DEVELOPMENT OF A BENCHMARKING SYSTEM FOR IRISH BEEF FARMS USING DATA ENVELOPMENT ANALYSIS

Eoghan Finneran, Paul Crosson

AGRIC, Teagasc, Grange, Dunsany, Co. Meath, Ireland

Abstract

Agricultural extension trends have involved greater use of collaborative "discussion group" dissemination approaches. These discussion groups involve regular participatory meetings between a consistent cohort of farmers and extension practitioners with occasional input from industry and research stakeholders. In Ireland, policy change, small farm scale and low incomes are some of the factors incentivising beef farmers and industry to seek increased whole-farm income efficiency. Whole-farm comparative analysis may provide a means of identifying and explaining efficiency drivers at farm level. This article describes the development of BEEFMARK, a benchmarking model with potential to act as a tool to facilitate farmer-farmer and farmer-adviser group learning within discussion groups. BEEFMARK utilised Data Envelopment Analysis (DEA) to measure beef farm income and scale efficiency and to identify and characterise efficient peer farms which act as benchmarks for similarly structured, but lower efficiency farms. Market derived gross output (€) per livestock unit was positively associated with farm efficiency while greater overhead and concentrate feed expenditure was negatively associated with income and scale efficiency.

Keywords: beef, benchmarking, comparative analysis, efficiency, efficient peers

1. Introduction

Internationally, beef production is characterised by low productivity, and consequently low profitability relative to other farm enterprises (Rakipova *et al.*, 2003; Newman and Matthews, 2007). In Ireland, incomes on beef farms have typically been supplemented by other farm enterprises, direct payment farm subsidies and off-farm incomes (Kinsella *et al.*, 2000; Hennessy and Rehman, 2008). The domestic and international macro-economic environment since 2007 has resulted in decreased availability of off-farm employment in rural regions of Ireland (CSO, 2012). This reduced off-farm employment, coupled with impending changes in the distribution of farm subsidies under reform of the European Union (EU) Common Agricultural Policy (CAP) has led to a renewed focus on beef farm profitability and efficiency amongst farmers and agricultural extension.

1.1. The discussion group in comparative analysis

Farm comparative analysis involves identifying and measuring the management and structural differences between successful and unsuccessful farms. The ultimate objective is to help extension practitioners and farmers themselves identify specific production strategies likely to increase farm profits (Sheehy and McAlexander, 1965; Fleming *et al.*, 2006). While traditionally blueprints for efficient farm production were devised by agricultural researchers and passed down to farmers via the medium of farm advisors, the identification of successful farm systems has in recent decades

Acknowledgements: The authors gratefully acknowledge the co-operation of the farmers and Teagasc staff participating in the National Farm Survey and the eProfit Monitor programme.

become more of a participative process (Lacy, 2011; Hennessy and Heanue, 2012). This change has been partly driven by a realisation that research findings are not universally relevant to all farmers in practice and participatory approaches enable exploration of on-farm issues which may not be considered by the top-down approach (Lacy, 2011). Discussion groups, farm open days and group forums utilising multi-directional communication channels have become increasingly common means of information dissemination and exchange in farm extension (Millar and Curtis, 1997).

1.2. Whole-farm analysis and benchmarking

Gross margin per hectare (GM/ha) is commonly used as a profit measure when comparing farms employing pasture-based production systems (McCall and Clark, 1999). However two criticisms are often made of the "partial accounting" nature of this measure:

- The exclusion of fixed costs from gross margin calculation means that farm systems which employ inherently higher ratios of fixed costs to variable costs appear to achieve greater profits (Firth, 2002; White *et al*., 2010).
- The expression of profit on a per hectare basis neglects the productivity of other assets employed. It creates a bias in favour of farms which substitute other fixed assets (e.g. buildings or machinery) for land in their production system (Farrell, 1957; Fleming *et al.*, 2006; Shadbolt, 2012).

A solution to these weaknesses is the measurement of *whole-farm economic efficiency*. This concept was based on the principles described by Farrell (1957). Including all fixed and variable costs in whole-farm; rather than partial measures of efficiency permits more robust specification of strategies that may improve profitability over both the short and long-term (Tauer, 1993).

Benchmarking is a comparative analysis approach which involves identifying tangible blueprint targets with the aim of improving efficiency and profitability (Fleming *et al*., 2006). This paper describes the development of a benchmarking model BEEFMARK, which utilised data envelopment analysis (DEA) to measure whole-farm income and scale efficiency on Irish beef farms. The qualitative validation of BEEFMARK using an independent commercial farm dataset and its ability to identify efficient peer farms are discussed in the context of designing a discussion group tool.

