Identifying efficiency trends for Queensland broadacre beef enterprises

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Abstract

Productivity and efficiency improvements in agriculture have recently been targeted as Federal Government priorities in Australia. This research examined a dataset of 116 broad-acre beef enterprises from Queensland who participated in a program, *Profit Probe*, developed to improve management and profitability of enterprises.

The aim of this research was to identify the sources, if any, of productivity growth for this sample of enterprises. Two potential sources of productivity growth were identified: 1. Technological progress involving a contraction (expansion) of the cost (output) frontier, and; 2. Efficiency improvements involving a convergence of the average production function toward the frontier. Given these two potential sources of productivity growth, the Stochastic Frontier Analysis approach was ideally suited to discern and measure technological change and efficiency change. Changes over time were observable due to the unbalanced panel nature of the data with 116 enterprises observed over a range of years from 1999 to 2008.

A Cobb-Douglas functional form for the cost function was estimated following testing of the Translog form which showed higher order terms were not significant. An input oriented minimum cost frontier was chosen over the output oriented production frontier approach due to the consideration that output decisions were largely exogenous whilst input decisions were endogenous. Deterministic predictors of inefficiency were included using the panel inefficiency effects frontier of Battese and Coelli.

There was no evidence of technological progress in the ten years from 1999 to 2008 for this sample of enterprises. There was however evidence of efficiency improvements despite pre-existing high efficiency levels. In particular there was evidence that the *Profit Probe* program significantly contributed to efficiency improvements for participating firms with improvements continuing with repeated participation in the program. Additionally cost efficiency was shown to be an important component of profit maximisation but most likely was not a sufficient condition with output prices, as a quality and market indicator, being highly significantly related to profit levels.

1. The beef industry in Australia and Queensland

The livestock sector accounts for approximately 45% of the total value of agricultural production in Australia with beef cattle representing the largest single industry within this sector (Nossal, Sheng and Zhao 2008). Over the past ten years Australia's broad-acre, or extensive, beef industry has been expanding in terms of production. This expansion has occurred most significantly on farms with large (1,600 to 5,400 head) or very large herds (> 5,400 head) in Northern Australia (Mackinnon 2009, Nossal *et al*. 2008).

In Queensland the broad-acre beef industry is of particular importance as it accounts for a larger proportion of Australia's cattle herd than any other state or territory and represents the largest agricultural industry in Queensland by value (QDPI 2009). Queensland's beef cattle industry (including feedlots) accounted for 38 per cent of all jobs in Queensland agriculture in 2006-07 (Australian Food Statistics 2007), approximately one third of the Gross Value of Production (GVP) from Queensland's primary industries (QDPI 2009) and 32 per cent of specialist beef cattle enterprises (QDPI 2009).

Although output and productivity have been increasing over the past three decades (Nossal *et al*. 2008) there are other factors which are acting simultaneously to reduce the competitiveness of Australian livestock enterprises including: drought, declining terms of trade, barriers to trade, and rising input prices (Fletcher, Buetre, and Morey 2009; Nossal *et al*. 2008). The importance of the beef industry to employment and export earnings for Queensland suggests that changes in output, productivity and efficiency of beef producing enterprises is important for both the businesses themselves and industries representing inputs into the value adding process for beef production. Most notably the beef industry represents a substantial source of employment and income for people living in rural communities throughout Queensland (Fletcher *et al*. 2009).

The Australian Federal government has acknowledged the importance of maintaining productivity growth in Australian agricultural industries with the release of a set of Rural Research and Development Priorities (DAFF 2007). The first of these priorities is to "Improve the productivity and profitability of existing [rural] industries and support the development of viable new industries" (page 4). Thus, in addition to direct enterprise benefits of improving productivity and indirect social benefits to rural communities, the Federal Government has prioritised a focus of research and extension on improving productivity of rural industries, of which beef cattle production is a major component (Nossal *et al*. 2008, Fletcher *et al*. 2009).

The data used in this research originated from broad-acre beef enterprises in Queensland which participated in a profit analysis program called *Profit Probe*. The program was designed by a private consulting firm, Resource Consulting Services, to analyse the sources of profit and loss within agricultural enterprises and provide managers with information to facilitate an increase in profit through improved management. The focus of the *Profit Probe* program suggests that most positive impacts of the program will be observed through an increase in business efficiency rather than through a change in the extant production technology. In order to make the delineation between production technology and efficiency changes clear we provide the following definitions adapted from Coelli *et al*. (2005, page 2-3):

Productivity – is simply a ratio of outputs on inputs and is directly affected by changes in the production technology and efficiency

Production technology – is the set of technology available to a manager for use in the production of outputs from a set of inputs. It can be in a tangible form such as physical capital or in intangible forms such as human capital or knowledge. The production technology can be supplemented by, for example, advances in knowledge or improved machinery.

Efficiency – is the efficiency with which an enterprise utilises the extant production technology and available inputs to create output(s). Efficiency is an ordinal measure usually being measured as efficiency relative to the most efficient enterprise(s) or group(s) within a sample.

From the definition above, an agricultural enterprise may improve productivity by accessing improved production technologies, by improving the efficiency with which they produce output (only if there is some inefficiency present in their operations) or through a combination of these. Further, in order to maximise profit an enterprise operating in competitive input and output markets must simultaneously act to minimise costs and maximise revenues (Varian 1992).

