50-59	39	13.9	16	5.7	15	5.3
40-49	18	6.4	5	1.8	11	3.9
30-39	6	2.2	1	0.4	4	1.4
<30	4	1.4	0	0	1	0.4
Total	280	100	280	100	280	100
Mean Efficiency	0.7365		0.8483		0.8771	
Medium efficiency	0.7235		0.871		0.9555	

The number of farms exhibiting pure technical efficiency is greater than the number of scale efficient farms, although the average level of pure technical efficiency is lower than the average level of scale efficiency (0.85 versus 0.88). Sixty-six per cent of farms operate at 0.9 or greater scale efficiency, compared to 46% achieving pure technical efficiency. Twenty three per cent of farms achieve pure technical efficiency but not scale efficiency, and these are, apart from 4, operating under increasing returns to scale. Farms combine resources properly but need to increase farm size.

In examining scale in relation to herd size, mean level of efficiency increases with herds of up to 230, (mean 0.76), then starts to decline (mean 0.74). Approximately forty per cent of farms with both large and middle-sized herds achieve efficiency of more than 0.8, compared with 36% of farms with herds less than 130. The degree of inefficiency is more spread with both the larger and the smaller sized herds. Increasing returns exist for 73% of the farms and in all herd sizes. Many farms could be operating larger herds but to avoid loosing the benefit of the extra size, the best management practices of scale efficient peers would need to be adopted.

Table 9: Frequency Distribution of overall technical efficiency by herd size (WestVic Dairy Region)

	Herd Size						Total number of farms	
	<130		130-230		>230			
Effic. Interval	Freq.	Dist.(%)	Freq.	Dist (%)	Freq.	Dist.(%)	Freq.	Dist.(%)
100	13	21.3	16	12.9	10	10.5	39	13.9
90-99	5	8.2	11	8.9	8	8.4	24	8.6
80-89	4	6.6	22	17.7	20	21.0	46	16.4
70-79	7	11.5	27	21.8	13	13.7	47	16.8
60-69	12	19.7	23	18.5	22	23.2	57	20.4
50-59	4	6.6	19	15.3	16	16.8	39	14
40-49	9	14.7	6	4.8	3	3.2	18	6.4
30-39	4	6.6	-	-	2	2.1	6	2.1
20-29	3	4.9	-	-	1	1.1	4	1.4
Total	61	100	124	100	95	100	280	100.0
Mean	0.697		0.757		0.737		0.737	
Medium	0.675		0.766		0.72		0.733	

Table 10: Returns to Scale by Herd Size (WestVic Dairy Region)

	Increasing returns to Scale		Constant returns to Scale		Decreasing Returns to Scale		Total	
Herd Size	Freq.	Dist.	Freq.	Dist.	Freq.	Dist.	Freq.	Dist.
<130	48	17.14	13	4.64	-		61	21.8
130-230	104	37.14	16	5.71	4	1.4	124	44.3
<230	53	18.93	21	7.5	21	7.5	95	33.9
Total	205	73.2	50	17.9	25	8.9	280	100
Av.Herd	198		272		483		237	
Medium	180		188		420		190	

5. Conclusion

The purpose of this paper has been to explore the distribution of technical efficiency in the industry across Australia and within individual dairy regions, and to see if there is any relationship between farm size and efficiency. The degree of efficiency varies across the different regions and for a select few regions the efficiency is decomposed to determine the contribution of pure technical and scale factors to the overall degree of efficiency.

Scale inefficiency was a significant contributor to the inefficiency experienced by farms in the Dairy South Australia region, a relatively high technically efficient dairy region in Australia. If farms in this region were to increase their scale of operation, the overall degree of technical efficiency should increase. In the WestVic region, another reasonably efficient dairy region, farmers need to examine not just their scale of operation, but also the best practices of efficient peer farms, to increase their overall technical efficiency. Although increasing returns existed for 73% of the farms in the WestVic region, the degree of pure technical inefficiency for many farms was also significant. Farm extension services providers can assist in identifying the best management practices and give advice to farmers on how to improve their technical efficiency.

Dairy regions vary as to what is the optimal scale of operation. In terms of herd sizes, all regions could have their farms increasing in scale of operation, although just how large the herds should be varied between the regions. This variation in optimal scale between herd sizes implies a range of farm sizes will continue to exist across the regions. Emphasis needs to be placed on selecting appropriate technology for the scale of operation to achieve technical efficiency in production.

