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Profits, Costs, and the Changing Structure of Dairy Farming

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Profits, Costs, and the Changing Structure of Dairy Farming

James M. MacDonald, Erik J. O'Donoghue, William D. McBride, Richard F. Nehring, Carmen L. Sandretto, and Roberto Mosheim

Abstract

U.S. dairy production is consolidating into fewer but larger farms. This report uses data from several USDA surveys to detail that consolidation and to analyze the financial drivers of consolidation. Specifically, larger farms realize lower production costs. Although small dairy farms realize higher revenue per hundredweight of milk sold, the cost advantages of larger size allow large farms to be profitable, on average, even while most small farms are unable to earn enough to replace their capital. Further survey evidence, as well as the financial data, suggest that consolidation is likely to continue.

Keywords: Dairy farming, economies of scale, economies of size, dairy farm structure, milk costs

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Summary

Dairy farming in the United States is undergoing dramatic changes, driven by both supply and demand factors. Consumption is shifting from fluid milk, generally produced for local markets, toward manufactured products, such as cheese, and dairy-based ingredients produced for national and global markets. Innovations in breeding and feeding systems have led to large increases in the amount of milk that a cow produces. Milk production is shifting toward Western States such as California, Idaho, and New Mexico, and to much larger farms. The number of dairy farms with fewer than 200 cows is shrinking, while the number of very large operations, with 2,000 or more cows, doubled between 2000 and 2006.

What Is the Issue?

Large dairy farms first emerged in the Western States, but are now appearing in traditional dairy States as well. This report documents shifts in the location and size of dairy farms and takes a look at what those changes may mean. If the shift in farm size reflects economies of scale in dairy production—that is, lower costs on larger farms—then increasing farm size also enables milk to be produced with fewer resources, thereby reducing prices to consumers. However, the shifts also concentrate animal wastes from manure onto a much smaller land base and may exacerbate pollution associated with concentrated livestock production.

What Did the Study Find?

Large dairy enterprises generate returns that, on average, well exceed their full costs. At the same time, smaller dairy farms mostly incur economic losses—the value of their production does not exceed full costs, including the costs of capital and time committed by their owners. Large farms incur much lower costs, on average, than smaller farms, and these advantages accrue across a wide range of sizes. Costs per hundredweight of milk produced fall by nearly half as herd size increases from fewer than 50 head to 500 head, and continue to fall, but less sharply, at even larger herd sizes.

Dairy investment decisions are consistent with the financial evidence. Farms with fewer than 200 cows accounted for over two-thirds of the nationwide inventory of cows in 1992. By 2006, their share of the nationwide inventory had dropped to 38 percent. Meanwhile, farms with at least 1,000 head of dairy cows are growing more prevalent. They accounted for less than 10 percent of inventory in 1992 but more than a third by 2006. Structural shifts are evident among the largest farms, too. During the 1990s, farms with 1,000–3,000 head were adding the most capacity, but capacity additions have since shifted to even larger farms, with 3,000–10,000 head.

Some small dairy farms are profitable, and others continue to earn enough to remain in operation. As a result, structural change is likely for the foreseeable future, with a continuing decline, rather than a sudden disappearance, of small and midsize dairy operations. The ongoing structural changes will continue to place downward pressure on milk prices.

Excess nutrient applications, which arise from animal manure and can cause water and air pollution, appear to be intensified on larger operations. But their production cost advantages still outweigh the likely additional costs of manure treatment and removal, and it is unlikely that manure management regulations will reverse the ongoing patterns of structural change.

How Was the Study Conducted?

Confidential farm-level records from successive censuses of agriculture (1992, 1997, and 2002) were used to depict changes in the location and size distribution of dairy farms. More aggregated public information on the size distribution of dairy farms is drawn from annual dairy surveys carried out by USDA's National Agricultural Statistics Service (NASS).

Additional farm-level data come from the annual Agricultural Resource Management Survey (ARMS), administered jointly by the Economic Research Service (ERS) and NASS. Dairy farms in major milk-production States were targeted with commodity-specific ARMS versions covering operations during 2000 and 2005. These surveys provide detailed information for analyses of costs, manure management practices, and operator expectations for survival. Data from successive years of version 1 of the ARMS are used to develop measures of potential excess nutrient production on dairy operations.

This study focuses on conventional dairy production, and does not assess costs and farm sizes among organic dairy operations, a rapidly growing but still small segment of the industry. The 2005 ARMS dairy version contains comprehensive information on a sample of organic producers, and other research projects are analyzing those data.

Introduction

Dairy farming in the United States is undergoing dramatic changes, driven by both supply and demand factors. Consumption is shifting from fluid milk, generally produced for local markets, toward manufactured products, such as cheese, and dairy-based ingredients produced for national and global markets. Innovations in breeding and feeding systems have led to large increases in the amount of milk that a cow produces. The location of milk production is shifting toward Western States such as California, Idaho and New Mexico. Finally, production is shifting to much larger farms. The number of dairy farms with fewer than 200 cows is shrinking rapidly while very large operations, with 1,000 to 30,000 cows on one site, account for rapidly growing shares of production. Large dairy farms first emerged in the Western States, but are now appearing in traditional dairy States as well.

Earlier Economic Research Service (ERS) and USDA studies document the broad patterns of structural change in the dairy sector (Blayney, 2002; Miller and Blayney, 2006; U.S. Department of Agriculture, 2004). This report focuses on issues surrounding the growing size of dairy operations and the closely linked factor of location. The increasing share of larger farms suggests that they have cost advantages over small operations, but the size of such advantages, and the range of herd sizes over which they apply, is uncertain. Knowledge of each dimension of scale economies is crucial to understanding the structural changes in the industry. Finally, the report evaluates the links among dairy farm consolidation, concentration of cow manure, and manure management strategies and regulations.

This report focuses primarily on conventional (nonorganic) dairy farms. Although our analysis of farm size and locations covers all dairy farms, the cost structure of organic farms is sufficiently different from conventional operations as to require a separate cost analysis.

Changes in the Size and Location of U.S. Dairy Farms

The emergence of large dairy farms, and the continued shift of production toward such farms, is the principal focus of our analysis. We also touch on geographic shifts in production, a closely intertwined component of structural change.

Between 1970 and 2006, the number of farms with dairy cows fell steadily and sharply, from 648,000 operations in 1970 to 75,000 in 2006, or 88 percent (fig. 1). Total dairy cows fell from 12 million in 1970 to 9.1 million in 2006, so the average herd size rose from just 19 cows per farm in 1970 to 120 cows in 2006.[1] Moreover, because milk production per cow doubled between 1970 and 2006 (from 9,751 to 19,951 pounds per year), total milk production rose, and average milk production per farm increased twelvefold.

These changes reflect a trend toward greater specialization as well as greater size. However, like much of agriculture, dairy farms come in a wide range of sizes. The largest U.S. dairy farms have over 15,000 cows, though farms with 1,000–5,000 cows are more common. Large dairy farms account for most inventory and production in Western States, and a growing share of production elsewhere.

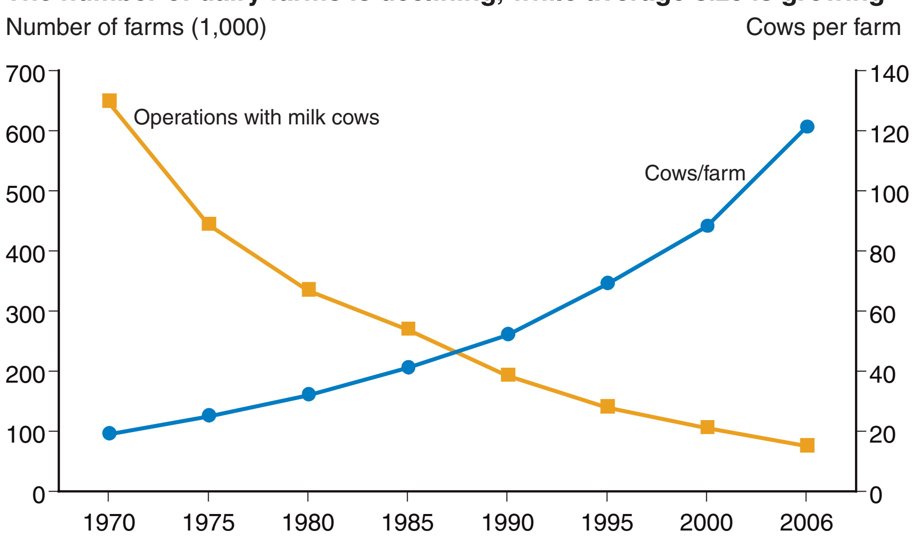
The smallest class of dairy farms (fewer than 30 cows) still accounted for nearly 30 percent of all operations with milk cows in 2006, but had only 2 percent of all cows and provided just over 1 percent of total dairy production (table 1). Such farms, which frequently combine a very small dairy enterprise with other commodity enterprises or with off-farm work, are disappearing rapidly.