Broad-acre beef enterprises in Queensland, and indeed around Australia, are characterised by low-intensity production with relatively low physical (labour, capital and fodder or energy) inputs per unit of output relative to intensive systems such as feedlots and irrigated pastures (Stafford Smith 2000). This low intensity production system relies largely on annual pasture growth under given climatic conditions which, in the case of Australia, are extremely variable (Stafford Smith 2000). Thus, although broad-acre beef enterprises have significant control over inputs into the production system, they have relatively little influence over short-term production possibilities due to highly variable pasture growth year on year. This limitation suggests that, for profit maximising firms, the target of revenue maximisation is limited to quality improvements and marketing decisions (e.g. timing of stock turnoff and breeding practices for stock renewal). Quality however is also limited by pasture quality, itself largely a function of land type and climate. Given these limitations it is proposed that cost minimisation is the key strategy for broad-acre beef farms in Queensland to maximise profits.

The literature on efficiency and productivity analysis provides many approaches to examine how efficiency and productivity differ across cross-sectional units and/or across time (e.g. Coelli *et al*. 2005; Kumbhakar and Lovell 2000). The desire to separate productivity into technological progress and efficiency components has resulted in the development of methods to calculate or estimate production frontiers from which, for panel data, both technological progress and efficiency can be independently measured/predicted and assessed. Due to the inherent volatility in production in this dataset, originating in part from climate variability, this research approached the issue of measurement of efficiency and technological progress using the stochastic (estimation) approach rather than the deterministic (e.g. Data Envelopment Analysis) approach. Stochastic Frontier Analysis was introduced initially and independently in 1977 as stochastic production frontier estimation by Aigner, Lovell and Schmidt and by Meeussen and van den Broeck (Coelli *et al*. 2005). Much of the literature on SFA has focused on the estimation of production frontiers (e.g. Battese and Coelli 1995; Battese and Broca 1997) which does not explicitly consider inputs in the implied decision function of managers (Kumbhakar and Tsionis 2008). Others have utilised input distance functions or estimated cost or profit frontiers, however many of these have not fully considered the implications of the orientation of the specified frontier/distance function (Kumbhakar and Tsionis 2008). In this research a cost frontier was specified due to the consideration that broad-acre beef enterprises have more control over inputs than outputs of the production process (Stafford-Smith 2000). Thus the data generation process for the dataset used in this research is expected to be more appropriately modelled by an input oriented approach (where input decisions are endogenous) rather than an output oriented approach (where output decisions are endogenous). Despite additional information being available on the prices received for output for each enterprise, there was some uncertainty as to the ability of managers to choose output levels and output quality in the short term under significant climatic and capital constraints (Stafford Smith 2000). For this main reason, and despite strong indications of profit maximising intentions (participation in *Profit Probe*), a cost frontier was deemed more appropriate than a profit frontier. Indeed, if the ability of managers to influence output is adequately attenuated, cost minimisation may be a sufficient condition for profit maximisation.

The focus of this research is to provide an insight into changes in how businesses participating in specialised management programs such as Profit Probe minimise costs in broad-acre beef cattle enterprises in Queensland. This directly addresses the Rural Research and Development Priorities set out by the DAFF (2007). Specifically, the aims of this research were:

1) To identify changes in the efficiency of beef production over time and factors that may influence that efficiency, and;
2) To identify how the level of efficiency affects production, cost minimisation and profit maximisation outcomes.

The dataset used in this analysis involved an unbalanced panel on 116 enterprises across ten years from 1999-2008. This paper is structured as follows. The next section provides a review of efficiency and productivity analysis with specific focus on issues of measurement in agricultural industries. A discussion of the methods applied and data description follows. Results are then presented with discussion incorporating insights from the literature and interpretations of the results. Conclusions summarise the findings of this research with respect to the aims of the research.

2. Methods

A key question in the analysis of agricultural performance is to identify whether improvements in performance are being generated through improving technology and innovation or increasing overall management efficiency. Improvements in technology and innovation can be expected to result from research and development, with innovative producers increasing their production relative to the average producer. In this case, changes will occur through a cost or production frontier moving over time. In contrast, improvements in management can be expected from more widespread adoption of best management practices and production systems, with average producers closing the gap between innovative enterprises and their production systems. In this case changes will occur through more producers moving closer to the cost or production frontier.

The need for a model allowing for both deterministic (function of variables) and stochastic inefficiency (unexplained variation in inefficiency) is met by the inefficiency effects stochastic frontier model due to Battese and Coelli (1993;1995). This model simultaneously estimates a stochastic frontier function and inefficiency parameters in a panel data maximum likelihood estimator.

A Cobb-Douglas functional form for the cost function was specified with a linear time variable included[1]. A rainfall deviation variable was also included in an attempt to capture variation in the minimum cost frontier due to changing environmental conditions between years. Data on four input prices were used. Homogeneity of degree one in prices was imposed by dividing the Labour price data, Energy price index, Fodder price index and Total Costs by the Reserve Bank of Australia cash rate (a proxy for the cost of capital). Logarithms of Total Costs, output, and input price variables were then taken to make the equation linear in parameters. The estimating equation specification is shown below:

[1] A translog functional form was initially estimated but higher order and interaction terms were insignificant. This lead to the Cobb-Douglas function form representing the translog specification with higher order and interaction terms restricted to zero.

$$\ln TC_{it} = a + \beta 1 \ln Output_{it} + \beta 2 \ln LabourP_{it} + \beta 1 \ln FodderP_t + \beta 1 \ln EnergyP_t + \theta time_t + \alpha Raindiff_{it} + v_{it} + u_{it}$$

Where:

$$u_{it} = z + \delta time_t + \delta DIROH_{it} + \delta \#Probes_{it} + \varepsilon_{it}$$

DIROH = Direct/Overhead costs

#Probes = Number of probes undertaken

In order to predict inefficiencies and draw conclusions from observations on the vector of predicted efficiency, the Battese and Coelli (1988) estimator, provided in Coelli *et al*. (2005, p255) was utilised. This predictor is preferred over the alternative Jondrow *et al*. (1982 in Coelli *et al*. 2005) estimator because it minimises the mean square error (Coelli *et al*. 2005).

