LABOUR PRODUCTIVITY – EFFECTS OF SCALE, CAPITAL INVESTMENT AND ADOPTION OF NOVEL TECHNOLOGY

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Abstract

This study investigated interrelationships among labour-use, scale of dairy enterprise, replacement of labour with capital investment, introduction of alternative management technologies and net farm profitability on a sample of Irish dairy farms. Farm labour input data were collected from 171 full-time dairy farmers, over a 2-year period. The farms were grouped into three categories; < 50 cows (small), 50-80 cows (medium) and > 80 cows (large). Financial analysis of the farms was carried out using the Moorepark Dairy Systems Model. Milking labour input data was recorded for both conventional and rotary parlours and a cost benefit analysis was conducted. The effect of altering milking frequency from twice a day (TAD) to once a day (OAD) over a full lactation was also examined from both productive and economic viewpoints. Small, medium and large farms had an average dairy labour input of 49.7, 42.2 and 29.3 h/cow/yr. Benefits of larger scale were reflected in terms of a reduced portion of total costs represented by labour (31%, 29% and 24%). Partial replacement of milking labour with a rotary milking parlour was economically viable for a herd size of 350 cows and OAD milking which reduced labour considerably reduced income by just €4,500. Thus, there is a critical need to accelerate a scale increase in dairy operations from the current average of 51 cows and to introduce investments and technology that would improve labour efficiency.

Keywords: capital investment on-farm, farm scale, labour replacement, labour requirement, milking frequency

Introduction

The Dairy industry continues to be one of the most important enterprises in Irish Agriculture, both as a significant contributor the economy (26% of Agri-Food Exports and 31% of Agricultural Output) (DAFRD, 2005) and as a source of income to 23,000 farm households. However, dairy farmers will need to increase the scale of their operation to compensate for the effects of both a downward pressure on milk price and the effect of inflation on farm incomes. However, expansion in scale of enterprise would have a direct and significant effect on farm labour as a component input requirement of production. While there are indications that increased scale of enterprise may lead to improved labour efficiency, it may also lead to an increase in absolute labour demand. Maximising labour efficiency will mean the use of reduced levels of labour in a more productive manner.

The hypothesis posed in this study was that labour efficiency on Irish farms (and thus, farm profitability) may be increased by two strategies, (i) increasing the scale of the dairy enterprise and (ii) reducing labour demand by either capital investment, such as a rotary milking parlour in place of a conventional parlour or the introduction of a technology, such as once a day (OAD) milking. To test this hypothesis, it was necessary to focus on the following specific objectives:
To quantify the annual labour input per cow, relating to a range of dairy farm tasks, across a range of herd sizes

To measure the milking performance and labour input associated with different milking parlour types

To test the OAD milking concept from a production perspective

To establish farm financial indicators for the different scenarios of enterprise scale, capital investment and OAD milking technology, based on the labour data from the on-farm labour study.

Materials and Methods

Quantification of labour input on-farm

One hundred and forty three full-time dairy farmers mainly in the Munster region of Ireland participated in the study. The labour study involved the recording of labour input data for various defined farm duties across a range of different task categories. Data were collected over a two-year period between February 2000 and January 2002. Participant farmers recorded labour input on consecutive 3 or 5-day periods once per month on either timesheets or electronic data loggers. The 29 farm duties for which time (labour input) was recorded were classified into 10 task categories. These task categories were Milking, Management, Maintenance, Grassland, Cow care, Calf care, Cleaning, Veterinary and Miscellaneous. The herds were grouped as follows; small (<50 cows) medium (50-80 cows) and large (>80 cows) for data analysis, and had average herd sizes of 42, 59 and 141, respectively.

Generation of farm financial indicators

The Moorepark Dairy Systems Model (MDSM) (Shalloo et al., 2004) provided the mechanism by which the labour data could be analysed economically. This is a stochastic budgetary simulation model (formulated within a Microsoft Excel sheet) of a dairy production system. The labour data for each of the three herd size categories, recorded in this trial were integrated into the MDSM and farm profitability was determined for the three different scales of dairy enterprises. Key assumptions of the MDSM include: Gross milk price (c/kg) = 22.5; Fat price (c/kg) = 274.3; Protein price (c/kg) = 547.4; Price ratio, protein to fat = 2:1; Quota lease price (c/l) = 9.8; Replacement heifer price (€) = 1,397; Cull cow price (€) = 270 (basic); Labour costs (€/month) = 1,905; Concentrate cost (€/tonne) = 190.