The next three size classes (30–200 cows) tend to specialize in dairying. These classes are also in sharp decline, with farm numbers falling by 30 percent between 2000 and 2006 (table 1). Production is shifting to farms with

[1]Dairy enterprises have calves and heifers, which are not yet ready to give milk; they may have bulls; and they have milk cows, which have given birth to calves. At any time, some fraction of a farm's milk cows are dry, usually in preparation for calving. Unless otherwise noted, herd sizes in this report refer to the number of milk cows on a farm, including dry milk cows.

Figure 1

The number of dairy farms is declining, while average size is growing



Source: USDA, NASS.

Table 1

Changes in the size structure of U.S. dairy farms, 2000-2006

Herd size	Number of operations		% change	Percent of inventory		Percent of production	
No. Head	2000	2006		2000	2006	2000	2006
1-29	30,810	21,280	-31.0	2.9	1.9	1.8	1.2
30-49	22,110	14,145	-36.0	9.1	6.0	7.7	4.9
50-99	31,360	22,215	-29.2	22.0	16.3	19.4	14.3
100-199	12,865	9,780	-24.0	18.0	14.1	17.3	13.0
200-499	5,350	4,577	-14.4	16.7	15.0	18.0	15.0
500-999	1,700	1,700	0	12.0	12.6	13.7	14.3
1,000-1,999	695	870	+25.2	10.1	12.5	11.6	13.9
2,000+	280	573	+104.6	9.2	21.6	10.5	23.4
Total	105,170	75,140	-25.5	100.0	100.0	100.0	100.0

Source: USDA, NASS *Milk Production*, Feb. issue (through 2004); USDA, NASS *Farms, Land in Farms and Livestock Operations* (after 2004). Herd size refers to all dairy cows on an enterprise, including dry cows but excluding calves, heifers, and bulls.

at least 500 cows, with the most striking changes occurring in dairies with at least 2,000 milk cows. The number of farms in this largest size class more than doubled between 2000 and 2006, as did its shares of cow inventory and total milk production.

Large and small dairy farms are organized in fundamentally different ways (Short, 2004; Sumner and Wolf, 2002). Large farms usually purchase significant amounts of feed and contract with other operations to raise their heifers offsite. Small farms grow more of their own feed and raise their heifers onsite. Large operations tend to confine their milk cows in large barns or in drylot feedyards, while small operations may graze their cows on pasture. Most labor on small dairy farms is provided by the operator and the operator's family, whereas large farms rely extensively on hired labor (although they are usually family-owned and operated).

Changes in the location of milk production are closely intertwined with changes in farm size. In table 2, production and structure indicators are reported for each of the 16 largest dairy States, which together account for 83 percent of U.S. milk production. For each State, we report milk production and the share of a State's production in small (fewer than 100 cows) and large (500 or more cows) farms.[2] Production data are for 1994, 2000, and 2006 (the most recent available) and structure indicators are for 2000 and 2006.

[2]The largest class in State-level data covers farms with 500 or more cows.

Large farms dominate in California, the Nation's largest milk-producing State. Farms with at least 500 cows accounted for 88 percent of California's production in 2006, and production there grew by more than half between 1994 and 2006, as the State's share of national production rose from 16 to 21 percent (table 2). Other States in the West and Southwest show similar patterns—substantial growth in production and a concentration in large dairy farms.

Milk production in traditional dairy States in the Northeast, Eastern Corn Belt, and Upper Midwest comes more from small dairies than from large. Although the three regions together maintained stable milk production volumes in 1994–2006, their share of national production fell by 4.5 percentage points.

Table 2
Milk production and farm structure in major dairy States

State	Production			Herd size <100 head		Herd size >499 head	
	1994	2000	2006	2000	2006	2000	2006
	(Billion pounds)			(Percent of State production)			
Northeast	24.0	25.5	25.3	46.5	38.9	10.4	21.3
NY	11.4	11.9	12.0	34.0	28.5	16.0	31.0
PA	10.2	10.9	10.7	63.0	53.0	3.0	10.0
VT	2.4	2.7	2.6	35.0	26.0	16.0	29.0
E. Corn Belt	12.3	12.8	15.3	39.9	28.4	13.1	31.2
IN	2.3	2.6	3.3	51.0	29.0	10.0	43.0
MI	5.5	5.9	7.1	28.0	18.0	20.0	39.0
OH	4.5	4.3	4.9	49.5	36.0	5.5	23.0
Upper Midwest	31.7	31.0	31.8	56.7	48.2	8.9	15.6
MN	9.3	8.8	8.4	59.5	47.5	8.5	17.5
WI	22.4	22.2	23.4	56.0	45.0	9.0	19.0
Southwest	11.6	13.6	17.8	2.8	1.6	78.2	87.3
NM	3.3	5.6	7.6	0.2	0.2	98.0	98.0
AZ	2.1	2.9	3.7	0.4	0.5	95.0	98.0
TX	6.2	5.1	7.1	7.0	2.0	47.0	78.0
West	37.3	50.1	59.9	1.8	1.3	73.4	84.2
CA	25.0	33.3	38.8	0.6	0.5	78.0	88.0
CO	1.6	1.9	2.5	3.0	1.9	63.0	83.0
ID	3.8	7.8	10.9	4.5	2.0	74.0	89.0
OR	1.7	1.6	2.2	8.0	6.0	39.0	54.0
WA	5.2	5.5	5.5	3.0	2.4	58.0	70.0
16 major States	116.9	133.0	150.1	26.9	20.4	41.0	54.0
US	153.6	167.6	181.8	28.9	20.4	35.8	51.6

Source: USDA, NASS *Milk Production*, monthly issues (through 2004); USDA, NASS F*arms, Land in Farms and Livestock Operations* (after 2004).

But structural change is not simply a matter of regional differences. Large farms' share of milk production is increasing in every major dairy State. According to newspaper reports, over 40 large farms, each with 1,000-5,000 cows, were built in Michigan, Ohio, and Indiana between 1998 and 2006. Farms with upwards of 1,000 head are also appearing in other traditional dairy States in the East and Midwest, either through the expansion of longstanding family operations or through new construction with investor financing.[3]

[3]See Dao (2005), Henry (2004), and Martin (2005) for articles on the construction of large dairies in the Indiana-Michigan-Ohio area; Martin (2004) for Wisconsin; or Gullickson (2006) for Pennsylvania.

Scale Economies and Structure in Dairy Farming: Background

Strong structural changes—specifically, the ongoing shift of production to larger operations—suggest that there may be significant economies of scale in dairy production, in the form of cost advantages accruing to increased herd sizes. This report assesses the sources, magnitude, and extent of scale economies, and traces their impact on the industry. However, there are several elements to the link between scale economies and farm structure, and we must first describe those elements.

A longrun average cost curve is depicted in figure 2.[4] The figure consists of three regions. At low levels of output, average costs decline with increases in output. The figure also displays a range of constant average costs, in which average costs do not vary with increases in output, and a range of diseconomies of scale (rises in average cost as production increases).[5]

Five elements of figure 2 are important for evaluating scale in an industry:

- The level of output at which scale economies are just exhausted (and at which constant returns set in) is called the firm's *minimum efficient* scale.
- The *cost penalty from small scale*—how much higher are the costs of small firms that are unable to realize minimum efficient scale?
- The output level at which diseconomies set in is called the *maximum efficient scale*—the largest firm size that can be achieved while still realizing all scale economies. Diseconomies are clearly important in agriculture, since even very large farms are still fairly small businesses.
- Cost curves are *efficiency frontiers*—they reflect the minimum costs that a firm can achieve, given available technology and prices paid for inputs. In practice, actual costs could exceed frontier costs (and thus be *inefficient*) because some inputs are in fixed supply and cannot easily be adjusted to the level needed to achieve the efficiency frontier, because of a poor operating environment (reflecting weather or topography) or because the operator is less effective than other operators.
- A cost curve reflects a given set of input prices. Changes in input prices would shift the curve, but could also alter scale relationships and therefore the shape of the curve.