2. Methodology

Data envelopment analysis is a non-parametric linear programming methodology for measuring efficiency (Farrell 1957; Charnes *et al*. 1978). DEA is non-parametric in that the efficiency frontier is defined by the most efficient farms in the sample rather than by the modeller. This means that DEA efficiency blueprints have been empirically measured on farms rather than being the product of theoretically possible calculations (Farrell, 1957).

Fried *et al.* (2008) defined productivity as a ratio of aggregated outputs to aggregated inputs and efficiency as the ratio of measured productivity to potential productivity. Figure 1 illustrates how efficiency is calculated in the BEEFMARK model. The 'best observed practice' farms exhibit an efficiency score of one and the efficiency frontier created by joining their production functions 'envelops' farms below the frontier which have an efficiency score of less than one (Farms A and E). Efficiency models can be either output or input oriented. BEEFMARK efficiency scores are output oriented because inputs such as land and labour on most farms are essentially fixed and therefore model results prescribing changes of such input variables would be largely impractical

(Tauer, 1993; Newman and Matthews, 2007). Output oriented efficiency scores give the farmer an indication of how output can be increased by more judicious and efficient management of the existing farm inputs.

2.1. The benchmark dataset

Data from the Teagasc National Farm survey (NFS; Hennessey *et al.*, 2012) for 2009 and 2010 were used as the benchmark dataset for the initial development of BEEFMARK. The NFS is an annual voluntary survey of approximately 1,100 farms, representative of over 100,000 farms in Ireland, providing data to the Farm Accountancy Data Network (FADN). The modelled farms were categorised as either 'cattle rearing' (CR) or 'cattle other' (CO) within this dataset. Cattle rearing farms are primarily suckler farms while CO farms are primarily beef finishing farms.

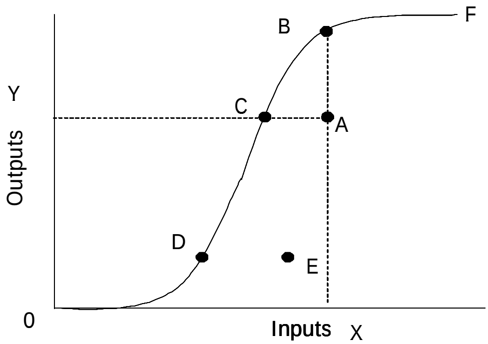

Figure 1. Illustration of efficiency calculation and efficient peers

2.2. BEEFMARK model inputs and outputs

The eight model inputs were land area farmed (ha), number of livestock units (LU), total labour units employed (paid and unpaid), concentrate feed expenditure, fertiliser expenditure, other variable input costs, overhead costs and total direct payment subsidies; all annual, whole-farm values. Whole-farm output was annual net income; nominally family farm income (FFI measured in €/farm). FFI includes income from subsidiary farm enterprises, market derived income from cattle and farm direct payments.

2.3. Bootstrapping

To address sampling bias BEEFMARK employed a bootstrapping re-sampling procedure to all sample farms as described by Simar and Wilson (1998). Sampling bias is a problem inherent in all DEA models (Latruffe *et al.*, 2005). The bootstrap involved 10,000 random Monte Carlo re-samples. This procedure produced a distribution of efficiency scores and a bootstrap bias term for each sample farm. The bootstrap bias term (essentially a sampling error term) was deducted from the deterministic efficiency score (ES) to give the bias-corrected efficiency score. Income efficiency (IES) and scale efficiency (SES) scores referred to throughout this article are bias-corrected efficiency scores.

2.4. Efficient peers

Efficient peers (EP) act as commercial blueprint farms for similarly structured, but less efficient farms. Each sample farm in the BEEFMARK model which is classed as inefficient has an EP. This EP represents the closest farm on the best-practice frontier and indicates the shortest radial route for the inefficient farm to achieve efficiency. In Figure 1, farm B is the EP for inefficient farm A and farm D is the EP for farm E. The farm acting as EP for the greatest number of inefficient farms was identified as the "most common efficient peer". The most common efficient peer shared more common characteristics than the other efficient farms with the inefficient farms in the sample. By observing the characteristics which differed between the inefficient farms and their most common efficient peer, pathways to increased efficiency could be deduced.