Feasibility of capital investment in milking facilities

Work routine times (WRTs) were recorded for different milking activities in conventional swing-over parlour, using a hand-held data logger (Armstrong and Quick, 1986). WRTs associated with cow preparation were also recorded and milking performance observed on four commercial farm milking facilities with rotary milking parlours. The WRT elements recorded were as follows: cow entry and exit; washing and drying of teats; drawing of foremilk; dry wiping of teats; changing of clusters and disinfection of teats. The WRTs recorded for different cow preparation procedures were subsequently used to calculate optimum milking performance (cows/h), using the formula: $60/WRT = 60/UT*n$ (UT = unit time; n= number of units). The milking performance data was then used to calculate the milking labour input data for full and minimal preparation in conventional and rotary parlours.

The milking labour input data for the conventional and rotary parlours was used in conjunction with the MDSM to carry out a cost benefit analysis on both parlour types.
The following assumptions were used in the cost benefit analysis:

Difference in cost of conventional and rotary milking units €150,000
20-unit conventional = €200,000; 46-unit rotary = €350,000

Loan borrowed over 15 years @ 5 %,

Asset depreciated against profits @ 5 %

Capital allowance against tax = (6 years x 15 %) + (1 year x 10 %)

Discount rate = 3.0 % p.a.

Labour requirement (h/cow/yr)	Rotary	Conventional
Full preparation	26.3	29.3
Minimal preparation	25.3	27.3

Once a day milking technology

Sixty spring-calving multiparous Holstein-Friesian cows were assigned after calving to four treatments in a 2x2 factorial design: Twice a day (TAD) milking on a high or low nutritional level; once a day (OAD) milking on a high or low nutritional level. Nutritional level was defined by concentrate offered (420 and 135kg) and post-grazing height (75 and 55mm). Mean calving date for all cows was 11th March. Individual cow milk yield, milk composition, somatic cell count (SCC), cow live-weight (LWT) and body condition score (BCS) was recorded over two complete lactations.

Economic analysis was carried out on the production data generated from this trial using the MDSM and farm profitability was determined for the TAD and OAD milking frequencies at both the high and low nutritional levels.

Results

Effect of scale of enterprise on farm financial indicators

Labour input on-farm

Average annual total dairy labour input per cow was 41.4 h (SD ±14.2) for an average herd size of 77.4 cows and a milk quota of 388 x10^3 litres. Average annual dairy labour input (h) per cow for combined and specific dairy task categories on farms of three different herd-size groups is shown in Table 1. Annual dairy labour input per cow declined ($P<0.001$) with increasing herd-size group. Annual labour inputs per cow for milking, maintenance, management, grassland, cow care, calf care and cleaning were reduced ($P<0.05$) with increasing herd-size group. No significant differences ($P>0.05$) were found between herd-size groups with regard to annual labour inputs per cow for veterinary and miscellaneous.

Table 1: Average annual dairy labour input (h) per cow for combined and specific dairy task categories on farms of three different herd-sizes

	Herd-size group				
	Small (n=51)	Medium (n=78)	Large (n=42)	sem	Significance
Total dairy labour	49.8^{a}	42.2^{b}	29.3^{c}	1.64	***
Milking	17.4^{a}	13.7^{b}	8.9^{c}	0.42	***
Maintenance	8.5^{a}	6.8^{ab}	5.3^{b}	0.76	*
Grassland	6.3^{a}	5.1^{b}	3.2^{c}	0.31	***
Management	5.0^{a}	5.0^{a}	3.5^{b}	0.38	*
Cow care	4.5^{a}	4.8^{a}	3.2^{b}	0.29	***
Calf care	3.1^{a}	2.6^{a}	2.1^{b}	0.18	**
Cleaning	2.8^{a}	2.1^{b}	1.3^{c}	0.19	***
Veterinary	1.7^{a}	1.5^{a}	1.2^{a}	0.13	NS
Miscellaneous	0.5^{a}	0.6^{a}	0.6^{a}	0.11	NS

^{abc} Means within a row with different superscripts differ significantly; * P<0.05; ** P<0.01; *** P<0.001; NS=non-significant; n = number of farms.