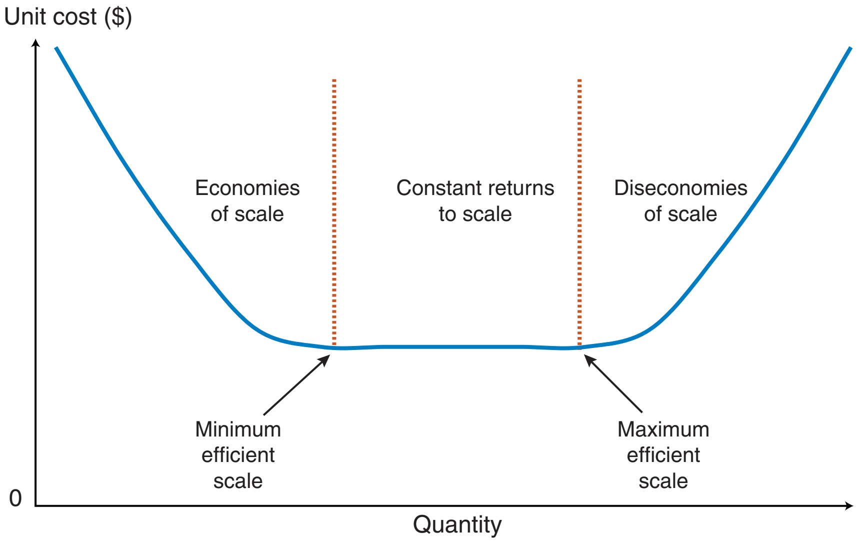
When we assess how cost-scale relationships affect the size structure of farms, it is important to consider all of these elements. Minimum and maximum efficient scales drive the potential range of farm sizes and, coupled with product demand, largely determine how many farm operations will be in business in the long run. The cost penalty from small scale affects the likely survival of smaller operations that cannot realize minimum efficient scale. The efficiency of operations affects survival and the actual industrywide cost changes from structural change. Finally, relative price changes could alter the existing pattern of scale advantages. Increases in prices paid for hired labor, purchased feed, or manure transportation would, all else being equal, raise costs more for large dairy farms than for small since they use those inputs more intensively.

[4]The average cost curve represents how costs vary with output, for a given set of input prices. Changes in input prices, or technological innovations, could shift the position and shape of the curve.

[5]Technically, Chambers (1988) reserves the term "economies of scale" for a specific technological relationship—the increase in output attendant upon an equiproportionate increase in all inputs. However, if production is not homothetic, then that technological relationship will not capture the full change in longrun average costs attendant upon output growth (in non-homothetic production, cost minimizing factor proportions vary with output). Chambers uses the term "economies of size" for relationship between costs and output, but we use "economies of scale" to be consistent with the industrial organization literature (Panzar, 1989).

Figure 2

Visualizing scale economy concepts



Source: USDA, ERS.

Explicit and Implicit Costs in Dairy Production

In assessing dairy production costs, analysts must be careful to account for all relevant costs. Some are explicit and easy to record. For example, farms that purchase feed record feed expenses and quantities. Hired labor is also an explicit cost to operations; the operator incurs a specific expense for the hours worked during any time period.

But significant implicit expenses are also incurred on dairy farms and are much harder to measure. For example, farm operators and their families contribute labor to the dairy enterprise. Although unpaid, the cost of the labor should still be recognized. The operator or family members could have earned income by working off the farm, and their foregone labor earnings represent the opportunity cost of the farm's unpaid labor.

Dairy farms often incur two other important implicit expenses, for home-grown feed and for capital equipment and structures. Homegrown feeds and forage represent implicit costs because the operator could have sold the feeds or the land supporting their production. Many operations own equipment and structures, and do not record an explicit annual expense for their use. But capital use remains an implicit cost to the farm that could have invested the money elsewhere and earned a return on it.

Two other issues pertain in developing cost estimates: joint production and common costs. Dairy production yields a joint product—milk and livestock, the dairy animals that are culled from the herd and sold. If products are truly joint, the costs of producing them cannot be attributed separately to each product, and attempts to do so may simply underestimate the costs of the enterprise. Next, some costs—such as taxes, administrative overhead, and some energy expenses—are borne at the level of the whole farm (they are common to all commodities produced on a farm). Different analytical approaches may have different means of accounting for joint products and common costs, and this may lead to different estimates.

Measuring Dairy Costs With ARMS

USDA's Agricultural Resource Management Survey (ARMS) provides data on input use, expenses, production, and farm characteristics for a large representative sample of U.S. farms (Appendix). The annual survey contains multiple versions, some targeting producers of specific commodities. Two dairy versions underlie our analyses; one collected data from the year 2000 from dairy farms in 22 States, and the other collected data for the year 2005 from dairy farms in 24 States.

The 2005 survey included specific questions targeted at organic dairy operations and a sample design that would ensure adequate statistical coverage of them. About 1 percent of the Nation's dairy cows were certified organic in 2005. Organic operations tend to be smaller than conventional farms, and to have higher expenses and higher revenues per cwt of milk produced. Our 2005 cost analysis excludes organic operations because their cost structure differs significantly from conventional producers. Organic operations were not separately identified in the 2000 data, when they accounted for about 0.4 percent of the nationwide herd, and some organic operations probably appear in that data set.[6]

[6]McBride and Greene (2007) provide an analysis of organic dairy costs of production, and a comparison to conventional production, using the 2005 survey.

The ARMS asks dairy producers about cow inventories and milk production, technology choices, structures and equipment, input use and expenses, and manure management strategies and technologies. It also elicits information on revenues, expenses, production, assets, and liabilities at the whole-farm level, as well as information about the farm operator's household.

The survey's information can be combined with additional analyses and data to estimate implicit expenses. ERS staff use off-farm wage data from another version of ARMS to estimate the opportunity costs of unpaid labor hours used on the farm. Market price data, from other USDA sources, are used to value the reported quantities of homegrown feed and forages fed to dairy cows. Finally, ERS analysts produce annualized estimates of the cost of replacing the capital used for cattle housing, milking facilities, feed storage structures, manure handling and storage structures, feed handling equipment, tractors, trucks, and purchased dairy herd replacements, plus the interest that the remaining capital could have earned in an alternative use. ARMS respondents report the type, capacity, and characteristics of different types of equipment and structures in the dairy enterprise. ERS analysts add information on acquisition prices, useful lives of various types of capital, and interest rates to estimate annual capital replacement costs.

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.

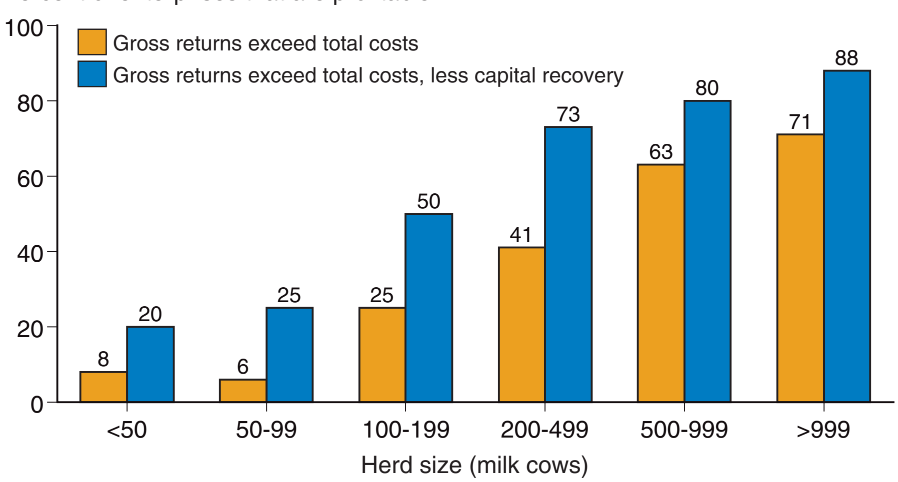
The estimates of net returns are based on national averages, and there is often a wide variation around average performance in agriculture. Some small operations may be exceptionally well-managed, while others may have below-average input prices or above-average product prices. As a result, even though 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

Percent of enterprises that are profitable



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.

[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.

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.