2.5. BEEFMARK operation

The BEEFMARK model was run in four discrete steps:

1. Scale and income efficiency scores were calculated using "FEAR" in the R language (Wilson, 2009).
2. All sample farms were assigned to top, middle and bottom thirds ranked in order of bias-corrected efficiency score. To identify determinants of efficiency, explanatory management, environmental and demographic variables were then compared across these thirds using a Mann-Whitney test for difference of means (Table 4). This procedure was repeated for scale efficiency.
3. Efficient peers were identified using "DEAP" (Coelli, 2005).
4. Because DEAP identified peers based on deterministic efficiency scores, the most common efficient peers were ranked on bias-corrected efficiency scores (stage 1 output). An EP was only identified as such by BEEFMARK if it was in the top 20% of its respective sample both in terms of income and scale efficiency.

2.6. BEEFMARK dataset comparison

The consistency of BEEFMARK was qualitatively assessed using an independent dataset of Irish beef farms. The independent dataset comprised approximately 500 beef farms which recorded farm production and financial data using the Teagasc web-enabled profit analysis program, the "eProfit Monitor" (ePM), over the years 2009 and 2010. Model input and output variables were equivalent to those used for the analysis of NFS farm data described above. Comparative analysis results were compared between the datasets to assess the performance of BEEFMARK under differing beef farm samples.

3. Results and discussion

3.1. Mean efficiency scores and comparative analysis of explanatory variables

Table 1 details the mean efficiency scores and proportion of farms operating at increasing and decreasing returns to scale and scale efficiency for the benchmark (NFS) and the independent (ePM) datasets for 2009 and 2010.

Tables 2 and 3 show the comparative analysis results for the NFS and ePM datasets, respectively, with farms ranked on IES. Higher concentrate and overhead expenditure per LU were consistently associated with lower income efficiency. Lower efficiency NFS farms were more fragmented (results not shown). Stocking rate, farmer age, and off farm employment had no

Table 1. Mean efficiency scores and percentage of farms operating at scale efficiency, increasing and decreasing returns to scale for the benchmark (NFS) sample and the independent (ePM) sample of Irish beef farms

Dataset	Farm Sample	Year	Bias	IES	SES	IRS %	SE %	DRS %
Benchmark dataset	Cattle Rearing	2009	0.06	0.80	0.67	1	2	96
		2010	0.10	0.71	0.73	4	2	94
	Cattle Other	2009	0.12	0.66	0.60	0	13	87
		2010	0.12	0.64	0.57	0	12	88
Independent dataset	Cattle Rearing	2009	0.10	0.61	0.54	0	6	94
		2010	0.07	0.73	0.36	0	2	97
	Cattle Other	2009	0.15	0.67	0.55	0	15	85
		2010	0.09	0.78	0.41	6	2	92
Overall mean			0.10	0.70	0.55	2	7	92
Benchmark dataset mean			0.10	0.70	0.64	1	7	91
Independent dataset mean			0.10	0.70	0.46	2	6	92
2009 mean			0.11	0.69	0.59	0	9	91
2010 mean			0.09	0.71	0.52	3	4	93
Cattle Rearing mean			0.08	0.71	0.57	1	3	95
Cattle Other mean			0.12	0.69	0.53	2	10	88

Bias = sampling bias calculated by 10,000 bootstrap re-samples. IES = Income efficiency score. SES = Scale efficiency score. IRS = increasing returns to scale. SE = Scale efficient. DRS = Decreasing returns to scale

Table 2. Characteristics of top and bottom 1/3 of National Farm Survey beef farms ranked on bias corrected income efficiency score

		Cattle Rearing						Cattle Other					
Year		2009			2010			2009			2010		
Scale efficiency tercile		Top 1/3	Bottom 1/3		Top 1/3	Bottom 1/3		Top 1/3	Bottom 1/3		Top 1/3	Bottom 1/3	
Income efficiency score		0.89	0.69	***	0.84	0.57	***	0.82	0.50	***	0.79	0.47	***
Scale efficiency score		0.58	0.51	***	0.65	0.58	***	0.56	0.59	NS	0.50	0.57	NS
Cattle numbers	LU	44	46	NS	43	46	**	52	54	NS	56	52	NS
Land farmed	ha	42	45	*	47	44	NS	42	44	NS	46	47	NS
Farm gross output	€	40,600	35,129	NS	41,745	38,508	NS	48,263	42,041	NS	54,545	41,712	NS
Farm direct payments	€	21,057	18,565	***	21,224	18,230	***	21,754	20,366	NS	22,943	18,774	NS
Stocking rate	LU/ha	1.24	1.21	NS	1.11	1.23	NS	1.34	1.33	NS	1.35	1.23	*
Overhead costs	€/LU	285	438	***	329	430	***	275	337	***	296	454	***
Concentrates fed	€/LU	74	123	***	82	125	***	103	123	*	143	181	NS
AI expenditure	€/cow[1]	8	7	NS	6	8	NS	-	-		-	-	
Gross output	€/LU	978	772	***	1,058	864	***	918	790	**	992	976	*
Family farm income	€/ha	230	194	NS	232	205	NS	265	290	NS	338	278	NS