Farm financial data

Effect of scale on selected dairy farm output variables for small, medium and large dairy enterprises is shown in Table 2. Benefits of larger scale are reflected in the number of hours per cow per year required to manage the farm business. This is then converted into the observed benefit of greater return to labour input, as evidenced by proportionally reduced overall labour cost and reduced portion of total costs represented by labour (30.7%, 28.7% and 24.3%) with increasing herd size.

Table 2: Effect of scale on selected dairy farm output variables for small, medium and large dairy enterprises

Variable Measured	Small	Medium	Large
Milk Price (c/l)	24.02	24.02	24.02
Farm size (ha)	19.13	24.00	60.37
Quota size (litres)	236,000	296,000	745,000
Milk Yield per cow (l/cow)	5,300	5,300	5,300
No. Cows Milking	45.28	56.80	142.96
Stocking rate (L.U/ha)	2.62	2.62	2.62
Labour Units	1.12	1.19	2.14
Hours/cow/year	49.87	42.25	30.3
Milk Produced (kg)	240,030	301,055	757,722
Total Reciepts (€)	78,754	98,776	248,610
Variable Costs (€)	29,582	37,901	93,375
Fixed Costs (€)	41,892	45,393	81,650
Depreciation Charges (€)	11,823	13,523	26,240
Total Costs (€)	83,298	96,007	201,266
Net Farm Profit (€)	-4,544	2,975	73,308
Margin Per Cow (€)	-100	49.21	334
Margin per adj. ha	-96	48	320
Margin per L milk (c/L)	-1.89	0.93	6.29
Labour Costs (€)	25,543	27,143	48,988
Labour as % of total costs	30.66%	28.27%	24.34%

Feasibility of capital investment in milking facilities

Milking performance in conventional and rotary milking parlours

Optimum milking performance (cows milked/h) and milking labour input (h/cow/year) for minimal and complete cow preparation in conventional and rotary milking parlours are shown in Table 4. The data indicated that optimum milking achieved in a conventional parlour, by one operator was 120 and 86 cows per hour, when minimal (pre-milking) and full cow preparation practices (washing + pre-milking + drying) were employed, respectively. Alternatively, optimum milking achieved in a rotary parlour, by one operator was 200 and 150 cows per hour when minimal and full cow preparation was employed, respectively. The resulting milking labour input for minimal and complete cow preparation in conventional and rotary parlours was 5.1, 7.1, 3.1 and 4.1 h/c/yr, respectively. It was assumed that the 29.3 h/c/yr dairy labour input incorporated time associated with full cow preparation in a conventional parlour. This dairy labour input level was adjusted to account for minimal preparation in a conventional parlour and full and minimal preparation in a rotary parlour. Thus, dairy labour input levels of 27.3, 29.3, 25.3 and 26.3 h/c/yr were calculated for minimal and complete cow preparation in conventional and rotary parlours, respectively.

Table 3: Optimum milking performance (cows milked/h) and milking labour input (h/c/yr) for minimal and complete cow preparation in conventional and rotary milking parlours

	Conventional swing-over parlour		Rotary milking parlour	
	Pre-milking only, wrt*=0.5 min	Full preparation, wrt*=0.7 min	Pre-milking only, wrt*=0.25 min	Full preparation, wrt*=0.33 min
Optimum unit number	20	15	46	36
Optimum milking performance (cows/h)	120	86	200	150
Milking labour input (h/c/yr)	5.1	7.1	3.1	4.1

*wrt= time associated with all elements of the milking procedure for each cow
Optimum milking performance was used to calculate milking labour input

