
Decomposing variation in dairy profitability: the impact of output, inputs, prices, labour and management

P. WILSON

*Agricultural and Environmental Sciences, University of Nottingham, Sutton Bonington Campus,
Loughborough LE12 5RD, UK*

(Revised MS received 30 July 2010; Accepted 6 October 2010; First published online 11 January 2011)

SUMMARY

The UK dairy sector has undergone considerable structural change in recent years, with a decrease in the number of producers accompanied by an increased average herd size and increased concentrate use and milk yields. One of the key drivers to producers remaining in the industry is the profitability of their herds. The current paper adopts a holistic approach to decomposing the variation in dairy profitability through an analysis of net margin data explained by physical input–output measures, milk price variation, labour utilization and managerial behaviours and characteristics. Data are drawn from the Farm Business Survey (FBS) for England in 2007/08 for 228 dairy enterprises. Average yields are 7100 litres/cow/yr, from a herd size of 110 cows that use 0.56 forage ha/cow/yr and 43.2 labour h/cow/yr. An average milk price of 22.57 pence per litre (ppl) produced milk output of £1602/cow/yr, which after accounting for calf sales, herd replacements and quota leasing costs, gave an average dairy output of £1516/cow/yr. After total costs of £1464/cow/yr this left an economic return of £52/cow/yr (0.73 ppl) net margin profit. There is wide variation in performance, with the most profitable (as measured by net margin per cow) quartile of producers achieving 2000 litres/cow/yr more than the least profitable quartile, returning a net margin of £335/cow/yr compared to a loss of £361/cow/yr for the least profitable. The most profitable producers operate larger, higher yielding herds and achieve a greater milk price for their output. In addition, a significantly greater number of the most profitable producers undertake financial benchmarking within their businesses and operate specialist dairy farms. When examining the full data set, the most profitable enterprises included significantly greater numbers of organic producers. The most profitable tend to have a greater reliance on independent technical advice, but this finding is not statistically significant. Decomposing the variation in net margin performance between the most and least profitable groups, an approximate ratio of 65:23:12 is observed for higher yields: lower costs: higher milk price. This result indicates that yield differentials are the key performance driver in dairy profitability. Lower costs per cow are dominated by the significantly lower cost of farmer and spouse labour per cow of the most profitable group, flowing directly from the upper quartile expending 37.7 labour h/cow/yr in comparison with 58.8 h/cow/yr for the lower quartile. The upper quartile's greater milk price is argued to be achieved through contract negotiations and higher milk quality, and this accounts for 0.12 of the variation in net margin performance. The average economic return to the sample of dairy enterprises in this survey year was less than £6000/farm/yr. However, the most profitable quartile returned an average economic return of approximately £50 000 per farm/yr. Structural change in the UK dairy sector is likely to continue with the least profitable and typically smaller dairy enterprises being replaced by a smaller number of expanding dairy production units.

INTRODUCTION

The UK dairy sector has witnessed considerable developments in resource use and output achieved over recent decades. There has been a clear structural trend in the sector, summarized by an increase in average milk yields, increased use of concentrates per cow, reduced cow numbers and substantial reductions in the number of dairy farms (Robertson & Wilson 2009). Arguably the key driver to producers remaining in the dairy sector is the profitability achieved from their herd. While other contemporary analyses have focused upon particular aspects of dairy cow or herd performance, for example the effect of breed and feeding systems on milk yield and related productive performance indicators (e.g. Walsh *et al.* 2008), modelling energy, nutrient and dietary requirements in dairy production (Chaves *et al.* 2006; Tedeschi *et al.* 2008), the effect of extended calving intervals (Arbel *et al.* 2001), examining the influence of human–animal interactions (Bertenshaw & Rowlinson 2009) and labour-use efficiency (Wilson 2009), the current paper adopts a more holistic approach by decomposing the variation in dairy profitability as measured by net margin per cow. Within this analysis, the influence of labour use, managerial factors and the physical input–output relationships of key importance to dairy profitability are examined.

Considerable variation in physical and financial performance has long been noted in agricultural and dairy-specific production systems. Variation in physical labour use across herds from 1947 to 1949 indicated substantial differences in the labour requirement per cow, from 236 h/cow/yr for herds of less than 10 cows, to 135 h/cow/yr for herds of 50 cows and over (Maunder 1951), with clear labour economies of size present as herd size increases. Using dairy production data from 2004 to 2007, Wilson (2009) identified a similar trend in labour economies of size reporting average labour use of 42.5 h/cow/yr, with the most labour efficient group of producers (top 0.25 by labour use efficiency) using 26.7 h/cow/yr (average herd size of 146 cows) and the least labour efficient group using 68.3 h/cow/yr (average herd size of 57 cows). Similar labour economies of size were also noted for the UK by Colman *et al.* (2004) and for Ireland by Gleeson & Kinsella (2003) and O'Brien *et al.* (2007).

Within livestock production systems, the influence of the 'human' factor has been previously examined and noted to influence productive performance. Hence, while measuring physical labour use is of importance, other factors including the link between management, stockmanship and enterprise performance are of potential value to explore. Svennersten-Sjaunja *et al.* (1997) argued that successful management on dairy farms includes the use of daily milk records (rather than monthly) to facilitate enhanced monitoring and management. Huirne *et al.*

(1997) examined management aspects on dairy farms in the Netherlands and note that maximizing annual profit and balancing costs and returns are the two goals that farmers attach the highest importance to. Rougoor *et al.* (1998) concluded that 'More research is needed on management aspects of the farmer: how does a farmer make decisions.' Seabrook (1994) examined the psychological interaction between the milker and the dairy cow noting that 'positive' actions of the stockperson lead to increases in cow performance, a finding reinforced by the analysis of Bertenshaw & Rowlinson (2009). However, Seabrook (2000) noted that enhanced efforts by staff do not lead to enhanced dairy output, although reductions in herd performance are likely to lead to higher levels of dissatisfaction amongst staff. Raussi (2003) reinforced the importance of human–animal interactions and argues that changes in animal husbandry potentially lead to less individual animal attention being provided and that management of animals within groups becomes of importance.

