What Can ARMS Tell Us About Scale Economies in Dairy Farming?

The ARMS dairy versions provide detailed data for large samples of dairy farms of widely ranging sizes. The data collected offer a powerful resource for analyzing dairy farm costs. Although there have been other studies of dairy production costs, we focus on ARMS-based studies because the data are recent and they encompass large samples across a wide range of farm sizes and locations. Two approaches have been applied to ARMS data: dairy enterprise cost-of-production (COP) accounting and econometric estimates of dairy cost functions.

Cost-of-Production Accounting

COP accounts use detailed data on farm inputs and outputs, drawn from ARMS and external sources, to build estimates of total costs of production and gross returns. ERS develops cost and return estimates for several commodities. This report presents estimates of mean costs and net returns for 4 farm size classes in 2000, based on a sample of 819 farms (table 3), and for 6 farm size classes in 2005, based on a sample of 1,462 farms (table 4). Estimates are expressed in dollars per hundredweight (cwt) of milk produced. More COP documentation is provided on the ERS website, at www.ers.usda.gov/Data/ARMS/CostOverview.htm.

In 2000, mean costs of production fell as enterprise size increased (table 3). For example, average total costs on farms with at least 500 milk cows ($12.39 per cwt) were 18 percent below average total costs on farms with 200–499 cows, a sizeable advantage. Costs were much higher for farms with fewer than 200 milk cows. Thus, there may be important economies of scale in dairy production. Estimated "ownership costs" (particularly for housing, milking facilities, and machinery) fall sharply as farm size increases, suggesting that larger enterprises use their equipment and structures more intensively. Labor costs per cwt of milk also fall quite sharply. Finally, feed costs account for a large share of total costs across farm sizes, but appear not to be a source of substantial scale economies, as average feed costs did not fall sharply with size.[7]

COP estimates for 2005 cover a wider range of size classes, with the largest class in the 2000 data, 500 or more cows, split into two. Average costs of production still fall as herd size increases, and the differences are large. Farms with 1,000 or more cows realized average costs 15.4 percent below those in the next smaller class (500–999 cows) and 24 percent below farms with 200–499 cows. Costs at smaller operations are considerably higher (table 4).

The 2005 data also reveal some sources of cost advantage. Overhead expenses, particularly those associated with capital recovery and with the operators' unpaid labor, still fall sharply as herd size increases. But note that average operating costs also fall noticeably at larger sizes, and the largest farms seem to incur lower total feed costs (purchased plus homegrown plus grazed), per cwt of milk produced, than small operations.[8]

[7]The costs shown here, drawn from the dairy COP estimates at the ERS website, exceed those reported in Short (2004), who also used the 2000 ARMS dairy version. Short excluded several implicit costs—those associated with unpaid labor provided by the operator and the operator's family, farm overhead, and the value of the enterprise's land that is used to support the dairy enterprise (she includes implicit capital costs). Including these implicit costs raises the cost estimates more for smaller than for larger enterprises, so the scale economies apparent in table 3 are much larger than those in Short (2004).

[8]Feed accounts for large shares of total costs at dairy farms, ranging from 30 percent of total costs in the smallest class to 55 percent in the largest. Increases in feed prices, such as those resulting from increased ethanol-based demand for corn, have substantial effects on costs. Hired labor, often from Mexico and Central America, accounts for 10–12 percent of total costs at larger farms.

Table 3

Dairy costs of production, by herd size, 2000

	Enterprise size (number of milk cows)			
	<50	50-199	200-499	>499
Mean herd size (*milk cows)*	33	88	313	955
Output per cow *(pounds*)	14,932	16,157	17,420	17,326
	Dollars per hundredweight			
Total operating costs	11.61	9.75	8.49	8.63
All feed	8.16	6.54	5.83	6.17
Total labor costs	11.90	6.04	2.77	1.86
Hired labor	0.32	1.01	1.45	1.41
Unpaid labor	11.58	5.03	1.32	0.45
Total ownership costs	6.88	5.08	3.89	1.90
Housing facilities	1.57	1.31	1.14	0.48
Milking facilities	1.33	0.66	0.10	0.06
Machinery	2.26	1.43	0.54	0.26
Total costs	30.39	20.87	15.15	12.39
Gross value of production	15.74	14.68	14.06	13.41
Net returns	-14.65	-6.19	-1.10	1.02

Source: ERS estimates, at www.ers.usda.gov/data/arms/CostOverview.htm
Herd size refers to all dairy cows on an enterprise, including dry cows but excluding calves, heifers, and bulls. Gross value of production for the dairy enterprise includes milk, cull cattle sales, and other revenue generated by the dairy enterprise. Net returns are the difference between gross value of production and total costs.