Cost benefit analysis of conventional and rotary milking parlours

The labour and the cost data included in the MDSM were analysed using economic indicators for herd sizes ranging from 200 to 600 cows. The total discounted farm profit after tax and the discounted cash flow were used to determine the interaction of type of parlour and herd size. The after-tax farm profitability was higher for the conventional parlour compared to the rotary parlour for both minimal and full cow preparation, for up to 350 dairy cows (Table 4). For herd sizes of 350 and greater, the rotary parlour was more profitable for full preparation. The rotary parlour was more profitable for minimal preparation when herd sizes increased to 450 cows. While profit is an important indicator of farm performance, it should not be taken in isolation from cash flow when farm investments are being analysed. Cash flow followed a similar trend to farm profit over the 10-year period, with a higher cash flow associated with the rotary compared to the conventional parlour, with full cow preparation when herd size was greater than 400 cows (Table 5).

Table 4. The sum of 10 years of farm profit after tax, inflation adjusted

Cow Numbers	**200**	**250**	**300**	**350**	**400**	**450**	**500**	**550**	**600**
Rotary full preparation	496,380	624,924	779,041	932,913	1,086,495	2,790,875	1,392,786	1,559,540	1,697,864
Rotary minimal preparation	505,652	635,756	792,077	948,137	1,103,891	2,838,897	1,414,543	1,585,500	1,724,037
Conventional full preparation	517,106	637,257	782,164	926,780	1,071,108	2,742,828	1,358,899	1,516,391	1,645,537
Conventional minimal preparation	540,801	665,022	815,480	965,649	1,115,531	2,838,578	1,414,411	1,579,509	1,714,044

Table 5: The sum of 10 years of cash flow, inflation adjusted

Cow Numbers	**200**	**250**	**300**	**350**	**400**	**450**	**500**	**550**	**600**
Rotary full preparation	708,012	977,608	1,247,351	1,516,608	1,785,364	2,053,626	2,321,390	2,536,277	2,855,427
Rotary minimal preparation	722,349	999,871	1,269,847	1,542,854	1,815,361	2,087,372	2,358,883	2,629,903	2,900,523
Conventional full preparation	768,352	1,026,479	1,276,625	1,529,923	1,782,729	2,035,034	2,286,843	2,538,155	2,788,973
Conventional minimal preparation	806,828	1,074,479	1,334,102	1,596,942	1,859,320	2,121,201	2,832,583	2,643,469	2,903,858

Once a day milking technology

Cow production characteristics of TAD and OAD milking frequencies

The effect of TAD and OAD milking frequencies at high and low nutritional levels on cow production and milk quality is shown in Table 6. OAD milking in association with a low nutritional plane reduced milk yield and yield of milk solids (MS) ($P<0.001$) compared to TAD milking and a high nutritional plane, respectively. Fat and protein contents of milk were increased ($P<0.001$) with OAD compared to TAD milking. Fat content was not affected by nutritional level, but protein content was reduced ($P<0.05$) at the low compared to the high nutritional level.

Table 6: Effect of milking frequency (MF) and nutritional level (NL) on mean cow milk production, live-weight (LWT), body condition score (BCS) and milk SCC

	Milking frequency (MF)		Nutritional level (NL)		sem	Sig. MF	Sig. NL
	TAD	OAD	High	Low			
Milk yield (kg/cow)	6013	4437	5669	4780	156.1	***	***
Milk solids yield (kg/cow)	437.0	351.1	428.8	359.4	11.50	***	***
Fat (g/100g)	3.99	4.40	4.17	4.22	0.061	***	NS
Protein (g/100g)	3.29	3.53	3.46	3.36	0.029	***	*
Lactose (g/100g)	4.55	4.52	4.55	4.52	0.034	NS	NS
LWT at 275 DIM[1] (kg)	627	678	680	624	10.9	**	***
BCS at 275 DIM	2.73	3.49	3.31	2.92	0.076	***	***
SCS (SCC Log_{10})	4.77	4.82	4.64	4.94	0.077	NS	**

*** = P<0.001, ** = P<0.01, * = P<0.05, NS = P>0.05

Financial analysis of TAD and OAD milking frequencies

The effect of TAD and OAD milking frequencies at high and low nutritional levels on cow production and milk quality is shown in Table 7. The number of cows required to produce the same EU fat adjusted milk quota in the TAD high nutritional level group was increased from 76 to 94, 95 and 111 for the OAD high, TAD low and OAD low treatments, respectively. Milk price was higher for the OAD milked groups due to higher milk constituents, however, milk sales were reduced compared to TAD groups. Farm profit was reduced for OAD compared to TAD groups by €4,205 and €4,630 at the high and low nutritional levels, respectively.