A previous examination of the England and Wales dairy sector (Dawson & Hubbard 1987) focused upon the impact of managerial ability on economies of size. Defining management by the proxy variable of margin over feed and forage per litre, Dawson & Hubbard's empirical analysis of 405 farms (Dawson & Hubbard 1987) identified that better managed farms produce milk at lower average cost and have larger optimal levels of output. Mukhtar & Dawson (1990) noted that costs are reducing and the optimal herd size is increasing over time. A criticism of the approach of Dawson & Hubbard (1987) is that the definition of management is interlinked with performance rather than being exogenous. Outside of the dairy sector, others have sought to address this criticism by seeking to explain variation in efficiency levels by capturing managerial inputs to production through biographical aspects (e.g. age and education) of managers (Wilson *et al.* 1998) and by analysing both biographical aspects and managerial behaviours (e.g. sources of independent advice and business objectives) (Wilson *et al.* 2001). Wilson *et al.* (1998, 2001) identified biographical aspects and managerial behaviours as important drivers in explaining variation in technical efficiency; however, these studies also note that a large amount of variation in performance remains unexplained. Nuthall (2009) explores managerial ability in agricultural production, and from a stratified random survey of 740 farmers, concludes that a farmer's exposure to experiences, management style and early life experiences are important factors in determining ability.

The link between dairy herd size and financial and physical performance has been identified by numerous authors. Colman *et al.* (2004) noted that dairy profitability increases with herd size, flowing from increased concentrate use and higher yields. The stocking rate of

the most profitable producers from the study of Colman *et al.* (2004) indicated that these high performing units operate high-input–high-output production systems. Franks *et al.* (2002), drawing on data from 1996/97 in England and Wales, reinforced the findings of Colman *et al.* (2004), noting not only that there are substantial economies of scale in dairy production but also that many other factors affect the net returns to milk production, in particular the concentrate to milk conversion ratio. Robertson & Wilson (2007, 2008, 2009) in their annual reports on *Dairy Farming in England* provided further contemporary evidence of variation in performance in the dairy sector, finding that greater concentrate use, higher yields and larger herds typify the best performing herds when examined on the basis of gross margin per cow.

While the above notes a number of key drivers in dairy profitability, these studies typically restrict their analysis to particular aspects of milk production, for example labour use efficiency, stockmanship and managerial drivers, influence of herd size, or the link between concentrate use and milk yield. The current study seeks to overcome restrictions of previous research that has focused on particular aspects in isolation, by examining a more complete set of factors within a single analysis. In doing so, the paper explicitly aims to identify the key performance drivers in dairying and, moreover, to quantify the impacts of these performance drivers when analysing the differential between the upper and lower quartile of dairy producers as assessed by net margin per cow performance.

DATA AND METHODOLOGY

From 2004/05 onwards, the English Farm Business Survey (FBS) has collected considerable additional information beyond the core financial and physical farm-level data which lies at its heart. The FBS captures data on owner–occupier, wholly tenanted and partly tenanted farms. In order to ensure that all farms are treated equally with respect to economic analysis of the data, a rental equivalent value is placed on any owned (included mortgaged) land and buildings for that farm, with this rental value reflecting land and building quality, investment and rental values in the area. To ensure that no double counting of costs is incurred in the account, interest charges on borrowed capital are excluded. In addition to imputing a rental value on owned land and buildings, the value of the farmer and spouse manual labour is also imputed to ensure that the value of this input is recognized. Since 2004/05 three main avenues of additional data capture in the FBS have been physical labour use and gross and net margins for the main agricultural enterprises. Capturing net margin per enterprise requires the allocation and apportionment of both variable and

fixed costs, following set methodological approaches. Through the allocation and apportionment of fixed costs to individual enterprises, farms that have a greater capital investment per cow, for example in machinery and equipment (e.g. dairy parlours) would incur greater costs per cow for machinery, other fixed costs and land (incorporating building costs). Hence, where farms have invested heavily in infrastructure to support their dairy enterprise, the FBS methodology will capture this through the annual cost of these depreciating assets. Thus the costs and returns within the FBS provide a full account of the individual farm situation, reflecting land and building quality and investment in machinery and buildings. For the 2007/08 year only, the FBS in England collected data on technical and business management inputs and behaviours alongside more biographical details of the farmers and managers taking part in the FBS. Thus, data for the FBS accounting year 2007/08 for England are available that combines information on input–output relationships, labour use and managerial behaviours and characteristics. The 2007/08 data, while available for only one accounting year, thus represent a uniquely valuable data set with which to study dairy performance using a more holistic approach than has previously been possible. The 2007/08 data contain a large set of 228 observations, and were used as the source of data for the current study. Data are weighted using the ‘standard’ FBS farm weight supplied with the farm level data: post data collection, the FBS sample is compared to population data collected via the June Census Survey of Agricultural production, and individual weights are attributed to farm returns within the FBS to reflect the inverse of the proportion of farms within the FBS sample in comparison with the population data. The FBS weights, when applied to the individual farms, aggregates up the FBS sample to provide a representation of the population. Applying weights to farm level data samples is a recognized methodological approach to provide population representative results (e.g. Colman *et al.* 2004; Robertson & Wilson 2009). The data sample is considered for all (conventional and organic) producers and additionally for the subsample of producers that are conventional dairy farms (199). Average and performance quartiles are produced on the basis of net margin per cow performance where quartile A represents the highest net margin group and quartile D the lowest net margin group. The grouping of producers into net margin performance quartiles permits comparative analysis to be undertaken in groups that are commonly used and understood in both the academic literature (Colman *et al.* 2004) and benchmarking services (RBR 2010). Statistical tests are undertaken across the performance groups to test the null hypothesis that there is no difference in the continuous variables (*t*-tests) and the number of producers classified within particular