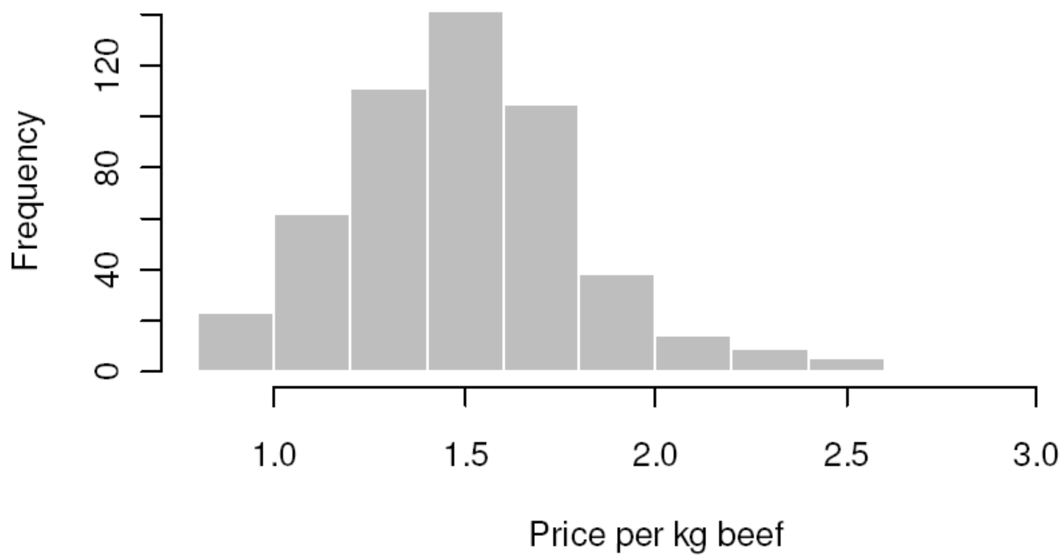
The model was estimated in the R program (www.r-project.org) using the Optim library and the likelihood function, modified to represent a minimum cost frontier conditional on output (rather than a maximum production frontier conditional on inputs), from Battese and Coelli (1993). Battese and Coelli specified an inefficiency effects, panel data model which captured both the production or cost function parameters and deterministic regressors for inefficiency effects. The likelihood function in Battese and Coelli (1993) was originally specified as an output oriented production frontier but was modified to represent an input oriented minimum cost frontier for this research. Ordinary Least Squares (OLS) estimates on the non-frontier cost function were used as starting values for the Nelder-Mead optimisation routine used in R.

3. Data

Data for this research was developed from Queensland broad-acre beef enterprises participating in the *Profit Probe* Program. The program is run by an agricultural consulting firm, Resource Consulting Services, which services a range of agricultural enterprises in Australia. A total of 510 observations across 10 years of data for 116 beef enterprises in Queensland were available for this research. The panel of data was unbalanced meaning that enterprises did not necessarily participate in *Profit Probe* in each year from 1999-2008. Indeed the majority of enterprises participated in *Profit Probe* for only a subset of the ten years involved in the dataset with an average participation rate of 4.4 years. Each time that an enterprise participated in the program a detailed summary of production and other characteristics were collected, with the summary of that information made available for this research. Enterprises were located across a wide area of Queensland, with highly divergent natural resource and climate conditions. Enterprises did not necessarily participate in the program each year, and a number of new enterprises joined the program over the ten year period.

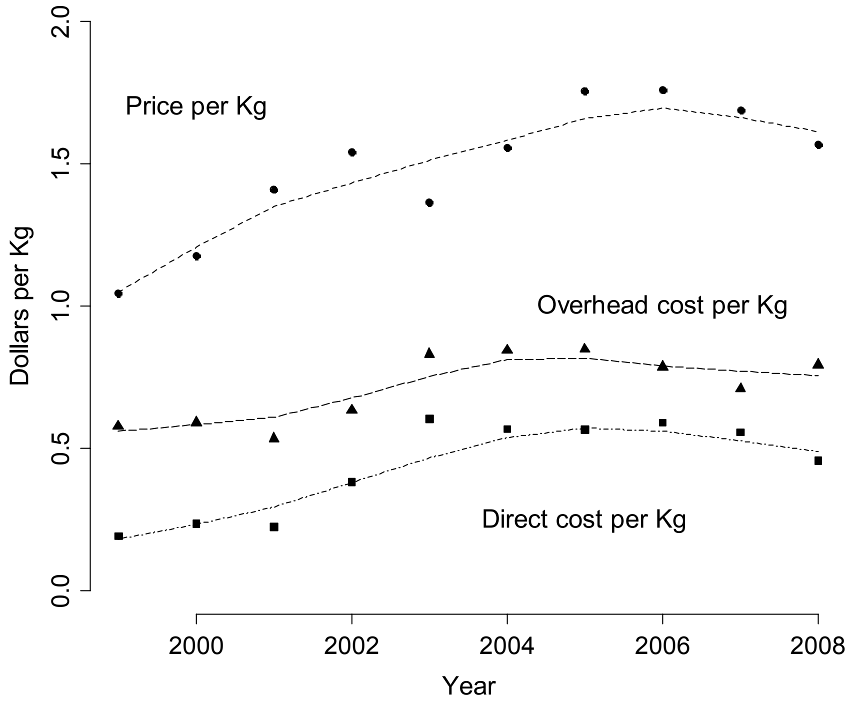
Costs of production, output (kilograms of beef produced), output prices, rainfall, and program participation were directly available from the dataset. Figure 3 shows the distribution of output prices received for enterprises in the sample.