Table7. Effect of milking frequency (MF) and nutritional level (NL) on farm financial indicators

Cow number	TAD High 76	OAD High 94	TAD Low 95	OAD Low 111
Milk price c/l	23.7	25.9	23.4	26.7
S.R. Lu/ha	2.34	2.57	2.55	2.66
Milk sales kg	439,737	408,744	443,200	388,232
Milk Returns €	104,216	105,648	103,822	103,716
Total Costs €	121,732	136,492	139,355	152,278
Labour Costs €	34,651	34,156	39,233	38,256
Farm profit €	17,338	13,133	7,842	3,212

Discussion

Economics of on-farm labour

The total dairy farm labour input in this study, measured at 41 h per cow for an average herd-size of 77 cows, compared favourably with the 54 h per cow recorded on Irish farms of a similar herd-size by O'Shea et al. (1988), indicating an increase in labour efficiency of 23 % over a 12-year period. The observed labour input per cow when linked to herd size was 1.7 times greater on farms of less than 50 cows than on farms of over 80 cows and is consistent with the findings of Hadley et al., 2002 where increasing herd sizes resulted in improved labour efficiency. Total dairy labour input of 49.7, 42.2 and 29.3 h/cow/year was measured on small, medium and large farms in this study, respectively. These annual hours per cow convert into 37.3, 44.0 and 63.5 cows per labour unit (LU) on small, medium and large herd size groups, respectively (assuming that 1848 h/annum [40 h/week] equates to one LU or one full-time farm operator). This is substantially less than the 150 cows typically managed by one LU on New Zealand dairy systems (New Zealand Dairy Board, 1996). The reduced labour input per cow on New Zealand farms may be due to larger herd size, and better facilities and layout relevant to tasks, such as milking and grassland and fewer tasks to be conducted per day. Labour costs account for more than 20% of total operating costs in Australia (Davies et al., 1999) while labour costs as a proportion of total costs recorded in the current study were 31, 28 and 24 % on small, medium and large farms, respectively. The results from the Bega Dairy Farm Benchmarking study indicate that tight control of overheads, labour costs and the ability to spread fixed costs over a larger milk output, represented the crucial difference between high and low profit farms (McKerrow, 1997).

A very significant improvement in efficiency with increased scale was evident in this study. The 3.2 fold increase in cow numbers was associated with a 1.9 fold increase in total labour costs. Additionally, even though the absolute total cost of labour was higher for the large herds, labour as a percentage of total costs was substantially lower (by approximately 6 percentage points for the large compared to the small enterprises). A further factor in the evaluation of the merits of herd expansion is the final profitability of the farm. Profitability in terms of cent per litre is the most important parameter to consider within a quota limiting scenario. In the current study, net farm profit was 4.3 times greater for the large compared to the small herd size. This is a consequence of the lower cost of labour associated with large (6.47 c/l) compared to the small herd size (10.64 c/l). Thus, when production is limited by quota, labour input has a very significant effect on farm profit.

Dairy farmers are currently facing a future of great uncertainty due to the fundamental reforms for milk policy with the EU Dairy farmers that opt to remain at their original scale can expect a large reduction (approximately 30% in real terms) in income (Shalloo et al., 2004). At the present time, it is considered that a herd of 100 cows is required even to maintain real income in the future Irish context (Hennessey and Thorne, 2006). Taking full employment of a farm operator as 1848 h/annum (40 h/week), the 29 h/cow labour input shown in the large herds in this study has to be considerably reduced such that, 100 cow herds may be managed by one operator. On larger farms, also, it must be ensured that it is labour efficiency rather than labour resources that is increased. Maintaining herd sizes large enough to obtain economies of scale while using capital resources efficiently will be vital in order to create a vibrant industry.