Table 1. *Average physical, financial, labour and managerial measures*

Measure	Mean of all farms	s.D.	Mean of conventional	s.D.
Average number of cows	110	75.7	111	77.3
Direct labour (h/cow)	35	14	35	13.8
Contract labour (h/cow)	2	2.8	2	2.8
Overhead labour (h/cow)	6	4.5	6	4.6
Total dairy labour (h/cow)	43	15.8	43	15.9
Forage area (ha/cow)	0.6	0.22	0.6	0.22
Yield (litres/cow)	7095	1423	7176	1391
Milk price (ppl)	22.57	3.10	22.07	2.48
	£/cow	£/cow	£/cow	£/cow
Milk output	1602	371	1590	365
Calves	58	34	58	34
Net herd replacements	-144	104	-143	105
Dairy output	1516	377	1506	371
Concentrates	408	138	405	138
Fodder	27	41	27	42
Vet and med	59	29	60	29
Other livestock costs	126	61	125	62
Seeds	10	9	10	9
Fertilizer	37	21	40	20
Sprays	6	7	6	7
Other variable costs	8	14	8	14
Total variable costs	681	207	681	210
Gross margin	835	279	826	272
Labour (paid for)	182	114	182	115
Contract	66	50	64	50
Total machinery costs	121	60	120	61
Total other fixed costs	116	44	113	42
Total fixed costs exc. land	484	165	479	167
Land	143	43	140	42
Total fixed costs	627	183	619	184
Net Farm Income (NFI) for enterprise	208	242	206	240
Farmer and spouse labour	156	115	153	113
Total costs	1464	327	1453	331
Net margin	52	256	53	263
Age (years)	51	9.8	52	9.7
College or degree qualification	0.48		0.43	
Regularly benchmarks	0.42		0.37	
Independent technical advice	0.43		0.42	
Organic dairy production	0.12		—	
Specialist dairy farms	0.91		0.91	
Lowland farms	0.79		0.77	
No. in sample	228		199	

production groups or managerial characteristics and behaviours (Chi-squared tests).

RESULTS

Table 1 shows the physical, financial, labour and managerial profile of the sample of dairy enterprises for all farms and for the conventional sample presented as a distinct group. Average performance indicates that herd size across the full sample is 110 cows, yielding *c.* 7100 litres/cow/yr, obtaining 22.57

pence per litre (ppl), drawing upon 0.56 ha/cow/yr that use 43.2 h of labour per cow (h/cow/yr); respective results for the conventional sample alone are 111 cows, 7180 litres/cow/yr, 22.07 ppl, 0.55 ha/cow/yr and 42.8 h/cow/yr. Financial dairy output (milk and calf sales adjusted for herd replacements and quota leasing) averages £1516/cow/yr (£1506/cow/yr; conventional results in parentheses), which, after total variable costs of £681/cow/yr (£681/cow/yr), leaves a gross margin of £835/cow/yr (£826/cow/yr). Accounting for total fixed costs of £627/cow/yr

Table 2. *Physical, financial, labour and managerial measures across net margin performance quartiles: all farms*

Measure	Performance quartiles				Statistical significance		
	A	B	C	D	A cf.	B cf.	C cf.
Average number of cows	149	136	95	66	>C, D	>C, D	>D
Direct labour (h/cow)	30.5	31.3	37.2	48.2	<C, D	<C, D	<D
Contract labour (h/cow)	2.6	2.3	2.0	1.2	>D	>D	
Overhead labour (h/cow)	4.6	4.9	7.0	9.4	<C, D	<C, D	<D
Total dairy labour (h/cow)	37.7	38.4	46.2	58.8	<C, D	<C, D	<D
Forage area (ha/cow)	0.52	0.51	0.62	0.67	<C, D	<C, D	
Yield (litres/cow)	7849	7092	6910	5868	>B, C, D	>C, D	>D
Milk price (ppl)	23.60	22.17	21.79	22.40	>B, C		
	£/cow	£/cow	£/cow	£/cow			
Milk output	1845	1573	1503	1314	>B, C, D	>D	>D
Calves	63	52	59	58	>B		
Net herd replacements	-120	-165	-153	-140	<B		
Dairy output	1788	1461	1410	1232	>B, C, D	>C, D	>D
Concentrates	416	401	413	398			
Fodder	25	29	24	31			
Vet and med	59	61	55	59			
Other livestock costs	116	120	128	154	<D	<D	
Seeds	11	10	8	10			
Fertilizer	40	42	35	28	>D	>D	
Sprays	8	6	5	4	>C, D		
Other variable costs	6	7	11	7			
Total variable costs	682	676	679	691			
Gross margin	1107	785	731	540	>B, C, D	>D	>D
Labour (paid for)	194	170	173	195			
Contract	79	64	64	45	>D	>D	>D
Total machinery costs	121	108	128	136		<D	
Total other fixed costs	111	105	122	138	<D	<C, D	
Total fixed costs exc. land	505	446	487	513	>B	<D	
Land	147	145	135	140			
Total fixed costs	652	591	622	654	>B		
NFI for enterprise	455	194	109	-113	>B, C, D	>C, D	>D
Farmer and spouse labour	120	125	184	248	<C, D	<C, D	<D
Total costs	1453	1392	1485	1593		<D	
Net margin	335	69	-75	-361	>B, C, D	>C, D	>D
Age (years)	49.8	51.5	51.8	52.2			
College or degree qualification	0.49	0.51	0.47	0.44	$P=0.893$		
Regularly benchmarks	0.53	0.53	0.33	0.30	$P=0.015$		
Independent technical advice	0.53	0.49	0.37	0.35	$P=0.149$		
Organic dairy production	0.21	0.05	0.07	0.16	$P=0.036$		
Specialist dairy farms	0.98	0.91	0.93	0.83	$P=0.027$		
Lowland farms	0.84	0.81	0.72	0.77	$P=0.427$		
No. in sample	57	57	57	57			