Figure 1: Histogram of Distribution of prices per kilogram received by sample enterprises



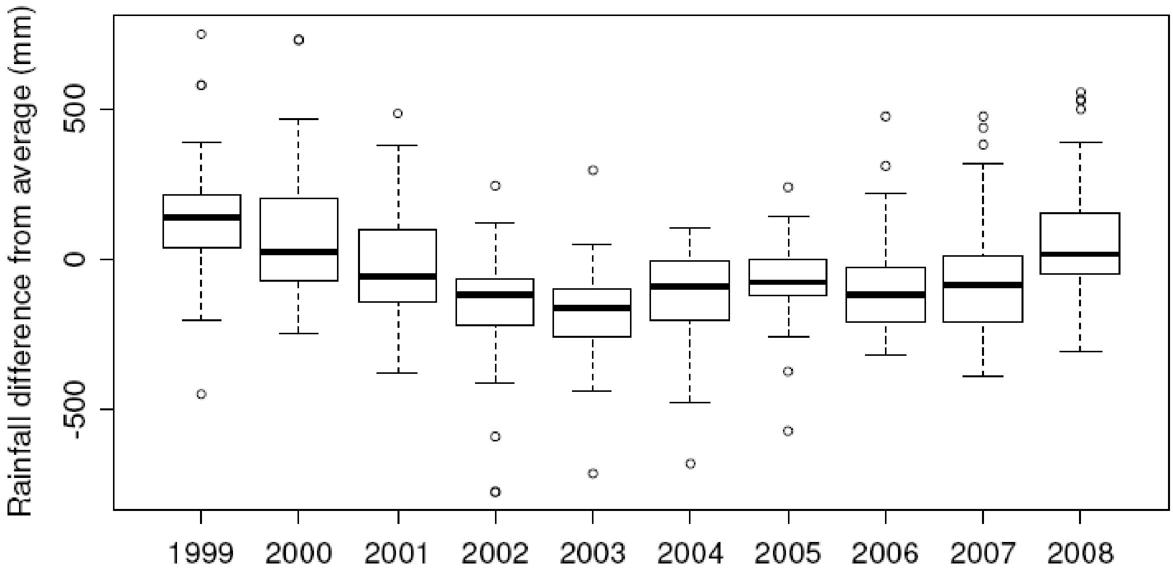
Prices received were initially increasing over the sample period with the trend beginning to decline in 2007 and 2008. During this time there was also a rise in both direct and overhead costs for sample enterprises. Figure 3 provides a comparison of these three indices from 1999-2008 for this sample of data.

Figure 2: Comparison of median prices per KG Beef and direct and overhead costs per KG beef produced for sample enterprises by year



Rainfall deviations were calculated by subtracting observed rainfall for each observation from the mean rainfall recorded for that property. This variable was calculated to reflect deviations in rainfall around the long term expected rainfall and provide some measurement of deviation from long-term expected pasture production possibilities. Figure 3 shows the distribution of rainfall deviations for sample enterprises in each of the sample years.

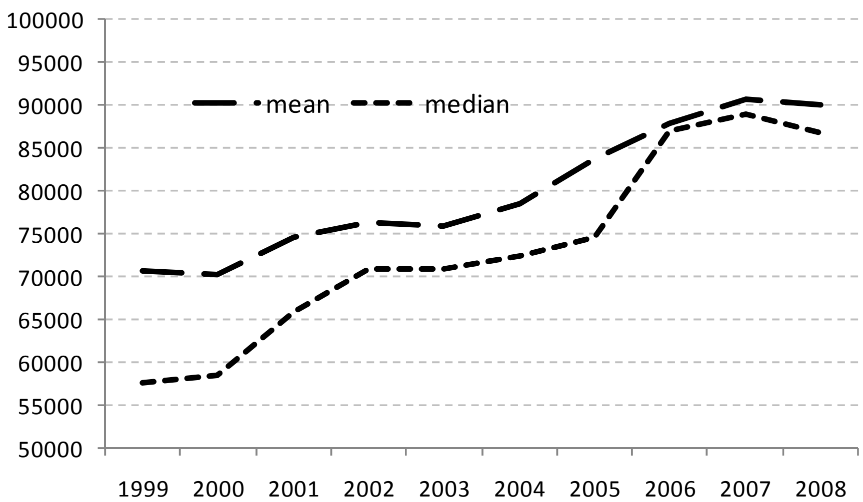
Figure 3: Distribution of rainfall deviations for enterprises across the sample period



Paid labour prices were calculated using data on labour expenses for paid full-time equivalent employees. Unpaid labour prices were estimated from data collected in the *Profit Probe* program. Subsequent outliers in the estimates of labour expenses were restricted to $25,000 per annum (1 observation) as a minimum and $150,000 per annum (8 observations) as a maximum. The final labour price was derived by calculating a weighted sum of paid and unpaid prices. The number of full-time equivalent employees in each of the paid and unpaid categories divided by total full-time equivalent employees was used as the weights in this sum.