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.

What Do Econometric Estimates Tell Us?

COP accounting estimates clearly show that average costs decline as herd sizes increase, and they provide some useful information for assessing the sources of the cost advantage, but they also have limitations. Specifically:

- Because the estimates do not distinguish between input quantity and input price, we cannot determine whether a cost advantage derives from more efficient input use or from lower prices paid.
- COP estimates reflect the average performance of farms in each size class. Farms vary in efficiency—some are best-practice efficient operations, while others may be poor performers. Consequently, costs can fall as herd sizes increase, either because larger enterprises tend to be more efficient or because technology creates scale economies that allow large enterprises to realize lower costs than equally efficient smaller enterprises.

Two econometric analyses estimate scale economies in dairy production with data from the 2000 ARMS dairy version (Tauer and Mishra, 2006; and Mosheim and Lovell, 2006). The studies take different approaches to the issue (see box, "Herd Size and Production Costs: Scale Economies or Inefficiency?"). Each finds that average production costs fall as herd sizes increase, and each aims to identify the roles of scale economies and inefficiency.

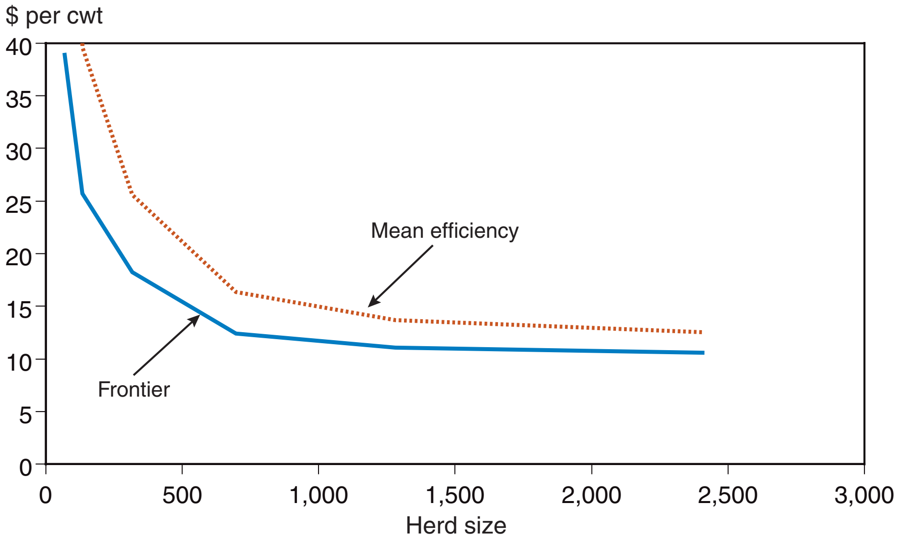
Tauer and Mishra (T&M) argue that most of the observed cost advantage of large herds follows from a greater incidence of inefficient production among smaller dairies. Scale economies were found to be quite modest once they accounted for inefficiency. Costs at fully efficient large dairies (1,000 milk cows) were estimated to be only $1.13 per cwt, or 11.3 percent, below those at fully efficient small (50 cow) dairies, in contrast to an $8.10 difference (36.8 percent) using unadjusted 2000 data. They estimated that average costs at efficient dairies with 1,000 cows were 3 percent below those of efficient dairies with 500-cow herds, versus a 14.3-percent difference based on unadjusted data.

Mosheim and Lovell (M&L) found scale economies to be much more important. In M&L's analysis, average costs among efficient producers decline sharply as herd size expands to 400 milk cows, and they continue to decline, but less rapidly, beyond that size (fig. 4). Among the most efficient operations, average costs fall to $10.57 per cwt at 2,400 head, compared with estimates of $11.05 at 1,300 head, $12.43 at 700 head, and $18.25 at 300 head. Furthermore, while the estimated cost advantages of further increases in herd size are modest at sizes above 1,000 head, M&L find that scale economies are not completely exhausted even among the largest operations in the sample (2,000-3,000 head).

M&L also found that inefficiency was an important source of cost differences. As in T&M, inefficiency was more prevalent among smaller operations. Costs for the average very large farm (2,400 head), at $12.55 per cwt, were 19 percent above frontier costs (fig. 4). Costs at average (mean efficiency) farms are 32 percent above frontier costs at 700 head, and 40 percent greater at 300 head.

Figure 4

Estimated scale economies in dairy production



Source: Data derived from Mosheim and Lovell (2006).

Herd Size and Production Costs: Scale Economies or Inefficiency?

The cost curve in figure 2 (p. 6) reflects how costs vary among producers who are choosing and using inputs in such a way as to minimize costs. Such producers are allocatively efficient in that they are choosing the combinations of inputs that will allow them to minimize the costs of producing a given level of output, and they are productively efficient in that they are getting the most out of the inputs that they've chosen. In that case, the declining cost curve represents scale economies that allow costs for efficient producers to decline as output expands. Scale economies are a technological concept, and in dairy production they may arise from several sources, including milking systems and milk storage, housing, feed storage and delivery systems, and manure handling equipment.

Inefficient operations would fall above the cost curve in figure 2, either because they are allocatively or productively inefficient. Operations can be inefficient because of events outside of the operator's control, such as bad weather; because the operation was originally designed and built to take advantage of input prices that no longer hold; or because of poor decisions made by the operator. The wide range of costs and returns exhibited by dairy farms in the COP estimates, as in other analyses of farm performance, strongly suggests that there may be important differences in efficiency among farms.

Analysts seeking to distinguish scale economies from inefficiency aim to identify the cost line depicted in figure 2. In principle, inefficient enterprises would have costs above the unit cost line, while efficient dairy enterprises would be on the line. Actual data points can fall above or below the line for other reasons, such as measurement errors in the data or an inability to control for other factors that affect costs. These are called random, or stochastic, errors. In trying to identify the unit cost line (scale economies) in the data, and to identify the extent of inefficient production, assumptions are made about the nature of the stochastic errors and about the nature of the technology that drives the shape of the line. The two analyses of the 2000 ARMS dairy data took different approaches to modeling and data development, and these differences affect their conclusions.

Tauer and Mishra (T&M) imposed two assumptions that are likely to reduce the estimate of scale economies in their analysis. First, they subtracted culled cattle revenues from the ERS cost-of-production estimates, on the grounds that those revenues represent the separable costs of livestock production and that they wanted to focus on the specific costs of milk production alone. But milk and cull cows are joint products, so costs cannot be meaningfully separated. Moreover, there is a strong inverse relationship between culled cattle revenues, per cwt of milk sold, and herd size in the sample. Thus, deletion of livestock sales from costs will reduce estimated production costs, and will reduce them more among smaller operations.

Continued on page 19

Continued from page 18

Second, T&M did not control for input prices in their analysis, but instead controlled for the locations (States) of farms (by inserting a dummy variable for each State). The practical impact of that approach is to limit the effective range of farm sizes considered to the range within a State—cross-State differences in farm size, which are large, were not used to assess scale effects. The adjustment for culled cow revenues and the imposition of State effects are each likely to reduce estimated scale economies.

Mosheim and Lovell (M&L) took a different conceptual approach to modeling costs. Costs at the level of the whole farm were analyzed, and the impact on costs of changes in all farm production (milk, but also crops and other livestock), as well as in input prices, was investigated. This approach is theoretically more appropriate than COP accounting, since it does not rely on potentially arbitrary rules for assigning joint or common costs to different farm enterprises, but it also presents significant technical and reporting challenges.

M&L developed an extensive set of input prices, and included those prices in their analytical model. The model allowed for a flexible specification of the relation between the scale of output and costs, and also accounted for inefficiency among producers. Cost data were drawn from ERS ARMS files, but two important expense categories were adjusted.

M&L used a different approach to estimating the implicit cost of capital equipment and structures used on the farm. The COP analyses build an estimate of capital stock by using detailed ARMS survey data on the structures and equipment used in the dairy enterprise, and estimating capital recovery costs from that information. M&L estimate costs for the whole farm, not just the dairy enterprise, in order to better model the impact of joint and common costs. The survey does not contain structures and equipment detail for the whole farm, so M&L estimate the farm's capital stock using data on estimated capital prices and a farm's financial flows.