A to D refer to net margin performance quartiles.

(£619/cow/yr), and the value of farmer and spouse labour of £156/cow/yr (£153/cow/yr) leaves a net margin of £52/cow/yr (£53/cow/yr), equating to 0.73 (0.74) ppl. Average farmer age is 51.3 years (51.9 years), with 0.48 (0.43) holding college or degree qualifications, 0.42 (0.37) of producers regularly financially benchmark, and 0.43 (0.42) of farm businesses receive independent technical advice.

Organic producers represent 0.12 of the overall sample, while 0.91 are specialist dairy farms (0.91 for the conventional sample) and 0.79 (0.77) are in the lowlands.

Table 2 compares the quartile groups – the upper quartile (A) represents the highest 0.25 of producers when measured by net margin per cow; quartile B represents the next best performing quartile group,

followed by group C, and group D represents the worst performing quartile group when examined on the basis of net margin per cow. Comparing the upper quartile group (A) with the lower quartile (D) for all the farms in the sample (organic and conventional combined) a number of key differences emerge. Herd size is significantly greater for the upper quartile (149 cows) in comparison with the lower quartile (66 cows), with the upper quartile producing *c.* 2000 litres/cow/yr more than the lower quartile and with significant differences in yields being found across all quartile groups. The upper quartile achieved a significantly greater milk price (23.60 ppl) than groups B and C, but this was not significantly different than the milk price for the lower quartile group D. The upper quartile uses a smaller forage area (0.52 cf. 0.67 ha/cow/yr lower quartile) and the labour input per cow is also lower for the upper quartile (37.7 cf. 58.8 h/cow/yr, respectively). While differences in labour use occur between groups, there is no significant difference in total labour use between quartiles A and B. Concentrate costs are similar and while this suggests that physical concentrate use is not significantly different across quartile groups, the bulk buying nature of concentrate purchasing of larger herds may result in price discounts per tonne. Hence, differences in physical concentrate use may not be statistically insignificant; unfortunately this cannot be explored from the cost data. Despite this similarity, the upper quartile's enhanced yield and better output price leads to dairy output being £556/cow/yr greater than the lower quartile. Note that significant differences in dairy output are observed between all performance quartile groups. Total variable costs are similar between the upper and lower quartiles, with no significant difference in total variable costs being found across these groups. It is instructive to note that total fixed costs are almost identical between the upper and lower quartile groups, and the only significant difference in total fixed costs that are observed are that the upper quartile A has a significantly greater total fixed cost per cow than quartile group B. The difference in net margin observed across the full sample of dairy farms is thus largely driven by the enhanced yield, price premium and differences in the input of farmer and spouse labour per cow. With respect to net margin, the upper quartile generated £335/cow/yr compared with a loss of £361/cow/yr for the lower quartile; significant differences in net margin are recorded across all performance groups. The upper quartile is typically slightly younger than the lower quartile (49.8; cf. 52.2 years lower quartile), albeit that there is no significant difference in average age across the quartile groups. The upper quartile contains a higher proportion of farmers who have obtained a college or degree qualification (0.49; cf. 0.44 lower quartile) although this result is not statistically significant. The largest

managerial difference between the quartiles is observed with respect to financial benchmarking and paying for independent technical advice. Benchmarking occurs on 0.53 of the upper quartile, while 0.53 of this group also pay for independent technical advice; by contrast the results for the lower quartile are 0.30 and 0.35, respectively. There is a significant difference in the number of farms that regularly benchmark, however, there is no significant difference across the quartile groups with respect to the number of farms that obtain independent technical advice. The upper quartile, for the full sample, contains a higher number of organic dairy producers (0.21) cf. 0.16 in the lower quartile (note that B and C both contain substantially lower numbers of organic producers) and this result is statistically significant. The upper quartile also contains a higher number of lowland farms (0.84) and specialist dairy farms (0.98) than the lower quartile with respective results of 0.77 and 0.83; a significant difference in the number of farms classified as specialist dairy farms per quartile group was found, however, there is no significant difference in the number of lowland farms found in each quartile group.