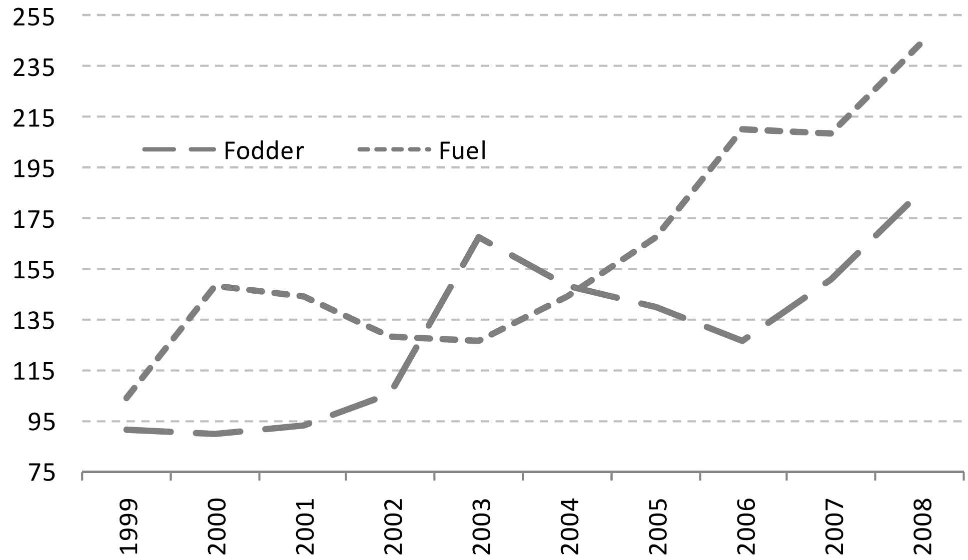
Estimated cost per FTE was increasing across the sample period. The median price per FTE for sample enterprises increased from approximately $57,000 per year to $87,000 per year (a 50.4% increase) representing an annualised increase of $3,000 or 5% per annum. Figure 12 shows the path of mean and median labour cost per FTE for sample enterprises over the period 1999-2008.

Figure 4: Time series of mean and median labour price for sample enterprises



Fodder and fuel price indices were obtained from the Australian Bureau of Agricultural and Resource Economics website (www.abare.gov.au). These price indices are shown in Figure 13. Price indices were calculated using the Fisher ideal price index with a base year of 1997-98 (ABARE, 2009). The price indices for fuel and fodder indicated substantial price increases in both inputs over the sample period with fuel prices increasing by over 130% and fodder prices increasing by more than 100%.

Figure 5: Trends in the prices of fodder and fuel for beef farmers in Australia



Source: ABARE (2009) – Farm input prices accessed online at www.abare.gov.au

4. Results and discussion

Results are split into three sections. The first deals with the description of the minimum cost frontier and elasticities of total cost with respect to input prices and output. The second deals with inefficiency as predicted using the Battese and Coelli inefficiency effects frontier model (1993). The third reports a Cobb-Douglas profit function to examine the importance of cost minimisation in enterprise profitability.

Table 1 shows the results of the estimation of an inefficiency effects input-oriented minimum cost production frontier as described in the previous section. The model is highly significant and estimated coefficients have the expected signs.

The positive and significant coefficient for Gamma indicates that stochastic inefficiency explains a significant proportion of positive deviations from the production frontier. A likelihood ratio test of the significance of the one-sided error term (inefficiency component of the cost frontier) rejected the null hypothesis that there were no inefficiency effects.

Ordinary Least Squares (OLS) was used to find starting values for the Nelder Mead optimisation routine. No starting values were available for the error components or the deterministic regressors for inefficiency. Sensitivity testing was carried out by varying starting values for a range of parameters. It was found that final estimates were sensitive to the choice of starting values. In order to achieve consistency, final estimates were compared to OLS estimates, particularly for the intercept (should be higher for OLS), output and input parameters (expect some but not excessive change). The final model here represents a plausible model which is parsimonious and relatively robust to changes in the main cost frontier parameters as well as with respect to the OLS estimates.

4.1 Minimum Cost frontier model

This section provides a description of the estimated minimum cost frontier. Focus is on the interpretation of input price coefficients in terms of their importance to total costs at the frontier and changes in the frontier due to time and climatic effects.

All input prices are positive as expected and required by economic theory (Coelli *et al*. 2005). Only the labour and fodder price coefficients are significant at the 5% level of significance whilst the coefficient for energy prices is significant at the 10% level of significance. The price of labour is the most important component of total costs with an elasticity of total cost with respect to Labour of 0.499. The elasticity of total cost with respect to output is 0.37, reflecting the higher cost of producing more output. Fodder prices are more important than energy prices in the costs of production for enterprises operating at the frontier.

The negative coefficient associated with Rainfall difference (difference from average rainfall) suggests that higher annual rainfall results in a contraction of the minimum cost frontier for given output levels. This result is expected but not significant at standard levels of confidence – it may prove to be stronger with the inclusion of some indicator of rainfall quality (i.e. flooding rain may be bad for production) and/or a longer time series.