M&L's estimates of the opportunity cost of unpaid farm labor exceed COP estimates. Since unpaid labor is more important on smaller operations, this approach raises estimated costs on small farms compared with COP and T&M's estimates, and raises the estimates of scale economies. The COP estimates are based only on off-farm wage earnings. M&L take the same regression-based approach that is used for the COP estimates, but they add earnings from operating another business to off-farm wage earnings. Since M&L include more sources of income in their analyses, their estimates of the costs of unpaid labor are higher.

Using Investment Data To Supplement Cost Estimates

In the ARMS data, average costs of dairy production fall sharply as herd sizes increase. Econometric analyses of the data strongly suggest that there are scale economies in dairy production, and there is evidence that costs continue to fall as herd sizes pass 1,000 head. But the econometric studies differ in their estimates of the magnitude of scale economies, and hence of the driving forces behind the cost-size relationship. T&M attribute most of the large cost difference between large and small dairies to widespread inefficiency among small producers. M&L find more inefficiency among small producers, but also find that scale economies create substantial cost advantages for large dairies.

In addition, the 2000 ARMS dairy sample contained few farms with more than 2,000 cows. While it is much more extensive, the 2005 sample is also thin for very large sizes. As a result, the data cannot be used to provide reliable estimates of cost differences among very large dairy farms, and we cannot learn much about maximum efficient scale.

Because the ARMS data provide only limited observations for tracking costs among large operations, and because the econometric estimates offer conflicting estimates of the importance of scale economies, we supplemented the analyses by tracking capacity additions.

We use an approach known as a "survivor analysis" (Stigler, 1958), which is based on the assumption that owners will build new plants at sizes that realize the lowest costs for the era in which they are built (that is, for the existing technology and input prices). If that is true, then one ought be able to infer the efficient range of plant sizes by analyzing the investment decisions made by operators of new plants. The approach does not require detailed cost information, but does require complete information on the size distribution of herds in each of several periods.

Fortunately, we have such information available from census of agriculture records (Appendix). We use data from the 1992, 1997, and 2002 censuses to analyze changes in the distribution of dairy farm sizes.[15] The total number of dairy cows fell from 9.5 million in 1992 to 9.1 million in 1997, where it remained in 2002 (table 7). But cows shifted to much larger farms. Farms with fewer than 200 milk cows accounted for 68 percent of all dairy cows in 1992, but lost nearly 2.5 million milk cows over the next 10 years as their share of total cow inventory fell to 44 percent. Meanwhile, farms with at least 1,000 cows gained over 1.7 million cows as their share of national inventory grew from 10 to 29 percent. Those investment decisions are entirely consistent with the COP findings (tables 3 and 4) that larger farms generally achieved economic profits (returns above the costs of capital), while farms with fewer than 500 cows incurred economic losses.

To learn more about behavior among large dairies, all farms with at least 1,000 milk cows were sorted into more detailed size classes, and size distributions for each census year were compared. Dairy farms with at least 1,000 cows added 653,000 dairy cows during 1992–97. Farms with 1,000–1,999

[15]The data in table 7 are drawn from censuses of agriculture, instead of the annual USDA/NASS surveys that underlie table 1. The census, conducted every 5 years, is less timely but more comprehensive.

head added 43 percent of that total, and farms with 2,000–2,999 head added another 28 percent (fig. 5). The remaining 29 percent of the added inventory, or 190,000 cows, was added by farms with at least 3,000 head. Large dairy farms in 1992–97 generally had between 1,000 and 3,000 cows.

The pattern changed sharply in 1997–2002. Large dairies as a group added over 1 million cows to their inventory, but nearly 70 percent (or 723,000 head) now went to farms with at least 3,000 head. Farms with at least 5,000 head added over 250,000 cows, four times more than the number added in 1992–97.

Investment in large new dairies is occurring in all major production regions, although the very largest still tend to be in the West (table 8). In 1992, there were only 15 dairy farms with at least 1,000 milk cows in traditional dairy States, compared with 483 in Western States. There were 976 large Western dairy farms by 2002, with farms of 3,000–10,000 head growing more prevalent. But the number of large dairy farms also expanded rapidly in traditional States as well, to 67 in 1997 and to 178 by 2002.

Table 7

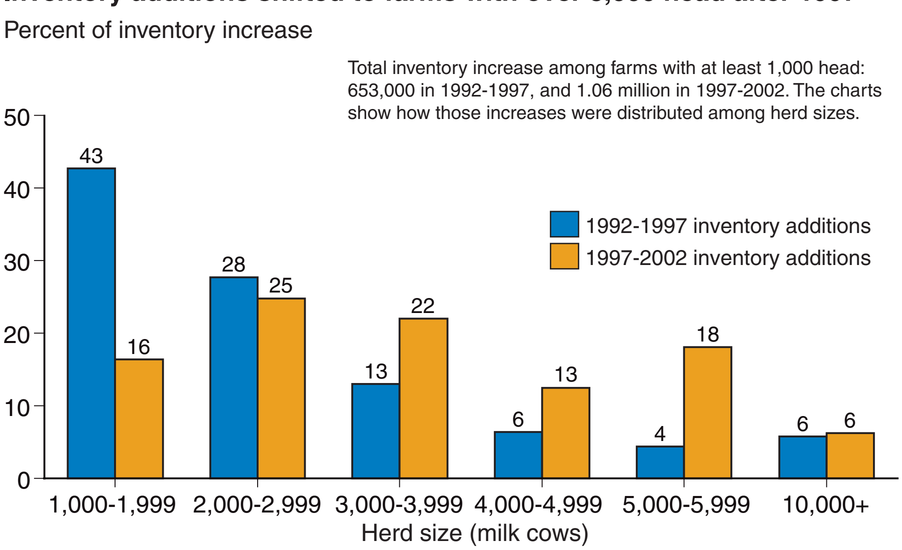
Changes in cow inventory, by farm size, 1992-2002

Herd size	Number of milk cows (1,000)			Change, 1992-2002 (1,000)	
	1992	1997	2002	1992-1997	1997-2002
0-199	6,497	5,186	4,028	-1,311	-1,168
200-499	1,302	1,395	1,336	+93	-59
500-999	756	924	1,115	+168	+191
>999	937	1,590	2,651	+653	+1,071
All farms	9,492	9,095	9,130	-397	+35

Source: Census of agriculture, for reported years. Herd size refers to all dairy cows on an enterprise, including dry cows but excluding calves, heifers, and bulls.

Figure 5

Inventory additions shifted to farms with over 3,000 head after 1997



Source: Census of agriculture farm records.

The data show sharp shifts of new capacity to very large dairies, with 3,000 to 10,000 head, and a slackening of investment in dairies with 1,000–3,000 head.[16] The capacity shifts mirror the data on exit expectations among large dairies, where 28 percent of those with 1,000-2,000 head expect to cease production within 10 years. This shift also suggests that there may have been constraints on dairy farm size (diseconomies of scale), but that those constraints have loosened in the last 10 years.[17]

[16]The very largest dairy farms may encompass several "pods" with barns and a milking facility for 2,000–3,000 cows in each.

[17]How big are the largest dairy farms? Eight farms in the 2002 census had over 10,000 milk cows, compared with 4 in 1997 and 1 in 1992. A farm in Indiana advertises that it has (in 2007) 30,000 milk cows in 10 pods on its site.

Table 8

Large dairy farms, by region and size class

Region and herd size	1992	1997	2002
		Number of dairy farms	
Western dairy States			
1,000-1,999 cows	401	545	606
2,000-2,999 cows	60	132	197
3,000-3,999 cows	9	40	94
4,000-4,999 cows	8	16	40
5,000 or more cows	5	12	39
Traditional dairy States			
1,000-1,999 cows	12	59	135
2,000-2,999 cows	3	7	27
3,000-3,999 cows	0	1	12
4,000 or more cows	0	0	4
Other States			
1,000-1,999 cows	37	50	54
2,000-2,999 cows	10	7	25
3,000-3,999 cows	5	8	9
4,000-4,999 cows	1	3	4
5,000 or more cows	3	3	8

Source: ERS tabulations, from census of agriculture microdata.
Western dairy States: AZ, CA, CO, ID, MT, NV, NM, OR, TX, UT, WA, and WY.
Traditional dairy States: CT, DE, IA, IL, IN, MA, MD, ME, MI, MN, MO, NH, NJ, NY, PA, OH, RI, VT, and WI.
Other States: AK, AL, AR, GA, FL, HI, KS, KY, LA, MS, NC, ND, NE, OK, SC, SD, TN, VA, and WV.