Capital substitution

It is anticipated that through the relaxation of milk quota policies across Europe, milk production from dairy farms will increase, which prompts the question as to what type of investments should be made on these farms in order to reduce overall labour requirements. Given that labour input is such a significant factor in influencing farm profit, and the fact that the milking process consumes the largest proportion (approximately 34%) of total dairy labour input on-farm, it is reasonable to consider that automation of some or all of the milking process could be potentially beneficial. The primary benefit associated with a rotary parlour compared to a conventional, swing-over parlour would be the reduction in labour and associated labour cost for milking. The results of the current study have indicated that when both the labour requirement and the initial cost of both parlour types were evaluated, the conventional parlour was financially advisable for herds of up to 350 cows, whereas, the rotary parlour was financially prudent for herds of greater than 350 cows. The greatest disadvantage of the rotary parlour is the high capital cost compared to the conventional milking system. The economic indicators showed that decision-making regarding milking parlour type (conventional versus rotary) on Irish dairy farms should depend largely on the size of the dairy operation, but it would also be influenced by changes in the initial capital cost, interest rates and cost of labour. From a non-economic perspective, the unavailability of skilled labour or the preferred management of a rotary parlour by an owner/operator could also be important.

Once a day milking

Potential benefits from OAD milking include increased labour productivity, reduced milking parlour expenses and improved lifestyle for farm families and staff, as observed by Clarke et al. (2006). These potential benefits may also apply in Ireland together with the increased opportunity to engage in additional employment to improve family farm income (FFI). The Irish OAD study has shown reductions of 26 % and 20 % in milk yield/cow and MS/cow, respectively, with OAD compared to TAD milking (O'Brien et al., 2005). There are at least three different dairy farm scenarios within which OAD milking may represent a feasible management tool in reducing the constraint of milking and developing other opportunities on the farm. The economic indicators developed in the current study firstly showed that the reduced yield associated with OAD may be partially compensated by increased cow numbers, assuming land is not limiting. In this scenario, herd size was increased while maintaining similar labour levels and OAD milking resulted in some loss in income, but increased flexibility with regard to time and labour within the system. If a low cost building approach was used to accommodate the extra cows, then profitability would be more favourable for OAD milking. Secondly, OAD milking, while retaining a similar herd size to the TAD milking regime would result in significantly reduced milk receipts. However, this option would allow flexibility to explore the possibility of carrying out some degree of alternative enterprise on or off-farm. This additional income would partially compensate for the income loss from OAD and would positively contribute to FFI. Thirdly, the extra time saved with OAD milking may be spent as leisure time.

Milking OAD will only suit the goals of some dairy farmers. The decision to change from TAD to OAD milking requires a calculation of the trade-off between economic and lifestyle goals.

Conclusion

The first part of the hypothesis posed at the commencement of the study, that labour efficiency may be increased by increasing scale of enterprise has been proven. The large compared to the smaller scale enterprises had lower labour input levels/unit of production and subsequently resulted in increased profitability. The second part of the hypothesis, that labour demand could be reduced by capital investment or introduction of a new technology was also proven. However, the application of economic parameters associated with each of these scenarios meant that (a) partial replacement of milking labour with a rotary milking parlour was only economically viable when herd size was greater than 350 cows. It also meant that (b) a reduction in milking labour by an OAD milking regime would be associated with some reduction in income and would therefore only be suitable for some dairy farm situations.

In conclusion, rapid and ongoing improvements in labour efficiency on Irish spring dairy farms will be critical for the viability of many farm businesses over the next few years. Thus, there is a critical need to accelerate a scale increase in dairy operations from the current average of 51 cows in order to compensate for the projected drop in milk price and to introduce investments that would improve labour efficiency. However, when farmers are attempting to reduce the costs of production, either by reducing labour or increasing enterprise size with the same labour, this objective should be approached in a manner that will not jeopardize management and erode much of the potential benefits associated with lower labour costs/unit of output.

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