Table 1: Inefficiency effects minimum cost frontier model

	Coefficient estimate	Standard error	P-value
Minimum cost frontier			
Intercept	2.50401	0.34077	0.00000
Ln Quantity	0.36875	0.02304	0.00000
Ln Labour price	0.49889	0.04334	0.00000
Ln Fodder price	0.29121	0.07466	0.00022
Ln Energy price	0.16415	0.09541	0.09090
Time	0.01515	0.01024	0.13341
Rain difference	-0.00013	0.00009	0.14937
Inefficiency effects			
Intercept	0.33010	0.06560	0.00000
Time	0.00466	0.00467	0.24211
Direct/Overhead costs	-0.08372	0.02410	0.00101
# Probes	-0.01264	0.00694	0.07619
Error components			
Gamma	0.47160	0.13620	0.00105
Sigma	0.35478	0.01139	0.00000
Log Likelihood	-1977.2398		

Note: the vector of labour prices were divided by 100 to equalise the magnitude of price vectors

There do not appear to be any changes in the position of the minimum cost frontier over time for this sample; however the coefficient for time is positive. The insignificance of the time coefficient is an indication that there has been no or insignificant technological progress over time for this sample. This result has implications for the fact that this data has been generated from an extension program aiming to improve the profitability of broad-acre beef enterprises in Queensland. The lack of a time effect on the minimum cost frontier for enterprises participating in *Profit Probe* suggests that the program does not improve the technology set available to extensive beef producers. This, however, may be consistent with the aim of *Profit Probe* which is to “provide[s] a very strong foundation for agricultural enterprises to make strategic changes to their businesses and then measure the improvements” (http://www.rcs.au.com/consultingservices/category_3/3/index.htm, accessed 27/12/2009).

The insignificance of the energy price and time coefficients may point to an estimation problem. Figure 5 shows a rapid and almost linear increase in energy prices over the sample period specified. Examination of the correlation between the vector of energy prices and time shows that they are correlated with an R-squared value of 0.85. A correlation value this high suggests that the effects of these two variables may not be distinguishable from each other in econometric modelling.

4.2 Inefficiency effects

Nossal *et al*. (2008) state that over the last ten years Australian broad-acre beef production has experienced a productivity improvement. The results shown in this analysis suggest that, at least for this sample of enterprises, the source of productivity growth has not been through technological progress. This section presents the results of research into how efficiency improvements may have generated productivity increases observed over the last ten years by Nossal *et al*. (2008).

The inefficiency model component measures deterministic variation in the inefficiency estimates for enterprises in the sample. In addition to the presence of stochastic inefficiency in the costs of production for this sample, there are several variables which are significant predictors of the level of inefficiency for each sample enterprise.

Table 1 shows the estimated coefficients for regressors of inefficiency in the sample. The positive and significant intercept term for the inefficiency effects shows that the distribution of inefficiencies is centred at 0.33 (above the frontier) rather than being centred at the frontier (no inefficiency) as suggested by the Aigner, Schmidt and Lovell frontier model (1977). Additionally, the ratio of direct to overhead costs, and the number of *Profit Probes* undertaken by sample enterprises are highly significant predictors of inefficiency for this sample. Inefficiency did not appear to be trending upward or downward over time independently of other factors.

The negative coefficient for the ratio of direct to overhead costs was highly significant and suggested that businesses with a higher level of direct costs, relative to overhead costs, were more efficient. In terms of improving efficiency, this suggests broad-acre beef enterprises should aim to minimise overhead costs and focus expenses on costs associated directly with the production of beef.

Enterprise efficiency was calculated for each observation available using the Battese and Coelli (1988) predictor of inefficiency found in Coelli *et al*. (2005). Figure 6 shows the trend in efficiency over time for the enterprises in the sample. There is some movement up and down in cost efficiency over the sample period, however in general there appears to be a convergence of mean efficiency (solid line) with median efficiency (dashed line). There was a slight (less than one percent) increase in mean cost efficiency over the sample period. There did not appear to be any significant relationship between rainfall deviations and cost efficiency, however there is a possibility that with a longer time series the lagged effects of positive or negative rainfall deviations may either change the position of the frontier or have an effect on enterprise efficiency.

Mean cost efficiency was calculated as 91.5% whilst median cost efficiency was calculated as 92.4%.

Figure 6: Average Cost Efficiency of enterprises by year

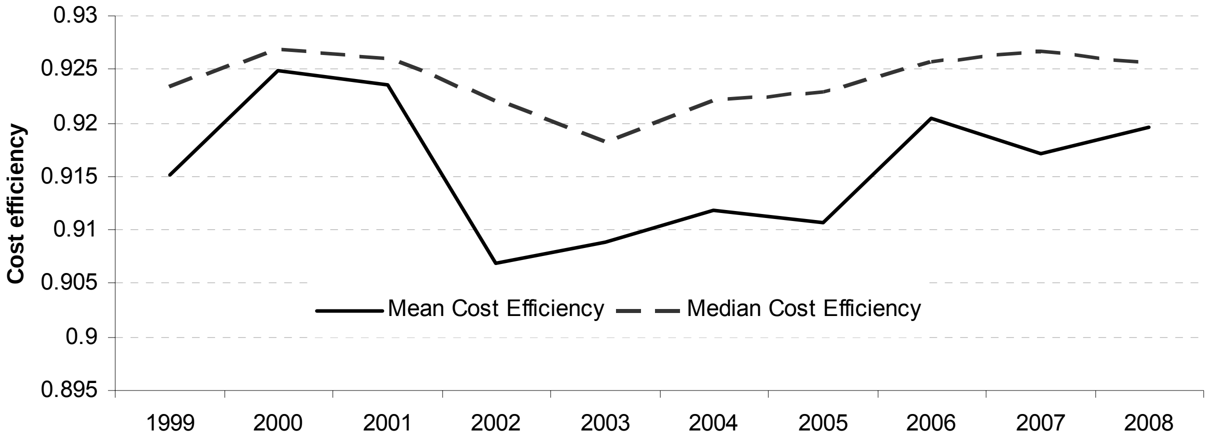
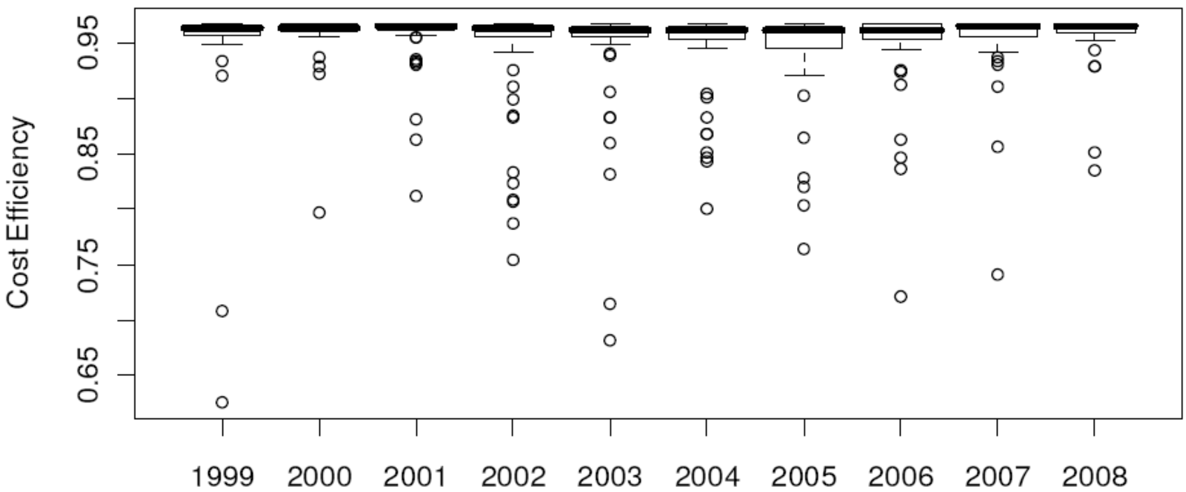