The differences noted above for the combined sample are also observed for the conventional sample considered on its own (Table 3). The difference in herd size between groups A and D is slightly greater than for the combined sample, and the difference in performance between groups with respect to yield, dairy output, gross margin and net margin are also marginally greater for the conventional sample considered alone; the difference in milk price across the performance groups is slightly lower for the conventional sample. While there was no significant difference in the age profile across the full sample of producers, when examining conventional producers, those in the best performing quartile have an average age of 50 years, which is significantly lower than the 54.2 years average for quartile group B. Following the results for the conventional and organic sample combined, when examining the conventional sample alone, there is no significant difference across groups with respect to college or degree qualifications, the use of independent technical advice and the number of farms located within the lowlands. However, as observed for the full sample, there is a significant difference across groups with respect to the number of producers per group that regularly benchmark their performance, and additionally with respect to the number of farms classified as specialist dairy farms.

In addition to analysis per cow, it is also instructive to examine the results for select measures on a per litre basis. Table 4 shows that the average milk price (for the full sample) of 22.57 ppl (22.07 ppl for the conventional sample) varies across performance quartiles, with quartile A receiving the greatest milk price of 23.60 ppl (22.82 ppl) and the remaining quartiles

Table 3. *Physical, financial, labour and managerial measures across net margin performance quartiles: conventional farms*

Measure	Performance quartiles				Statistical significance		
	A	B	C	D	A cf.	B cf.	C cf.
Average number of cows	152	134	100	64	<C, D	>C, D	>D
Direct labour (h/cow)	30	31	37	49	<C, D	<C, D	<D
Contract labour (h/cow)	2.5	2.4	2.1	1.0	<D	<D	
Overhead labour (h/cow)	4.8	4.6	7.1	9.8	<C, D	<C, D	<D
Total dairy labour (h/cow)	37	38	46	60	<C, D	<C, D	<D
Forage area (ha/cow)	0.50	0.50	0.60	0.65	<C, D	<C, D	
Yield (litres/cow)	8017	6971	7020	5979	>B, C, D	>D	>D
Milk price (ppl)	22.8	21.8	21.6	21.6	>B, C		
	£/cow	£/cow	£/cow	£/cow			
Milk output	1831	1523	1519	1302	<B, C, D	>D	>D
Calves	64	50	60	59	>B		
Net herd replacements	-126	-160	-154	-132			
Dairy output	1771	1414	1425	1228	>B, C, D	>D	>D
Concentrates	418	382	427	389			
Fodder	25	30	25	32			
Vet and med	63	59	56	61			
Other livestock costs	118	115	129	155	<D	>D	
Seeds	11	10	8	9			
Fertilizer	43	43	36	32	>D	>D	
Sprays	8	6	5	4	>C, D		
Other variable costs	6	7	12	7			
Total variable costs	692	651	698	689			
Gross margin	1079	763	727	539	>B, C, D	>D	>D
Labour (paid for)	193	163	175	202			
Contract	77	61	66	41	>D	>D	>D
Total machinery costs	119	104	131	136		<C, D	
Total other fixed costs	106	105	122	133	<C, D	<C, D	
Total fixed costs exc. land	495	433	493	511	>B	<D	
Land	144	145	132	135			
Total fixed costs	639	578	626	647	>B, C		
NFI for enterprise	440	184	101	-107	>B, C, D	>C, D	>D
Farmer and spouse labour	119	122	177	248	<D	<C, D	<D
Total costs	1450	1352	1500	1584		<C, D	
Net margin	321	62	-75	-356	>B, C, D	>C, D	>D
Age (years)	50.0	54.2	51.0	52.8	<B		
College or degree qualification	0.42	0.48	0.47	0.36	$P=0.607$		
Regularly benchmarks	0.48	0.48	0.35	0.18	$P=0.005$		
Independent technical advice	0.52	0.48	0.39	0.30	$P=0.114$		
Specialist dairy farms	0.96	0.92	0.94	0.80	$P=0.030$		
Lowland farms	0.82	0.80	0.67	0.78	$P=0.314$		
No. in sample	50	50	49	50			

A to D refer to net margin performance quartiles.

receiving milk prices in the range 21.79–22.40 ppl (21.59–21.84 ppl). Dairy output follows the milk price pattern, equating to 21.36 ppl (20.99 ppl conventional), with quartile A achieving the greatest dairy output of 22.78 ppl (22.09 ppl). Quartile group A records the greatest margin over concentrates of 17.48 ppl (16.88 ppl conventional) and the greatest

gross margin of 14.11 ppl (13.46 ppl). While Tables 2 and 3 demonstrated that costs per cow did not differ substantially across the performance groups, Table 4 shows that total costs per litre are lowest for group A at 18.52 ppl (18.09 ppl conventional) and greatest for group D at 27.14 ppl (26.49 ppl). The higher yields of group A, for both the full sample and the conventional

Table 4. *Price, output, costs and margins (pence per litre) across full samples and net margin performance groups*

Measure	All	A	B	C	D
All farms: conventional and organic					
Milk price (ppl)	22.6	23.6	22.2	21.8	22.4
Dairy output (ppl)	21.4	22.8	20.6	20.4	21.0
Margin over concentrates (ppl)	15.6	17.5	14.9	14.4	14.2
Gross margin (ppl)	11.8	14.1	11.1	10.6	9.2
Total costs (ppl)	20.6	18.5	19.6	21.5	27.1
Net margin (ppl)	0.73	4.26	0.97	-1.09	-6.15
No. in sample	228	57	57	57	57
Conventional farms only					
Milk price (ppl)	22.1	22.8	21.8	21.6	21.6
Dairy output (ppl)	21.0	22.1	20.3	20.3	20.5
Margin over concentrates (ppl)	15.3	16.9	14.8	14.2	14.0
Gross margin (ppl)	11.5	13.5	11.0	10.4	9.0
Total costs (ppl)	20.3	18.1	19.4	21.4	26.5
Net margin (ppl)	0.74	4.00	0.90	-1.07	-5.95
No. in sample	199	50	50	49	50