Table 4

Dairy costs of production, by herd size, 2005

	Enterprise size (number of milk cows)					
	<50	50-99	100-199	200-499	500-999	>999
Mean herd size	35	69	133	295	666	2083
Output per cow (lbs)	15,055	17,149	18,228	19,487	20,719	20,195
	Dollars per hundredweight					
Total operating costs	12.30	12.94	11.51	11.31	11.07	9.74
Purchased feed	3.60	3.75	4.12	5.00	5.64	5.99
Homegrown feed	5.02	5.07	4.06	3.01	2.58	1.47
Grazed feed	0.41	0.15	0.11	0.10	0.02	0.01
Allocated overhead	17.79	12.56	9.31	6.61	5.00	3.85
Hired labor	0.50	0.80	1.34	1.84	1.80	1.61
Unpaid labor	10.60	6.10	3.13	1.34	0.54	0.17
Capital recovery	5.26	4.56	3.89	2.55	2.03	1.66
Total costs	30.09	25.50	20.82	17.92	16.07	13.59
Gross value of prod.	17.87	17.56	17.20	17.25	16.56	16.54
Net returns	-12.22	-7.94	-3.62	-0.67	0.49	2.95

Source: ERS estimates, at www.ers.usda.gov/data/arms/CostOverview.htm
Herd size refers to all dairy cows on an enterprise, including dry cows but excluding calves, heifers, and bulls. Gross value of production for the dairy enterprise includes milk, cull cattle sales, and other revenue generated by the dairy enterprise. Net returns are the difference between gross value of production and total costs. Organic operations are excluded.

Net Returns

The gross value of production generated by the dairy enterprise includes payments from milk production, from sales of dairy animals, and from other sources (such as leasing of animals or space, dairy co-op patronage dividends, or the value of manure produced). Net returns are the difference between the gross value of production and total costs. Enterprises with positive net returns cover all costs, including costs of capital recovery.

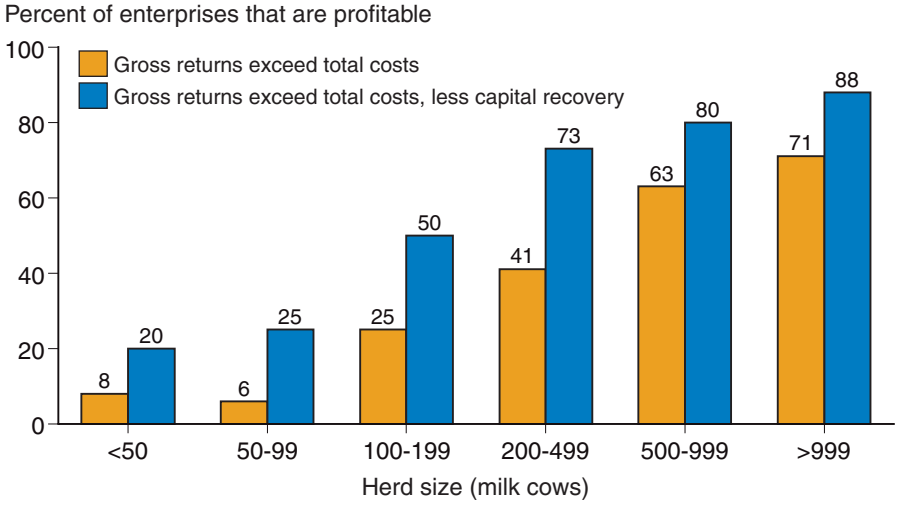
Farms with at least 500 cows had positive net returns, on average, in 2000, while the three smaller classes had negative net returns (table 3). In 2005, farms with 500–999 cows had net returns of 50 cents per cwt of milk, while farms with at least 999 cows had net returns of nearly $3 per cwt; the smaller classes again had negative net returns.