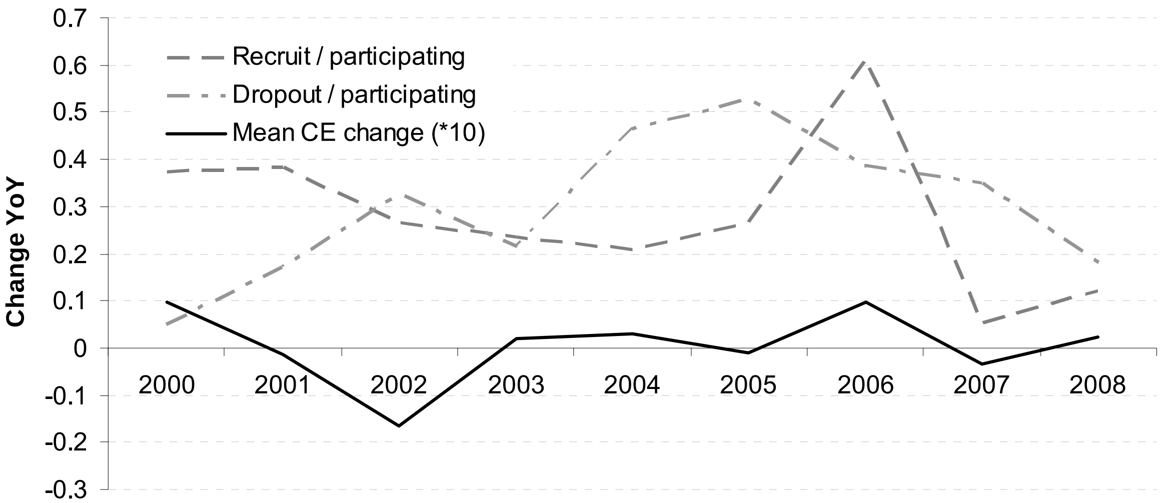
Figure 7 shows the annual distribution of cost efficiencies for this sample, which in combination with Figure 6 suggests that there is a convergence of lower cost efficiency enterprises to higher levels of efficiency.

Figure 7: Distribution of enterprise efficiencies by year



The *Profit Probe* participation variable (# Probes) suggests that inefficiency declines with increasing participation. Figure 8 shows the relationship between the ratio of recruits and dropouts to participating enterprises to the change in cost efficiency from the previous period for the years 2000-2008. The graphic shows that changes in cost efficiency appear to be inversely related to the ratio of dropouts to continuing enterprises. This suggests that the dropouts may lower the mean level of efficiency for that year by reducing management capacity within the sample.

Figure 8: Relationship between recruits/dropouts in the *Profit Probe* program to year on year predicted cost efficiency changes



Although there were indications of only marginal efficiency increases over the sample period, observed productivity improvements in the broad-acre beef industry may still be attributed to efficiency improvements. This result requires the assumption that efficiency improvements occur during participation in the *Profit Probe* program. The unbalanced nature of the panel, and the fact that enterprises participated in the program an average of only 4.4 years out of ten suggests that there is some turnover in participants in *Profit Probe* which in turn indicates that, if efficiency improvements are long-lasting for individual enterprises, industry efficiency may have improved by 5.5% for this sample of producers[2].

4.3 Cost efficiency and enterprise profitability

Prior to estimating the cost efficiency production model (Table 1) it was hypothesised that, for extensive beef producers, an aim of profit maximisation was equivalent to one of cost minimisation (i.e. revenue is exogenous). The rationale for this hypothesis was that short-term output possibilities from broad acre beef enterprises are exogenous, determined by land quality, existing capital such as fences, bores and improved pastures, and climatic influences (e.g. Stafford Smith 2000). Additionally, value adding in terms of targeting high value markets may be limited due to the extensive nature of beef production for these enterprises (little ability of managers to differentiate product). However the distribution of prices per kilogram beef received

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[2] Efficiency improvement calculated by multiplying the coefficient for # *Probes* by the average participation rate (4.4 years) and assuming that improvements are maintained following exit from the program and holding all else constant.

by sample enterprises (Figure 3) shows considerable variation, suggesting that there is some scope for revenue maximisation via improving product quality and timing turnoff of beef cattle.