However, technical efficiency is just one part of overall economic efficiency. No cost data has been considered. In addition, many factors, such as management style, experience, inputs used, can affect the technical efficiency of any farm and these need to be examined to see to what extent they explain technical efficiency differences before any policy encouraging farms to expand is developed.

Bibliography

Chambers RG, Fare R, Jaenicke E, Lichtenberg E (1998) Using dominance in forming bounds on DEA models: the case of experimental agricultural data. *Journal of Econometrics* **85**, 189-203.

Charnes A, Cooper WW, Rhodes E (1978) Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research* **2**, 429-444.

Cloutier L M, Rowley R (1993) Relative Technical Efficiency: Data Envelopment Analysis and Quebec's Dairy Farms. *Canadian Journal of Agricultural Economics* **41**, 169-176.

Coelli T, Rao P, D.S., Battese G (1998) 'An Introduction to Efficiency and Productivity Analysis.' (Kluwer Academic Publishers: Massachusetts)

Farrell MJ (1957) The measurement of productive efficiency. *Journal of the Royal Statistical Society, A* **CXX**, 253-290.

Fraser IM, Cordina D (1999) An application of data envelope analysis to irrigated dairy farms in Northern Victoria, Australia. *Agricultural Systems* **59**, 267-282.

Jackson M. (2002) Making the Big Splash. In 'The Weekly Times'. pp. 93. (Melbourne)

Jaforullah M, Whiteman J (1999) Scale efficiency in the New Zealand dairy industry: a non-parametric approach. *The Australian Journal of Agriculturaland Resource Economics* **43**, 523-541.

Murdoch S. (2002) The Australian Dairy Industry - An Analysis. In '2002 Australian Agribusiness Forum'. The Southee Complex, Sydney Showgrounds, Homebush

Weersink A, Turvey CG, Godah A (1990) Decomposition measures of technical efficiency for Ontario dairy farms. *Canadian Journal of Agricultural Economics* **38**, 439-456.

Zhang Y, Bartels R (1998) The Effect of Sample Size on the Mean Efficiency in DEA with an Application to Electricity Distribution in Australia, Sweden and New Zealand. *Journal of Productivity Analysis* **9**, 187-204.

Appendix

Figure 1: Farm Level Efficiency: All Australia

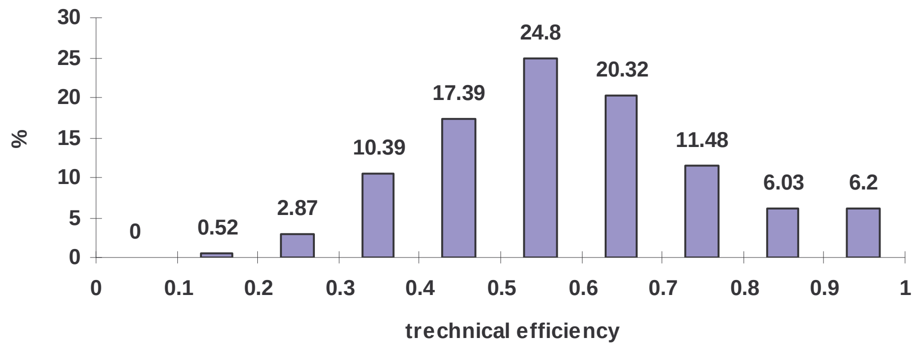

Figure 2: Dairy South Australia Region Farm Efficiency (%)

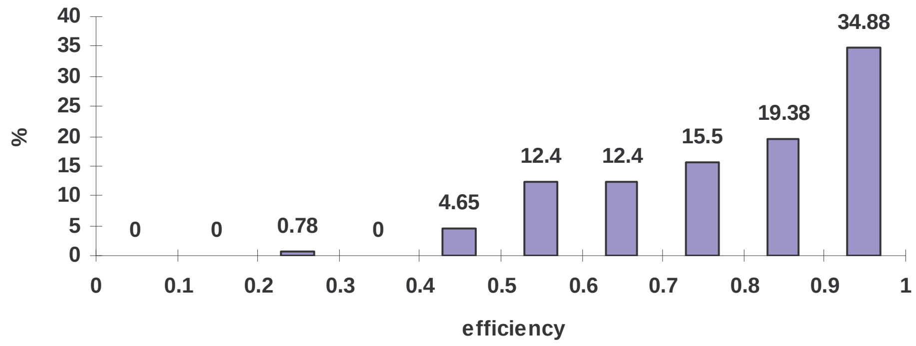

Figure 3: WestVic Dairy Region Farm Efficiency (%)