The estimates of net returns are based on national averages, and there is often a wide variation around average performance in agriculture. Some small operations may be exceptionally well-managed, while others may have below-average input prices or above-average product prices. As a result, even though small farms show losses on average, some can be quite profitable. For example, farms with 100-199 head had average net returns of -$3.62/cwt in 2005, but 25 percent of them realized positive net returns, with the gross value of production exceeding total costs, including the opportunity costs of capital and operators' labor (fig. 3). Six percent of farms with 50–99 head earned positive net returns, as did 41 percent of farms in the 200–499 class.

Net returns drive entry and expansion decisions: farmers are unlikely to commit capital and labor to new projects that are unlikely to cover the costs of those decisions. But farms that are already in business and are considering whether to continue operating make another judgement. Those operators have already committed their equipment and structures, and that sunk capital may be an opportunity cost that is virtually zero—the salvage value. Capital

Figure 3

Profitable dairy enterprises were more common among large farms in 2005



Source: ERS estimates, from 2005 ARMS dairy version.

recovery costs may, therefore, be irrelevant to the decision to continue operating. What matters in that case is not whether gross returns exceed total costs, but whether gross returns exceed the farm's operating costs, plus the opportunity costs of the operator household's labor.

To get at that measure, the share of farms whose gross returns exceed all costs except for capital recovery must be calculated. Fifty percent of farms with 100–199 cows meet that standard for profits, as do 25 percent of those with 50–99 cows and 73 percent of those with 200–499 cows (fig. 3). These farms will likely continue to operate because they cover their immediate costs, including the opportunity costs of operator labor.[9]

A substantial share of smaller dairy farms seems to earn enough from operations to keep operating, and in some cases to be quite profitable. But, on average, farms in smaller size classes are not covering the opportunity costs of their investment in capital and the operator's time. Correspondingly, large dairy farms are returning profits in excess of the owners' time and capital costs. The differences in estimated returns mirror the changes in structure—production is shifting away from smaller farms, toward much larger dairy farms. Because many existing smaller operations are economically viable and will remain so for a long time, structural changes will play out over an extended period of time.

Looking to the Future: Expected Structural Changes

The data show wide disparities in net returns across farm size classes, suggesting that structural shifts toward large operations will likely continue. We can use ARMS data to develop a forward-looking analysis of survival expectations among existing farms, as a check on the net returns findings. The 2000 and 2005 ARMS dairy versions asked respondents for the number of years that they expected their present operation to continue producing milk.[10]

Exit expectations have a strong inverse association with herd size. In the 2000 survey, over 30 percent of operators with under 100 cows expected their operation to end milk production by 2005, and over 50 percent by 2010.[11] By contrast, less than 4 percent of operators in the largest size class (500 or more cows) expected their operations to end milk production by 2005, and about 15 percent by 2010 (table 5).

The 2005 responses show the same strong inverse relationship. Nearly 36 percent of operations in the smallest size class, and over 25 percent in the 50–99 head class, expected to end milk production by 2010, with much higher shares expected to leave by 2015. In contrast, only 7 percent of the largest operations expected to close by 2010. The largest class is open-ended (1,000 or more head), and exit expectations are inversely related to size within the class as well, with exit expectations concentrated among operations with less than 2,000 head (28 percent of operations with 1,000–1,999 head expect to close by 2015, compared to 10 percent of those with 2,000 or more). The survey responses support the implications for structural change based on costs and returns—while many small dairy farms are economically

[9]However, if capital is not replaced, then the costs of maintaining it are likely to increase over time, leading to higher operating costs.

[10]Respondents could choose among six answers: less than a year, and 1, 2–5, 6–10, 11–19, and more than 20 years. The question emphasizes the operation instead of the operator, so transfer of the operation from father to son would not elicit a shutdown response.

[11]Cow inventories among farms with less than 100 cows actually fell by 26 percent between 2000 and 2005. That number reflects exit by farms operating in 2000 and entry by new farms.

Table 5
Prospective exit by dairy farms

Herd size	Sample observations	Percent of operations ending production: Within 5 years	Within 10 years
2000 ARMS			
1-49	54	39.0	59.0
50-99	416	30.7	57.0
100-199	186	21.4	47.0
200-499	87	13.9	35.2
>499	76	3.7	15.5
2005 ARMS			
1-49	164	35.5	69.5
50-99	289	26.1	48.2
100-199	347	18.5	43.1
200-499	336	10.3	29.3
500-999	179	8.2	20.7
>999	147	7.4	22.0

Source: Agricultural Resource Management Survey (ARMS), 2000 and 2005 dairy versions. Tabulation of responses to the question "How many more years do you expect this operation to continue producing milk?" Respondents chose among less than 1 year, 1 year, 2-5 years, 6-10 years, 11-19 years, and 20 or more years. Organic operations are excluded.

viable and will remain in business, many others will exit, and production will continue to shift to large farms.