[1] per cow or in-calf heifer. Signif levels: *** $P < 0.01$; *** $P < 0.05$; * $P < 0.10$

Table 3. Characteristics of top and bottom 1/3 ePM beef farms ranked on bias corrected income efficiency

		Cattle Rearing						Cattle Other					
Year		2009			2010			2009			2010		
Scale efficiency tercile		Top 1/3	Bottom 1/3		Top 1/3	Bottom 1/3		Top 1/3	Bottom 1/3		Top 1/3	Bottom 1/3	
Income efficiency score		0.77	0.45	***	0.86	0.59	***	0.83	0.49	***	0.90	0.63	***
Scale efficiency score		0.56	0.51	**	0.42	0.32	***	0.54	0.62	NS	0.37	0.46	NS
Cattle numbers	LU	86	83	NS	79	100	***	71	80	NS	67	97	NS
Land farmed	ha	52	51	NS	49	59	***	45	54	NS	43	62	NS
Farm gross output	€	82,372	67,960	NS	76,359	84,497	*	75,710	70,994	NS	74,799	84,079	NS
Farm direct payments	€	35,205	31,288	NS	31,312	34,106	NS	31,022	30,306	NS	31,605	32,135	NS
Stocking rate	LU/ha	1.66	1.67	NS	1.61	1.70	***	1.65	1.45	NS	1.63	1.45	NS
Overhead costs	€/LU	272	384	***	251	375	***	249	416	***	273	422	**
Concentrates fed	€/LU	168	190	NS	144	206	***	258	263	NS	226	283	NS
AI expenditure	€/cow[1]	8	16	NS	8	18	*	-	-		-	-	
Gross output	€/LU	992	822	***	981	857	***	1,066	927	**	1,099	927	**
Family farm income	€/ha	704	137	***	709	194	***	752	163	***	814	133	***

[1] per cow or in-calf heifer. Signif levels: *** P < 0.01; *** P < 0.05; * P < 0.10

significant effect on IES. The observed positive relationship of market gross output per LU with efficiency is indicative of either greater genetic merit of cattle or an improved productivity due to superior management relative to the mean. These results were discussed more thoroughly in Finneran and Crosson (2012) and Finneran and Crosson, (2013).

3.2. Comparison of the datasets

A number of sample by year interactions were observed. For example, in the 2010 cattle rearing ePM farm sample, land area farmed was significantly greater on the low IES farms. Farm direct payments were significantly greater on the NFS high IES cattle rearing farms but this was not observed on the ePM farms. However, apart from these exceptions the relationships between the explanatory variables and income efficiency were consistent across the data-sets. This suggests that despite differences in size and sampling procedure (ePM - farmer voluntary unbalanced sample; NFS - a nationally representative balanced sample) the bootstrapping procedure in BEEFMARK generally dealt well with sampling bias.

3.3. Analysis of efficient peers

The most common efficient cattle rearing peer on ePM farms in both 2009 and 2010 was identified and designated "Farm X". Table 5 details the characteristics of Farm X relative to the sample mean and the mean of the inefficient farms in the sample for which Farm X was a peer. It is evident that for most variables Farm X is more similar to the peer mean than the cattle rearing sample mean, as one would expect. However, the variables for which Farm X is different to the peer mean may indicate determinants of efficiency on Farm X. While Farm X is similar to its peers in terms of land area (ha), stock numbers (LU) and stocking rate (LU/ha), it achieved a market gross output (€/LU) three times greater than its inefficient peers. Similarly, Farm X incurred 25% less concentrate feed costs and 50% less overhead costs per LU than its peers. In addition, Farm X included no rental land in contrast with the 18% peer mean.

These efficiency drivers highlighted by the peer analysis had all been previously observed in the whole-sample comparative analysis results (Finneran and Crosson, 2012; Finneran and Crosson, 2013). However, as discussed by Fraser and Cortina (1999), identifying "real world" efficient best-practice farms gives much more weight to the comparative analysis learning experience for farmers than analysis of means of anonymous samples.