Effects of Structural Change: Manure and Excess Nutrients

The shift of production to much larger dairy farms, driven by significant cost advantages, is likely to continue. The shift also concentrates production in fewer locations and on confined feeding operations with smaller land bases. This spatial consolidation concentrates animal wastes as well as cows, and heightens the potential environmental risks associated with milk production. Here, we describe the pace of geographic consolidation in dairy production and evaluate the potential impact on excess nutrients applied to the land. We then review the environmental regulations developed to deal with dairy farms and other confined animal feeding operations, and summarize ARMS-based data on how dairy farms are managing their manure.

Geographic Consolidation of U.S. Dairy Production

What do we mean when we say that dairy production is spatially concentrating? First, although more milk is being produced then ever before, the industry is consolidating into fewer dairy counties. We sorted all U.S. counties according to the number of dairy cows in each, using census of agriculture data. We then determined the number of counties necessary to account for one-quarter of all dairy cows, and the number necessary for half.

The changes over time are striking. In 1969, 71 counties accounted for one-quarter of all dairy cows, but that count fell to 34 counties in 1992 and just 20 by 2002. Correspondingly, 247 counties accounted for half of all dairy cows in 1969, versus 130 in 1992 and 95 in 2002.

Larger dairy farms concentrate their herds on a more limited land base. Figure 6 shows how cow density varies with herd size for farms in traditional dairy States, where crop production and pasture have historically been combined with milk production. The figure shows two measures of density: cows per 100 acres of farmland and cows per 100 acres of cropland. For each measure, density rises as herd size increases, and densities in the largest class are twice those in the next largest.[18]

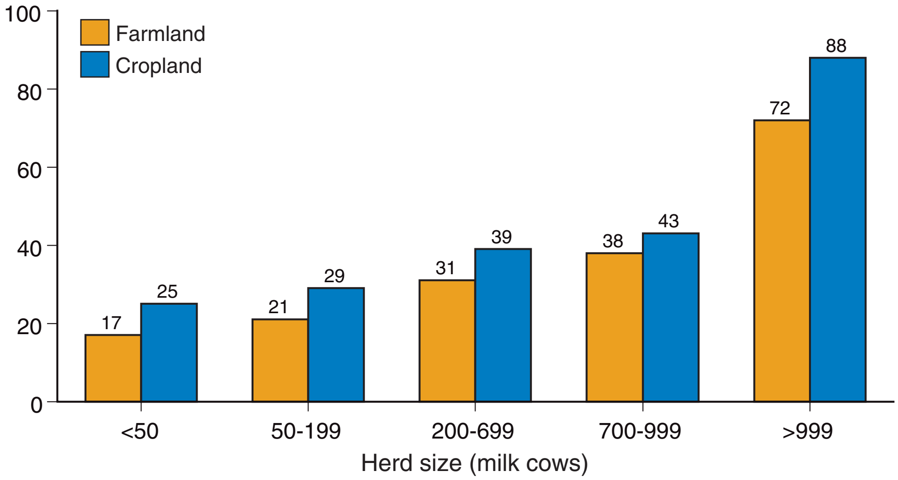
As dairy production consolidates geographically, the associated consolidation of manure may lead to the production of manure-based nutrients, primarily nitrogen (N) and phosphorus (P), in excess of what can be taken up by crop production on the dairy farm's land. If improperly managed, excess N and P applications can pose environmental and human health risks. That's not a necessary outcome of geographic consolidation: the farm might be able to remove manure for spreading on other operations or treat the manure to limit environmental harm. Before we consider manure management practices, we will next evaluate the potential changes in excess manure-based nutrients associated with dairy farm consolidation.

[18]Data are drawn from the 2005 ARMS dairy version, and show the ratio of milk cows to farmland operated and cropland across farms in each size class. For this figure, we chose size classes in accordance with regulatory standards.

Figure 6

Cow density increases with herd size

Cows per 100 acres



Source: 2005 ARMS dairy version.

Farm Size and the Potential for Excess Nutrients

The N and P available for crop production on a farm consists of the quantities of those nutrients found in the manure generated on the farm, along with the level of commercial fertilizers placed in the ground. Only certain levels of these nutrients are required to grow crops. Excess nutrients, if not properly managed, can build up in the soil and contribute to groundwater contamination, excess runoff to streams and rivers, and air pollution. We estimate the nutrients present in livestock manure on dairy farms, and compare them to the nutrients required by the farms' mix of crops, to show that large dairy farms can produce substantial excess nutrients from manure alone.

The analysis is limited to farms in traditional dairy production regions—the Northeast (New York, Pennsylvania, and Vermont) and the Midwest (Iowa, Illinois, Indiana, Michigan, Minnesota, Missouri, Ohio, and Wisconsin). Dairy farms in these regions typically raise crops and spread manure on farmland. With the region's production moving toward large industrialized operations, there may be increased stress on limited land bases.[19]

In developing measures of excess manure-based N and P, we follow the conceptual approach used in earlier ERS research (Gollehon et al., 2001; Ribaudo et al., 2003). We began with year-end livestock inventories for each of the four major species in the States we examine—beef cattle, dairy cattle, hogs, and poultry. To convert onfarm livestock inventories to estimates of manure production, we then applied the Kellogg et al. (2000) estimates of annual manure production, in tons, for animals of each species.[20] The nutrient composition of manure varies across species, and the same source provides species-specific conversion factors to construct estimates of N and P from each ton of manure for each species.

Next, the ARMS database describes each sample farm's crop mix—the acreage devoted to each crop that the farm produced and production, in bushels, from that acreage. We used that data to develop farm-level measures

[19]This analysis relies on data drawn from seven annual ARMS surveys conducted during 1996–2002. The version underlying these surveys carries less dairy farm detail than the dairy version, but nevertheless sufficient detail for these purposes, and a large sample size.

[20]Kellogg et al. report their estimates for animal units (AU), defined as 1,000 pounds of livestock (a mature dairy cow would be about 1.35 animal units, while a 250-pound hog would be 0.25 animal units). We converted their AU estimates to per-animal estimates.

of total N and P use by crops, relying on the estimates of assimilative capacity, in pounds of N and P per bushel, for each crop provided in Kellogg et al. (2000).[21] Finally, we subtracted onfarm nutrient use from manure-based nutrient production to generate estimates of potential manure-based excess nutrients on each farm.

We present mean values of those estimates, sorted by farm size class, in table 9. Superscripts refer to statistical tests of difference in excess pounds across herd sizes; each letter denotes that the entry is statistically different from the estimate reported in the cited column, at a 90-percent level of confidence.

On average, manure production generates nutrients that exceed the amounts required by the crops grown on dairy farms in all size classes. Moreover, consolidation into larger farms exacerbates the potential for excess nutrients. Estimates of excess N and P, based on manure production alone, are positive for all size classes, and rise sharply between the smallest and largest size classes. A great deal of variation in excess nitrogen production occurs within each size class, so that most across-class differences are not statistically significant. However, the phosphorus estimates rise sharply with herd size, and the differences across classes are statistically significant.

These findings are consistent with those reported in another ERS report, which used the 2000 ARMS dairy version to develop measures of potential excess nutrient production from manure (Ribaudo et al., 2003). That study took a different approach to measurement, estimating the amount of land needed for manure spreading in order to meet a goal of zero excess P (and alternatively, zero excess N). It then compared the needed acreage to the acreage over which the farm was actually spreading manure, and to the total acreage on the farm (since farms don't always spread manure on all their land). Most small dairy farms in traditional States had land available to meet nutrient standards, but few farms in the largest size class did.

Most farms do not rely on manure alone for crop nutrients; manure is costly to transport to fields, and often does not contain the appropriate combination of nutrients for specific crops and fields. Since farms also apply commercial fertilizers to crops, our estimates (table 9) understate the potential excess nutrients from manure and commercial fertilizer applications. While dairy farms of all sizes have the potential for substantial excess nutrient production, the potential appears to increase noticeably among larger dairy opera-

[21]In generating these estimates, we assume that soybean and alfalfa plants are net fixers of N, with each crop fixing nitrogen (35 pounds per bushel of soybeans, and 135 pounds for alfalfa hay) into the soil.