Milk prices can fluctuate sharply. The average farm-level milk price in 2005 was $15.14 per hundredweight. Prices fell to $12.90 in 2006 before rising to hit $20 in June 2007. In turn, this year's sharp price increases were driven by increased world demand for dry dairy products, lowered production subsidies in some countries, and ethanol-fueled increases in feed prices. At the prices realized in summer 2007, more small and midsized dairies will be financially viable. But milk demand and milk prices will continue to fluctuate, and the cost relationships outlined here have not been fundamentally altered. Larger operations still have substantial cost advantages, and shifts of production to larger operations will place downward pressure on industrywide costs and prices, thus offsetting some of the impact of any long-term increases in feed expenses.

Behind Net Returns: Revenues and Farm Size

The prices that farmers receive for their milk vary by region and are higher in those regions with more small operations. For example, milk prices ranged from around $14.00 per cwt in California and Idaho, where production is concentrated in large farms, to $15.60 in Wisconsin, $15.90 in New York, and $16.90 in Pennsylvania, where small farms still predominate (using 2005 USDA/NASS data on average annual prices received, for all milk). Revenues from milk sales account for most of the gross value of dairy production—89 percent, on average, across all 2005 sample farms—with revenues from the sale of dairy animals accounting for most of the remainder. Hence, the gross value of dairy production varies systematically across size classes, with smaller operations holding an advantage.

While milk prices tend to be higher in regions with smaller dairies, the variation in prices received across regions is far lower than the variation in costs across farms of different sizes. As a result, the price advantage that small farms gain by operating in Pennsylvania or Wisconsin will rarely be enough to offset their cost disadvantages. In addition, large dairy farms that locate in regions with higher prices can gain that revenue advantage and still realize scale economies. While the pattern of prices may have allowed some small and midsize producers to stay in operation longer, size-related price and revenue differences are much smaller than the cost differences that appear to be driving structural change.

Gross value of production does not include government payments. The 2002 farm bill introduced countercyclical payments under the Milk Income Loss Contract (MILC) program; farmers could receive direct payments in months when market prices fell below a target level. Specifically, the payments were equal to 45 percent of the difference between $16.45 and the reference market price for milk (the Federal Milk Marketing Order Class 1 price at Boston), when the reference price was lower. The program expired in September 2005, and was extended by Congress for 2 years, with payments reduced to 34 percent of the difference between the target and reference prices.

Payments are restricted to the first 2.4 million pounds of production on a farm. While farms of all sizes are eligible for payments, total annual payments are capped at the amount that would be provided to a producer with a herd of about 120 cows (at 2006 average milk yields). MILC payments therefore provide substantially more support, as a proportion of gross receipts, to smaller operations.[12] Payment rates on eligible production have ranged as high as $1.82 per cwt (in April 2003), but remained at zero for most of 2005, as the reference price remained above the target. While government payments under the MILC program are concentrated on small dairy operations, net returns at most small dairies remain negative even after accounting for MILC payments.

Because many small dairy farms operate near the margin of viability, enhanced revenues—from higher product prices, countercyclical support, or value-added activities such as agri-tourism or cheese-making—may sustain these operations. Other small operations may be able to adopt production technologies, such as managed grazing, that lead to lower gross returns, but substantially lower costs. Still others have turned to organic production, which offers higher milk prices (along with higher feed costs). Regardless, continued shifts of production to larger enterprises will place downward pressure on conventional milk production costs and prices, and that will impose powerful competitive pressures on small operations and on alternative products and production technologies.

Behind Net Returns: Estimates of Unpaid Labor Expenses

One major component of the small farm cost disadvantage is the opportunity cost of unpaid labor provided by operators and their families (table 4), which forms a much higher share of total costs in small farms than in large. Because our estimates of unpaid labor expenses loom large in cost differences, we examine the estimates more closely.

[12]The Government also sets a support price for milk. However, the support price has generally remained below market prices in recent years and, since it applies to all producers, it does not favor smaller operators. See Miller and Blayney (2006) and U.S. Department of Agriculture (2004) for analyses of dairy pricing and policy.