A to D refer to net margin performance quartiles.

sample, clearly impact on the per litre analysis to generate the lowest total costs per litre. Combining the higher milk price and the lower total costs per litre provides group A producers with an average return of 4.26 ppl (4.00 ppl conventional) net margin. Conversely the average producers in group D returned an economic loss of 6.15 ppl (5.95 ppl). For this particular year, the average milk production net margin was 0.73 ppl. For the average producer with 110 cows yielding just under 7100 litres/cow/yr, this equates to £5700/yr; for the average conventional producer returning 0.74 ppl, the return for the average 111 cow herd yielding 7160 litres is £5880/yr. For the average producer in the most profitable quartile, the economic return per dairy enterprise is approaching £50000/yr.

Because the FBS methodology places all farms on to a rental equivalent basis and to avoid double counting excludes interest charged on borrowed capital, it is additionally instructive to examine if there are differences in the liabilities of farms across the samples, when examining the actual debt levels of farms. Table 5 provides the loan account liabilities (e.g. land and building mortgages) and current liabilities (e.g. bank overdrafts, machinery hire purchase and, creditors) of the business across both the full sample and the conventional sample, together with total liabilities. It is instructive to note that there are no significant differences in loan account, current or total liabilities across the two samples, by performance group.

The results demonstrate considerable variation in net margin performance across the samples considered. Broadly the most profitable producers operate larger, higher yielding herds that also achieve a greater

Table 5. *Per farm loan account, current liabilities and net worth by net margin performance groups*

Measure	A	B	C	D
All farms: conventional and organic				
Loan account (£/farm)	66019	76697	55142	78966
Current liabilities (£/farm)	76682	56587	73568	72697
Total liabilities (£/farm)	142700	133554	128710	151663
No. in sample	57	57	57	57
Conventional farms only				
Loan account (£/farm)	63389	77094	58616	79420
Current liabilities (£/farm)	76386	54930	81282	64911
Total liabilities (£/farm)	139775	132024	139898	144331
No. in sample	50	50	49	50

A to D refer to net margin performance quartiles.

output price for their milk. In contrast to other studies (e.g. Robertson & Wilson 2009) total variable costs and total fixed costs per cow (before farmer and spouse labour) do not vary greatly across the performance quartiles. Also, previous studies have noted that the most profitable tend to incur greater concentrate costs per cow, while for the current sample this does not hold true. Within the full sample,

the proportion of organic producers in the upper quartile includes a greater proportion of organic farms, who achieve significantly higher prices for their milk (Wilson & Darling 2010), more than compensating for the lower yields from organic production. For the full sample, the difference in net margin returns between the upper and lower quartile groups is in the order of £700/cow/yr. At the average milk price for the full sample of 22.57 ppl, the yield differential alone accounts for just under £450 of this net margin differential (*c.* 0.65). The difference in milk price of approximately 1.2 ppl, at the average yield achieved, accounts for a further £85/cow difference (0.12 of net margin differential), with greater total costs per cow for the lower quartile (£140/cow/yr) and greater replacement costs (£20/cow/yr) together accounting for a further £160 differential (0.23 of net margin differential). Hence, on the basis of this large sample of dairy enterprises, and when analysing the determining factors of variation in net margin performance between the upper and lower quartile groups, an approximate ratio of 65:23:12 in yield differential (Y): cost saving differential (C): price differential (P) exists. For the conventional sample the respective YCP net margin decomposition ratio is 66:21:13.

DISCUSSION

Given the differentials in performance noted above, it is instructive to analyse the factors behind these 'key performance drivers' of greater yields, lower costs and higher milk prices. Yield differentials are in large part driven by the genetic ability of the herd, albeit that increased yields are now recognized as being linked to falling reproductive performance (e.g. Sun *et al.* 2009), yet in the current sample, on average, the higher yielding herds incurred the lowest net replacement costs, which account for the purchase price or value of heifers, respectively, bought in/transferred to the dairy herd net of cull sales. Given that the analysis presented herein is on a financial year basis, one potential explanation for the lower net replacement costs per cow (per year) flows from the potentially longer calving intervals on higher yielding herds with cows achieving more days in milk. Arbel *et al.* (2001) found significant financial benefits from extended calving intervals in their examination of high-yielding herds in Israel. However, the economic benefits of extended days in milk crucially depends on the relative difference between extended milk output to delayed calf returns, with shorter calving intervals being beneficial when calf values are high (Weller & Folman 1990). Statistical differences in net herd replacement costs are only observed for the complete sample between quartile groups A and B. Further analysis of the data indicates that while net herd replacements costs for organic farms are marginally