Table 9
Herd size and excess manure-based nutrients

Nutrient	Herd size (number of cows)				
	<50 (a)	50-199 (b)	200-699 (c)	700-999 (d)	>999 (e)
	Excess nutrients (pounds per cropland acre)				
Nitrogen	20^{bce}	30^{a}	24^{ae}	39	54^{ac}
Phosphorus	2^{bcde}	7^{acde}	10^{abde}	16^{abce}	29^{abcd}

Notes: The superscripts refer to the results of statistical tests of difference between columns. All tests are expressed at a 90-percent level of confidence. A lettered superscript denotes that the value reported in a column is significantly different from that in the superscript column.

Source: Agricultural Resource Management Survey (ARMS), version 1, 1996-2002, for 5,183 farms with dairy cows in IA, IL, IN, MI, MN, MO, NY, OH, PA, VT, and WI.

tions, particularly for phosphorus and as herd sizes exceed 1,000 cattle of all types. As dairy farming continues to consolidate into larger operations, this problem will likely become more widespread.

Regulations

Dairy farms, as well as other livestock and poultry operations, are subject to regulation of their manure management practices by Federal, State, and local governments. Regulatory efforts often focus on large operations.

Under the Clean Water Act of 1972, the Environmental Protection Agency (EPA) issued regulations in 1974 and 1976 that established effluent limitation guidelines for large feedlots. In 1999, EPA and USDA published a rule proposing a unified national strategy to limit the environmental impacts of animal feeding operations (AFOs). Following widespread discussion, proposals, comments, and analyses, a revised rule was published in February 2003, effective in April 2003, consisting of a set of regulatory requirements aimed at concentrated animal feeding operations (CAFOs). However, following a legal challenge to the 2003 rule, EPA was remanded to revise some portions of the regulations.[22]

[22]The history leading up to the 2003 rule is described in "National Pollutant Discharge Elimination System Permit Regulation and Effluent Limitation Guidelines and Standards for Concentrated Animal Feeding Operations (CAFOs); Final Rule," 40 CFR Parts 9, 122, 123, and 412, at http://www.epa.gov/fedrgstr/EPA-WATER/2003/February/Day-12/w3074.pdf .

An AFO is defined as an operation that confines animals for at least 45 days in a 12-month period with no vegetation in the confinement area. A CAFO is simply a concentrated AFO. The operation's size, location, means of wastewater conveyance, site characteristics, and other risk-related issues all factor into the authority's decision to categorize an operation as an AFO or a CAFO.

There are three main classes of CAFOs—large, medium, and small. All dairy operations with at least 700 cows are considered large CAFOs. A medium dairy CAFO has 200–699 cows and either discharges animal wastes directly, or has some manmade device (e.g., ditch, flushing system, etc.) that allows animal wastes to discharge directly into U.S. waters. A small dairy CAFO has fewer than 200 cows but is found by a local permitting authority to be a significant contributor of pollutants in the area.

The final ruling established guidelines that CAFOs must adhere to. Under the original 2003 regulations, all CAFOs had to apply for National Pollutant Discharge Elimination System (NPDES) permits, in effect recognizing all CAFOs as point sources of pollution.The revised rule requires only some CAFOs to obtain an NPDES permit—those that either discharge or propose to discharge animal wastes into U.S. waters. Unpermitted discharges are not allowed, except for agricultural stormwater. All CAFOs, permit holders as well as those obtaining the stormwater exemption, had to have a nutrient management plan (NMP) in place by July 2007.

To the extent possible, NMPs must meet nine minimum elements.[23] They must document:

[23]Described in the 2003 rule, p. 7226.

1) Adequate onsite waste storage;

2) Proper management of all animal mortalities;

3) Diversion of clean water, as appropriate, from any production areas on the operation;

4) No direct contact between confined animals and any waters of the United States;

5) Proper disposition of all chemicals and other contaminants used onsite;

6) Site-specific conservation practices to be implemented;

7) Protocols for the appropriate testing of the waste generated on the farm;

8) Protocols to land-apply waste in an acceptable fashion; and

9) Proper documentation of implementation and management of all the elements.

While these nine elements comprise the minimum necessary to operate in the new regulatory environment, more detailed requirements exist for CAFOs depending on their size, with larger CAFOs subject to more stringent guidelines than smaller ones.

EPA rules set minimum standards that CAFOs must meet. States implement the EPA regulations and may also set higher standards or pursue additional strategies. States have imposed minimum facility setback requirements to separate facilities from their neighbors and limit their odors. Some have also imposed tighter land application rules for manure that may apply to broader classes of farms.

Manure Management Strategies and Structural Change

Farms that cannot meet nutrient standards with their current land base have several options. They could reduce the size of their dairy operation. If this were the least costly option, it would lead to a change in farm structure away from large dairy farms. However, given the substantial production cost advantages to size, this would be a likely choice only if the alternatives were quite expensive.

Farmers could also expand the land base for spreading manure on crops, either by acquiring more land and expanding the farm's cropping enterprise, or by selling the manure to others, giving it away, or paying to have it removed.

Manure contains a lot of water, making it very costly to transport, but farmers can reduce those costs with treatment strategies that aim to separate manure solids from liquids. Solids can be more easily transported and applied to cropland or converted to garden fertilizers and other processed products, whereas liquids remain to be applied to onsite cropland. Treatment may also separate methane gas, used for power generation, from manure. Farmers can also reduce the amount of nutrients in manure, and the amount of manure produced per cow, by altering the feed provided to cows.

Ribaudo et al. (2003) analyzed the costs of removal, which may be the most likely mitigation strategy. They evaluated the increase in production costs that would arise from meeting different nutrient standards (N-based and P-based) for farms in three broad size classes and two broad production regions, under different assumptions of the willingness of other farms to accept manure. In general, the estimated effects on production costs were small. If 20 percent of nearby crop producers were willing to accept manure, production cost increases would range from 0.5 to 3.5 percent. Furthermore, while larger farms would see greater percentage increases in production costs, the differences were modest. The smallest farms (less than 425 head, in this analysis) in traditional dairy States would see cost increases of around 0.5 percent, while farms in the largest size class (more than 1,425 head) would see increases of 1.5 (N-based standard) to 3.5 (P-based standard) percent.[24] Given the production cost differences among farms in different size classes (table 4), the analysis suggests that the cost impacts of meeting N- or P-based standards are unlikely to alter the path of structural change.

[24]Costs were sensitive to variations in the willingness of nearby crop farmers to accept manure. As willingness increased from 20 percent, costs would fall. If only 10 percent would be willing to accept manure, then estimated costs for large operations could double, still a small impact compared with the production cost advantages of size.

We used data from the 2005 ARMS dairy version to ascertain the manure management strategies that dairies are following, particularly movement offsite (table 10). For ease of presentation and to generate useful sample sizes for some questions, we classified farms broadly by herd size (1–699 cows versus 700 or more, the cutoff used to define large CAFOs) and by region (Western dairy States and traditional dairy States).

Table 10

Manure management practices, by region, 2005

	Western dairy States		Traditional dairy States	
	0-699 cows	700 or more cows	0-699 cows	700 or more cows
	Percent			
Manure removal				
Farms removing manure (%)	22	57	5	27
Of the farms that remove:				
Percent of manure removed	17	47	2	15
Percent removed that is:				
Sold	16	17	42	34
Given away for free	49	48	53	41
Hauled away for a fee	35	35	5	25
	100	100	100	100
	Percent of farms			
Other practices and assets				
Have a CNMP[1]	70	45	26	91
Use a manure separator	6	16	2	12
Use an anaerobic digester	0	1	0	9
Use dewatering technology	9	37	1	15
Control manure dust	7	32	0	8
Manage feed for nutrients	4	9	4	39
Raise heifers offsite	15	16	10	25

[1]A CNMP is a comprehensive nutrient management plan.

Source: 2005 Agricultural Resource Management Survey, version 4 (Dairy). Western dairy States in ARMS 2005 include AZ, CA, ID, NM, OR, TX, and WA. Traditional States are IA, IL, IN, ME, MI, MN, MO, NY, OH, PA, VT, and WI.

In traditional dairy States, only about 5 percent of dairy farms with fewer than 700 cows, and less than 30 percent of those with 700 or more cows, removed manure from the farm to other sites. Of those that removed manure, smaller farms removed 2 percent of the manure generated on the farm while large farms (700 or more cows) removed about 15 percent, on average. So as of 2005, manure removal was not widely used in traditional production regions.