Unpaid labor expenses reflect the amount of unpaid labor provided, and the implicit opportunity cost of that labor. The ARMS questionnaire obtains information on unpaid hours provided by the principal operator, other operators, family members, and others. Total unpaid hours do not vary greatly with herd size and, as a result, unpaid hours per cwt of milk produced fall sharply as the volume of milk produced on the farm increases (table 6).

The opportunity cost of unpaid labor is based on the off-farm labor earnings of all farm households (El-Osta and Ahearn, 1996). Version 1 of the ARMS ascertains annual hours worked off-farm, and off-farm wages and salaries earned, by responding principal operators and their spouses. ERS analysts then use statistical regression analyses to identify how hourly off-farm earnings for all farm operator households vary, for operators and for spouses, by age, education, and location.[13] The results can then be used to estimate the off-farm wages that dairy operators and spouses—with specified age, education, and location characteristics—gave up by working on the dairy enterprise instead of off the farm.[14]

Estimated opportunity costs of off-farm labor varied across dairy farms in the 2005 survey, depending on location, the shares of total unpaid hours provided by operators and by spouses, and their ages and education. The mean off-farm hourly wage applied to dairy enterprises was estimated to be $17.58 per hour, and it varied from $15.08 at the 10th percentile (10 percent of farms had lower values) to $20.74 at the 90th percentile. It also varied systematically across farm sizes, from a mean of $16.85 among farms in the smallest size class to $20.55 in the largest class (table 6). Even though the estimated opportunity cost of unpaid labor was higher in the larger farms, the cost of unpaid labor per cwt of milk produced was much higher at smaller farms because they use much more unpaid labor per cwt.

Small farm production costs look more competitive with large farms if the opportunity cost of unpaid labor is ignored, if the earnings that unpaid labor could have obtained off the farm are lower, or if lower unpaid hours are reported. In turn, some small dairy operators may continue to operate, even at an estimated loss, because they are willing to accept less than they can earn in nonfarm employment. However, even with substantial changes in the estimated opportunity costs of off-farm labor, small dairy farms' costs would still, on average, be well above large farm costs and fall well below small farm revenues. For example, suppose

[13]The analysis also accounts for the decision to work off the farm, thus taking account of the additional information that can be obtained by including those who do not work off the farm.

[14]Some unpaid labor hours are provided by family members who are under 16. ERS values the opportunity cost of their labor at the minimum wage in their State.

Table 6
Drivers of unpaid labor expenses, 2005

	Enterprise size (number of milk cows)					
	<50	50-99	100-199	200-499	500-999	>999
	Annual means, by size class					
Production (*cwt*)	5,213	11,828	24,218	57,539	138,071	420,665
Unpaid hours						
Principal operator	2,376	3,095	3,124	3,111	3,150	2,987
All	3,339	4,190	4,372	4,111	3,742	3,450
Hours/cwt	0.64	0.35	0.18	0.07	0.03	0.008
Mean hourly wage (*$*)	16.85	17.50	17.58	18.89	19.53	20.55

Sources: Production and hours, as reported in Agricultural Resource Management Survey, 2005, version 4 (dairy). Mean hourly wage, imputed by ERS on the basis of statistical analysis of off-farm earnings reported in 2005 ARMS, version 1. Organic operations are excluded.

the average opportunity cost of labor were to fall to $10 an hour, well below the estimate of $17.50 for farms in the 50–99 size class. Unpaid labor expenses would fall to $3.49 per hundredweight, from $6.11, and total costs would fall to $22.97, still above the average gross value of production of $17.80 for farms in this size class, and far above large farm costs of $13.60.

How Does Structural Change Affect Industrywide Costs?

Shifts to larger enterprises, by allowing for scale economies, lower average dairy production costs. We can estimate the impact of recent structural change on industrywide costs by averaging the cost estimates for enterprises in different size classes (table 4), using weights drawn from the 2000 and 2006 size distribution of U.S. milk production (shown in table 1). We first calculate a weighted-average COP, using table 4 total cost estimates and weights reflecting the distribution of production in 2000, of $19.83/cwt. If we then recalculate using weights reflecting the 2006 distribution of production, the weighted-average COP falls 8 percent to $18.24. Many factors affect actual costs of production, but this is a sizeable impact in a short span of time. The longer run impacts of structural change could be quite substantial.