This hypothesis was considered by comparing two Cobb-Douglas profit functions – one with cost inefficiency explicitly incorporated and the other without but otherwise the same. This approach provides some insight into how cost inefficiency affects profitability but does not allow explicit statistical testing of the magnitude to which cost minimisation is of importance in profit maximisation. Potential autocorrelation issues are not dealt with in this research. Profit was normalised by enterprise asset values leading to a dependent variable framed around a Return on Assets (ROA). The dependent variable was further modified to be always positive by adding the lowest observed (negative) absolute ROA level, plus one, in any of the given years to all of the observations on the dependent variable. This procedure was adapted from Berger and Mester (1997). A linear-in-parameters Cobb-Douglas profit function was specified following the specification of the same functional form for the stochastic cost frontier in the previous section. Linearity (in parameters) was imposed by taking the natural log of the dependent variable and of input and output prices on the RHS of the equation. Time and rainfall-deviation components were also included in an attempt to capture any time trends or climatic influences. Table 2 presents the results of this analysis.

Table 2: Linear in parameters Cobb-Douglas profit function with and without cost inefficiency [3]

	No cost inefficiency		**Cost inefficiency**	
	Coefficient estimate	Standard error	Coefficient estimate	Standard error
Intercept	2.20178	1.8441	-4.7678**	2.1418
Ln Quantity produced	0.1697***	0.0472	0.2096***	0.0462
Ln Output price	0.3490*	0.2085	0.4783**	0.2030
Ln Labour price	-1.1069***	0.0906	-1.0042***	0.0895
Ln Fodder price	0.0968	0.2228	0.1739	0.2160
Ln Energy price	0.21400	0.2491	-0.0226	0.2445
Ln Interest Rate	-0.6231	0.4355	-0.6948	0.4218
Time	-0.1951***	0.0328	-0.1925***	0.0318
Rainfall deviations	0.0003	0.0002	0.0002	0.0002
Cost Efficiency	NA	NA	7.1929***	1.2213
	Adjusted R-squared 0.4504		*Adjusted R-squared* 0.4849	

[3] Cost inefficiency is represented inversely in the equation specification as cost efficiency with a potential range between 0 and 1 with 1 meaning perfect cost efficiency

*** = significant at 1%, ** = significant at 5%, and * = significant at the 10% level.

Both models explain over 45% of the variation in the dependent variable. The main difference between the two models is in the intercept term which is significantly reduced for the more general model (cost inefficiency included). Cost efficiency is positively and highly significantly related to ROA for this sample of broad-acre beef enterprises. Additionally it is clear that both output prices and labour prices are significant determinants of profitability while higher levels of production are significantly related to higher levels of profitability. It is unclear how the intensity of production (kilograms beef per hectare) is related to profitability.

Cost efficiency is a highly significant predictor of enterprise profitability. Output prices appear to be less important than labour prices and overall cost minimisation. This suggests that there is indeed some scope for revenue improvements but that, if revenue supplementation through improved management or capital investments is costly, cost minimisation may be a sufficient condition for profit maximisation in the broad-acre beef industry.

One final result to note from the models above is evidence of a cost-price squeeze. The time coefficient shows declining profitability over time which may reflect factors external to production such as rapidly increasing land capital prices and declining terms of trade over the sample period (Mackinnon 2009). This suggests that cost efficiency and technological progress will become an increasingly important consideration for broad-acre beef enterprises if reduced margins remain a factor of enterprises operating in this industry.

5. Conclusions

The research reported in this paper examined the cost efficiency of a sample of 116 broad-acre beef enterprises in Queensland who participated in a profit exploration tool called *Profit Probe*. This consulting and extension program is focused on identifying sources of profit in agricultural businesses and providing insights into how enterprises can be managed to improve profitability. It is expected that improvements in profitability can be gained through simultaneous cost minimisation and revenue maximisation when both of these aims can be influenced through management decisions.

Factors influencing cost minimisation and enterprise efficiency have been examined in this research using Stochastic Frontier Analysis. A minimum cost, input oriented frontier was estimated with the intention of examining predicted inefficiency levels over time for the sample of producers. The results showed that inefficiency was both present (albeit at low levels with a mean efficiency level of over 90%) and improving with the number of *Profit Probes* undertaken by sample enterprises. This suggests that provision of more specialised information and improvements in management can help to improve the relative performance of the average beef producer.

However, the results also showed that the cost-minimisation frontier was not changing over time, suggesting that technological progress in the industry has been low. Given the increase in cost inputs over time, the lack of technological progress means that the industry will come under increasing financial pressure. The lack of technological progress also raises questions about the effectiveness of expenditure in research and technology, and about the extent to which new developments are being diffused through the industry.

Prior to estimating the inefficiency model described above, it was hypothesised that cost minimisation may be a sufficient condition for a profit maximising enterprise in the broad-acre beef industry. This hypothesis arose from the consideration that short-term output possibilities were exogenously determined by land type, existing capital (including man-made capital and other types such as improved pastures), and climatic influences. A post-hoc profit regression comparison using linear in parameters Cobb-Douglas profit functions suggested that although cost minimisation was a necessary condition for profit maximisation it may not be sufficient. In addition to cost minimisation, enterprises may be able to influence the value added for the beef production component of their business – a significant determinant of profitability.

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