greater than for conventional farms, the variation in herd replacement costs is greater for conventional farms. Hence, the observed significant difference for the full sample flows from the slightly lower overall standard deviation associated with full sample. Milk yields are also influenced by managerial input, behaviours and feeding decisions (Tedeschi *et al.* 2008 – energy and nutrient requirements; Bertenshaw & Rowlinson 2009 – human animal interactions). Yet, while yield differentials are the key determinant to financial performance differentials, they do not explain all variation in net margin performance as noted above. Lower total costs combined with lower replacement costs provided a differential of £160/cow/yr for the full sample. The analysis within Tables 2 and 3 indicates that the majority of this cost differential is accounted for by the extra costs (*c.* £130/cow/yr) of farmer and spouse labour per cow within the lower quartile group; hence the major component of the cost saving achieved by the upper quartile flows from enhanced labour use efficiency, which as demonstrated in Table 2 ranges from 38 h/cow/yr for the upper quartile group to 59 h/cow/yr for the lower quartile group. Approximately 0.12–0.13 of the performance difference is due to a differential in milk price which, while potentially influenced by herd genetics with respect to milk quality, has generally been evidenced as linked to the individual milk selling arrangements negotiated by the producer. Milk selling arrangements in England are constrained in part by the availability of milk buyers in certain areas (Wilson & Darling 2010); however, managerial decisions taken with respect to negotiating milk contract arrangements and effective herd management to achieve higher quality milk are key factors impacting upon the milk price achieved. The above analysis of differentials in net margins between the upper and lower quartile groups indicates that *c.* one-third of the differential is arguably due to managerial input with respect to efficient utilization of labour (largely flowing from the enhanced economies of size that larger herds afford to producers, Wilson 2009) and achieving an enhanced milk price through improved milk quality and/or milk selling arrangements.

Overall, those in the upper quartile are slightly more likely to have obtained a college or degree qualification, and tend to be slightly younger though the impact of age is only significant with respect to the conventional sample between groups A and B. The upper quartile tends to have a much greater reliance on independent technical advice, and additionally a higher proportion of producers in this group undertake financial benchmarking with significant differences in the number of producers that regularly benchmark being observed across quartile groups. This level of management input arguably indicates that enhanced specialisation in dairying, concurrent with appropriate business support mechanisms, are

important for achieving profitable results. Substantial labour economies of size are present as shown by the upper quartile, with their typically larger herds, expending considerably less labour hours per cow than the lower quartile, and within this total labour utilization, the upper quartile tend to have a greater proportional reliance on contract labour.

The link between herd size, milk yield, milk price obtained, the use of financial benchmarking and the economies of size achieved with respect to the utilization of labour, suggest that the dairy industry in England will continue to undergo structural change with a smaller number of larger herds taking the place of a larger number of smaller herds. The analysis of Mukhtar & Dawson (1990) found that the cost curve in dairy production was moving out and to the right over time, indicating a shift towards larger herds operating at lower costs per litre of milk. On the basis of the factors that determine the variation in profitability from the current study, it is likely that this trend will continue, as has already been observed in previous contemporary studies of the sector (e.g. Robertson & Wilson 2009).

CONCLUSION

Variation in agricultural and dairy-specific production systems has long been observed in agricultural science disciplines. Previous studies have tended to focus on specific aspects of dairy performance, while the current paper has taken a more holistic approach, decomposing the variation in dairy profitability through an analysis of scale, yield, input use, labour utilization and managerial aspects. The current study has shown that the wide variation in performance

groups in the English dairy sector is largely accounted for by enhanced yields, lower labour use per cow and greater milk price achieved. A Y:C:P ratio of *c.* 65:23:12 has been found, and this provides dairy farmers and dairy advisors with evidence-based advice for focusing attention on particular aspects of their dairy enterprise. There is a clear trend that larger herds typically achieve higher yields, a greater milk price, are more efficient in their utilization of labour, are likely to be more specialized and additionally undertake financial benchmarking. This analysis has drawn on a unique data set for a single year which provides the range of factors examined in the current paper. The 2007/08 year was not atypical for dairying in the UK; however, it would have been beneficial to have a full set of information across more years, for a consistent grouping of producers, in order to test the robustness of these findings using a panel data approach. Future research could also seek to expand on the aspects identified in this paper by considering particular sub-groups of the data, for example, considering only lowland conventional producers, or examining the influence of biographical factors and managerial behaviours within particular herd size categories. The on-going structural change in the dairy sector looks set to continue, and the analysis presented above identifies the characteristics of those producers most likely to remain in dairy production.

Funding from the Agricultural Manpower Society is gratefully acknowledged. The co-operation of all farmers who took part in the Farm Business Survey is also acknowledged. Thanks are also due to the constructive comments from two anonymous referees.

REFERENCES

- ARBEL, R., BIGUN, Y., EZRA, E., STURMAN, H. & HOJMAN, D. (2001). The effect of extended calving intervals in high lactating cows on milk production and profitability. *Journal of Dairy Science* **84**, 600–608.
- BERTENHAW, C. & ROWLINSON, P. (2009). Exploring stock managers' perceptions of the human-animal relationship on dairy farms and an association with milk production. *Anthozoos* **22**, 59–69.
- CHAVES, A. V., BROOKES, I. M., WAGHORN, G. C., WOODWARD, S. L. & BURKE, J. L. (2006). Evaluation of cornell net carbohydrate and protein system predictions of milk production, intake and liveweight change of grazing dairy cows fed contrast silages. *Journal of Agricultural Science, Cambridge* **144**, 85–91.
- COLMAN, D., FARRAR, J. & ZHUANG, Y. (2004). *Economics of Milk Production in England and Wales 2002/03*. Special Studies in Agricultural Economics, No. 58. Manchester, UK: The University of Manchester.
- DAWSON, P. J. & HUBBARD, L. J. (1987). Management and size economies in the England and Wales dairy sector. *Journal of Agricultural Economics* **38**, 27–38.
- FRANKS, J. R., CAIN, P. J. & FARRAR, J. (2002). Economic efficiency in milk production: scale and non-scale effects. *Farm Management* **11**, 243–268.
- GLEESON, D. & KINSELLA, K. (2003). Factors affecting future expansion on small-scale dairy farms in Ireland. *Rural Management and Human Resources* **3**, 17–30.
- HUIRNE, R. B. M., HARSH, S. B. & DIJKHUIZEN, A. A. (1997). Critical success factors and information needs on dairy farms: the farmer's opinion. *Livestock Production Science* **48**, 229–238.
- MAUNDER, A. H. (1951). Labour in milk production. *Farm Economist* **6**, 304–307.
- MUKHTAR, S. M. & DAWSON, P. J. (1990). Herd size and unit costs of production in the England and Wales dairy sector. *Journal of Agricultural Economics* **41**, 9–20.
- NUTHALL, P. (2009). Modelling the origins of managerial ability in agricultural production. *Australian Journal of Agricultural and Resource Economics* **53**, 413–436.
- O'BRIEN, B., GLEESON, D., RUANE, D. J., KINSELLA, J. & O'DONOVAN, K. (2007). Profile of labour demand,