Removal is far more important in the Western dairy States. Twenty-two percent of farms with fewer than 700 cows, and 57 percent of those with 700 or more, removed manure from the farm. Farms that remove manure also remove a lot more of it: the smaller farms removed 17 percent while the larger farms removed nearly half, on average, of the manure generated onfarm. Large Western dairy farms often raise no crops, whereas dairy farms in traditional dairy States usually grow crops for feed and retain substantial acreage for spreading manure.

About half of the manure removed from dairy farms was given away for free in each region, but Western dairies (large and small) paid fees to have over a third removed. Eastern dairies were able to sell over a third of the manure removed from those operations. Because Western dairies remove far more manure, the increased quantities likely depress manure values, such that fees for removal must be paid more often.

There were enough observations of manure removal on Western dairy farms to allow for estimates of the effect of manure sales or removal fees on farm revenues and costs, expressed in terms of dollars per cwt of milk produced for easier comparison. Among farms that sold manure, the median fee received was 6 cents per cwt. Reported payments for manure ranged from 5 cents at the 25th percentile to 6 cents at the 75th—a narrow range, and a very small contribution to revenues for those farms. For those who paid to remove manure, the median expense was 15 cents per cwt, and reported fees ranged from 7 cents at the 25th percentile to 30 cents at the 75th.

Reported removal expenses ranged more widely than revenues, but even at the high end the removal fees were modest compared with the production cost advantages reported for large operations. At the high end of 2005 manure removal fees (30 cents per cwt of milk at the 75th percentile, or 2.2 percent of production costs at a large farm), the expense is still a fraction of the production cost advantage of large operations.

Another manure management strategy is technology that allows for less costly, and therefore more distant, manure transport, and that can produce other benefits from manure. Large dairy farms were much more likely, in each region, to use technologies that ease the transport and promote the further processing of manure. Nevertheless, none of the technologies—manure separators, dewatering, or anaerobic digesters—is widely used (table 10). The anaerobic digester, which produces electricity from the methane in manure and leaves a dry, nutrient-intensive product that can be transported easily, appears on less than 9 percent of large farms in traditional dairy States, and is virtually absent elsewhere.

Farms can also reduce manure and nutrient production from a given herd by raising replacement heifers offsite, or by altering feed mixes to reduce manure or its nutrient content. Each of those strategies is common, although not widespread, on large dairy farms in traditional dairy States (table 10).

Little manure is currently removed in traditional dairy States. However, pressure is growing for a substantial expansion of manure removal because of the expansion of large dairy farms, the links between herd size and excess nutrient production, and the requirements in nutrient management plans. In turn, if the costs of manure removal were high, then regulations could, in principle, slow or reverse the expansion of large dairy farms. However, current evidence indicates that manure removal expenses add only modestly to milk production costs. Furthermore, given the abundant cropland in traditional dairy States, along with deep markets for gardening fertilizers, short hauling distances, and the opportunities for easier removal offered by available processing technologies, it seems likely that markets could well develop for manure removal as more large farms appear in traditional dairy States.

Conclusions

U.S. milk production is rapidly shifting to much larger dairy enterprises. The shift occurred first in Western dairy regions, and milk production has increased in Western States as more capacity has been added in large-scale farms. However, similar changes are occurring in more traditional dairy States, which are rapidly adding large operations and losing smaller ones.

Large dairy farms have substantial cost advantages over smaller farms, derived from the ability to take advantage of economies of scale. On average, farms with at least 1,000 cows realize costs, per hundredweight of milk produced, that are 15 percent lower than farms in the next largest size class (500–999 head) and 35 percent lower than farms with 100–199 head. Other evidence suggests that costs may continue to decline as herds increase to and above 3,000 head.

Smaller farms tend to get higher prices for their milk than larger farms. But cost differences tend to overwhelm this advantage: larger farms, especially those with more than 1,000 cows, are realizing economic profits while most smaller farms are realizing negative net returns. In turn, differences in returns are driving investment decisions that are shifting production to larger farms.

Still, some small farms realize economic profits—in that the value of their production exceeds their total costs, including operating costs, capital recovery costs, and the opportunity costs of the operators' time. Others, although not returning enough to encourage reinvestment, earn enough to remain in business.

The continued shift of production to larger operations will likely reduce industrywide costs, leading to lower dairy prices for consumers even as it forces more small operations out. But the shift also creates increased environmental risks associated with the concentration of manure-based nitrogen and phosphorus. Federal and State regulators have been applying rules to govern the storage, application, and disposal of nutrients. Some large specialized dairies already remove most or all of their manure to other sites, at modest costs; moreover, large dairies have begun to invest in technologies that allow for lower cost transport of manure-based nutrients. At present, the costs of manure treatment and transport are not large enough to offset the considerable production cost advantage held by large dairies. Given this, production should continue to shift to large dairy farms.

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Appendix: Data Sources

Dairy Farm Numbers, Size, and Location

USDA's National Agricultural Statistics Service (NASS) publishes annual data on the size structure of dairy farms in *Farms, Land in Farms, and Livestock Operations* (before 2004, in February issues of *Milk Production*). NASS reports the number of operations, cow inventory, and milk production, by herd size class. Six classes are identified for State-level data—1-29, 30–49, 50–99, 100–199, 200–499, and 500 or more milk cows, with the largest class replaced by classes of 500-999, 1,000–1,999, and 2,000 or more for the nationwide data. The data are based on surveys of all large producers and samples of smaller producers.

The annual survey data are supplemented with the 1992, 1997, and 2002 Censuses of Agriculture. Confidential individual census records are used to analyze changes in farm size among large dairy farms. Census records report farm location and milk cow inventories at the end of the year, allowing us to summarize changes in the size distribution of dairy farms between census years. With an ongoing expansion of large commercial dairies, the 2002 census end-of-year estimates of large dairies will exceed the 2002 estimates in *Farms, Land in Farms, and Livestock Operations*, which rely on beginning and midyear surveys.

Data for Cost Analyses

Cost analyses are based on data from the dairy version of the 2000 and 2005 Agricultural Resource Management Survey (ARMS), a complex annual survey applied to a stratified random sample of all U.S. farms. ARMS is USDA's primary source of information on the financial condition, production practices, resource use, and economic well-being of U.S. farms and farm households.

ARMS is a large multiphase and multiversion survey. The sample is screened for continued operation and commodity coverage in Phase I, conducted in the summer of the reference year. In the following fall, randomly selected Phase I farms are surveyed in Phase II concerning their crop production practices and chemical use at the field or production unit level. Phase III, initiated during the winter following the reference year, draws information on farm income and expenditures, farm financial transactions, and the farm operator household.

Several versions of the Phase III survey are distributed. A short "core" version is distributed and returned by mail, while other versions require personal interviews with trained enumerators. One enumerated version (version 1) covers farms of all types. This version is used for the wage analysis reported in table 6 because it elicits information on off-farm hours worked, off-farm earnings, age, and education for farm operators and spouses. Other enumerated versions include sections aimed at specific commodity enterprises, including dairy versions covering the years 2000 and 2005. The 2000 ARMS dairy version covered 22 States: AZ, CA, FL, GA, ID, IA, IL, IN, KY, MI, MN, MO, NM, NY, OH, PA, TN, TX, VT, VA, WA, and WI. The 2005 version covered those States, plus ME and OR. The dairy versions elicit information on dairy enterprise production, inventories, expenses, assets, and technology use, as well as manure management and marketing practices. Further information on ARMS, including downloadable questionnaires, can be found at www.ers.usda.gov/Briefing/ARMS/.

Excess Nutrients and Manure Management Decisions

Data for the excess nutrient estimation were developed from ARMS, Phase III, version 1, which contains farm-level data on livestock inventories and crop acreage. The analysis focused on dairy farms in traditional production regions, where manure remains on the farm. Version 1, directed annually at all farms, covers several hundred dairy farms in each year, and a large sample could be obtained by drawing records for dairy farms in 11 States (IA, IL, IN, MI, MN, MO, NY, OH, PA, VT, and WI) from the 7 version 1 surveys carried out during 1996-2002. ARMS livestock inventory data were combined with external estimates of species-specific manure and nutrient production rates to generate estimates of manure-based N and P production on the farm. ARMS data on crop acreage were combined with external data on crop-specific nutrient uptakes to generate estimates of total nutrient uptake on the farm.

The data on manure management practices were drawn from the 2005 ARMS dairy version, which contained specific questions on those practices. The 2005 survey covered dairy farms in 24 States (listed above).