Table 5. Characteristics of Farm X, an efficient cattle rearing peer in 2009 relative to the cattle rearing sample mean and the mean of Farm X's inefficient peers

	Farm X	Sample Mean	Difference to sample mean %	Peer Mean	Difference to peer mean %
Income efficiency score	0.79	0.62	+17	0.61	+18
Ha	39	52	-24	35	+13
LU	72	86	-17	61	+16
Stocking rate LU/ha	1.82	1.68	+8	1.78	+2
Gross output €/LU	1108	902	+23	899	+23
Market Gross output €/LU	625	478	+31	447	+40
Gross margin €/ha	666	235	+184	166	+301
Family Farm Income €/ha	1355	437	+210	426	+218
Concentrate feed €/LU	150	180	-17	208	-28
Fertiliser €/LU	44	70	-37	70	-36
Other variable costs €/LU	139	180	-23	179	-22
Overhead costs €/LU	152	315	-52	304	-50
Proportion of land rented	0.00	0.15		0.18	

Ha = hectares, LU = livestock units (1 unit is equivalent to 1 dairy cow)

4. Conclusions

Greater efficiency on Irish beef farms was found to be associated with greater production from pasture and less purchased concentrate feed inputs. This provides a challenge for expanding beef output, given the limited availability of pasture and the decreasing returns to scale observed on larger farms. Market derived gross output (€/LU) was positively associated with farm efficiency while greater overhead and concentrate feed expenditure was negatively associated with income and scale efficiency. The BEEFMARK efficient peer procedure enables efficiency drivers to be observed at the individual farm level and could provide a valuable learning tool for farmers and extension practitioners within beef discussion groups.

5. References

Central Statistics Office, 2012. Labour market report - 2012. CSO, Cork, Ireland.http://www.cso.ie/en/media/csoie/releasespublications/documents/labourmarket/2012/qnhs_q22012.pdf

Charnes A., Cooper W.W., Rhodes E., 1978 Measuring the efficiency of decision making units. *European Journal of Operational Research,* 2**,** 429-444.

Farrell M.J., 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society. Series A (General),* 120**,** 253-290.

Finneran E., Crosson P., 2012. Identifying determinants of efficiency using Data Envelopment Analysis for Irish suckler beef farms. IN STEAD, D. (Ed.) *Agricultural Economics Society of Ireland Annual Meeting.* RDS, Dublin, Ireland.

Finneran E., Crosson P., 2013. Benchmarking scale efficiency of Irish beef farms. IN DISKIN, M. (Ed.) *Agricultural Research Forum.* Tullamore, Ireland, Teagasc.

Fleming E., Farrell T., Villano R., Fleming P., 2006. Is farm benchmarking the new acceptable face of comparative analysis? *Australasian Agribusiness Review,* 14.

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

Fried H.O., Lovell C.A.K., Schmidt S.S., 2008. *The measurement of productive efficiency and productivity growth,* New York, Oxford University Press, USA.

Hennessy T., Kinsella A., Moran B., Quinlan G., 2012. National Farm Survey 2011. Teagasc, Athenry, Ireland.

Latruffe L., Balcombe K., Davidova S., Zawalinska K., 2005. Technical and scale efficiency of crop and livestock farms in Poland: does specialization matter? *Agricultural Economics,* 32**,** 281-296.

McCall D.G., Clark D.A., 1999. Optimized dairy grazing systems in the northeast United States and New Zealand. II. System analysis. *J Dairy Sci,* 82**,** 1808-16.

Millar J., Curtis A., 1997. Moving farmer knowledge beyond the farm gate: An Australian study of farmer knowledge in group learning. *European Journal of Agricultural Education and Extension,* 4**,** 133-142.

Newman C., Matthews A., 2007. Evaluating the Productivity Performance of Agricultural Enterprises in Ireland using a Multiple Output Distance Function Approach. *Journal of Agricultural Economics,* 58**,** 128-151.

Rakipova A.N., Gillespie J.M., Franke D.E., 2003. Determinants of Technical Efficiency in Louisiana Beef Cattle Production. *Journal of the American Society of farm managers and rural appraisers,* 66**,** 99-107.

Shadbolt N.M. 2012. Competitive strategy analysis of NZ pastoral dairy farming systems. *International Journal of Agricultural Management,* 1**,** 19-27.

Sheehy S.J., McAlexander R.H., 1965. Selection of Representative Benchmark Farms for Supply Estimation. *Journal of Farm Economics,* 47**,** 681-695.

Simar L., Wilson P.W., 1998. Sensitivity Analysis of Efficiency Scores: How to Bootstrap in Nonparametric Frontier Models. *Management Science,* 44**,** 49-61.

Tauer L.W., 1993. Short-run and long-run efficiencies of New York dairy farms. *Agricultural and Resource Economics Review,* 22**,** 1-9.

Wilson P.W., 2009. FEAR 1.12 User's Guide. Clemson University, USA.