- resources and contribution on Irish dairy farms. *Journal of Rural Enterprise and Management* **3**, 33–44.
- RAUSSI, S. (2003). Human-cattle interactions in group housing. *Applied Animal Behaviour Science* **80**, 245–262.
- RBR (2010). *Rural Business Research, Farm Business Survey, Farm Benchmarking*. Cambridge, UK: University of Cambridge. Available online at <http://www.farmbusinesssurvey.co.uk/benchmarking/> (verified 11 November 2010).
- ROBERTSON, P. & WILSON, P. (2007). *Farm Business Survey 2005/2006: Dairy Farming in England*. London: HMSO. Available online at <http://www.ruralbusinessresearch.co.uk/> under RBR Publications; Farm Business Survey 2005/06 – Reports from RBR Units (verified 11 November 2010).
- ROBERTSON, P. & WILSON, P. (2008). *Farm Business Survey 2006/2007: Dairy Farming in England*. London: HMSO. Available online at <http://www.ruralbusinessresearch.co.uk/> under RBR Publications; Farm Business Survey 2006/07 – Reports from RBR Units (verified 11 November 2010).
- ROBERTSON, P. & WILSON, P. (2009). *Farm Business Survey 2007/2008: Dairy Farming in England*. London: HMSO. Available online at <http://www.ruralbusinessresearch.co.uk/> under RBR Publications; Farm Business Survey 2007/08 – Reports from RBR Units (verified 11 November 2010).
- ROUGOOR, C. W., TRIP, G., HUIRNE, R. B. M. & RENKEMA, J. A. (1998). How to define and study farmers' management capacity: theory and use in agricultural economics. *Agricultural Economics* **18**, 261–272.
- SEABROOK, M. F. (1994). Psychological interaction between the milker and the dairy cow. In *Dairy Systems for the 21st Century* (Ed. R. Bucklin), pp. 49–58. St. Joseph, MI: American Society of Agricultural Engineers.
- SEABROOK, M. F. (2000). Behavioural choices and productivity of dairy stockpersons – a pilot study. *Rural Management and Human Resources* **2**, 16–23.
- SUN, C., MADSEN, P., NIELSEN, U. S., ZHANG, Y., LUND, M. S. & SU, G. (2009). Comparison between a sire model and an animal model for genetic evaluation of fertility traits in Danish Holstein population. *Journal of Dairy Science* **92**, 4063–4071.
- SVENNERSTEN-SJAUNJA, K., SJAUNJA, L.-O., BERTILSSON, J. & WIKTORSSON, H. (1997). Use of regular milking records versus daily records for nutrition and other kinds of management. *Livestock Production Science* **48**, 167–174.
- TEDESCHI, L. O., CHALUPA, W., JANCZEWSKI, E., FOX, D. G., SNIFFEN, C., MUNSON, R., KONONOFF, P. J. & BOSTON, R. (2008). Evaluation and application of the CPM dairy nutrition model. *Journal of Agricultural Science, Cambridge* **146**, 171–182.
- WALSH, S., BUCKLEY, F., PIERCE, K., BYRNE, N., PATTON, J. & DILLON, P. (2008). Effects of breed and feeding system on milk production, body weight, body condition score, reproductive performance, and postpartum ovarian function. *Journal of Dairy Science* **91**, 4401–4413.
- WELLER, J. I. & FOLMAN, Y. (1990). Effects of calf value and reproductive management on optimum days to first breeding. *Journal of Dairy Science* **73**, 1318–1326.
- WILSON, P. (2009). *Analysis of Labour Usage Data from the Farm Business Survey 2004/05 to 2007/08*. Report submitted to DEFRA Agricultural Market Economics Division, December 2009. London: DEFRA. Available online at <http://www.ruralbusinessresearch.co.uk/> under RBR Publications; Technical Reports (verified 11 November 2010).
- WILSON, P. & DARLING, R. (2010). *Analysis of Milk Selling Arrangements on Dairy Farms in England 2008/09*. Report submitted to DEFRA Agricultural Market Economics Division, April 2010. London: DEFRA. Available online at <http://www.ruralbusinessresearch.co.uk/> under RBR Publications; Technical Reports (verified 23 November 2010).
- WILSON, P., HADLEY, D., RAMSDEN, S. & KALTSAS, I. (1998). Measuring and explaining technical efficiency in UK potato production. *Journal of Agricultural Economics* **49**, 294–305.
- WILSON, P., HADLEY, D. & ASBY, C. (2001). The influence of management characteristics on the technical efficiency of wheat farmers in eastern England. *Agricultural Economics* **24**, 329–338.