Drivers of Structural Change: Technology and Scale Economies

Production has shifted to much larger farms in the broiler, dairy, fed-cattle, and hog industries. To what extent do costs account for those shifts? If large farms do realize cost advantages, do they follow from technological scale economies? How large are the scale effects, and is there a level beyond which further size increases have little impact on costs? In evaluating the evidence for each commodity, we find that scale-related cost advantages are important factors in structural change, although the magnitude of the advantages, and the strength of the evidence, varies across commodities.

Multiple ARMS hog and dairy surveys provide data to support detailed cost analyses, for periods in which each sector was undergoing important changes. Our evidence for fed cattle and broilers is more limited. We have a single ARMS broiler survey and no fed-cattle survey, and major structural change occurred in the more distant past for those two commodities.

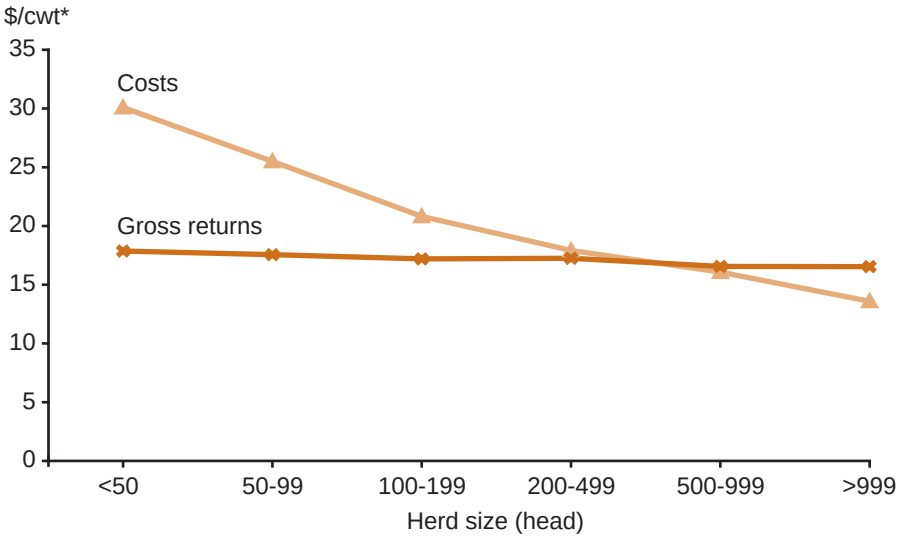
Dairy

ERS estimates of dairy costs of production show that larger farms had substantial cost advantages, on average, over smaller operations (see box "Measuring Hog and Dairy Costs and Returns" for details on how the estimates are constructed) in 2005. Farms in the largest size class—herds of 1,000 or more milk cows—had average costs of $13.59 per hundredweight in 2005 (fig. 6), about 15 percent below the average for farms in the next largest size class (500-999 head) and 35 percent below the estimate ($20.82 per cwt) for operations with 100-199 head. Average costs are much higher among even smaller operations.[10]

One source of scale economies in dairy is capital equipment—large and highly automated milking parlors and feed delivery systems. Structures

[10] Similar patterns appear for the 2000 data. Further details and analysis can be found in MacDonald et al. (2007), McBride and Greene (2007), and Mosheim and Lovell (2009).

Figure 6
Average costs and gross returns in 2005, by size of dairy herd



* Production cost per hundred pounds of milk produced on the farm.
Source: MacDonald et al. (2007).

Measuring Hog and Dairy Costs and Returns

ERS estimates include all costs and returns associated with production, including those borne by integrators and landlords as well as those borne by farm operators. Gross returns include cash receipts received from the sale of hogs, pigs, or milk; the value of livestock removed under production contracts; and the value of secondary products such as culled animals and manure. Cash receipts are reported directly in ARMS. Commodities removed under a production contract are valued using production reported in ARMS and State-average prices. Actual cash receipts are reported for some secondary products, while others are valued with reported production and State-average prices.

Some components of commodity production costs—like purchased feed, feeder animals, hired labor, bedding and litter, and fuels and electricity—are reported directly in the surveys. But significant implicit expenses are also incurred on farms. For example, farm operators and their families contribute their labor to the enterprise, but since that labor often does not receive a wage, an explicit expense can't be recorded. Nevertheless, the opportunity cost of the labor should be recognized since those hours could have earned income in another activity, such as working off the farm.

ERS estimates an opportunity cost of unpaid labor, based on the off-farm labor earnings of farm operators as recorded in version 1 of ARMS, which provides data on the annual hours worked and wages and salaries earned off-farm by respondents.

Hog and dairy farms can also incur implicit expenses for homegrown feed and for capital equipment and structures. ERS uses market price data from other USDA sources to value the quantities of homegrown feed and forages produced on the farm and fed to animals, as reported in ARMS. ERS also estimates the annualized cost of replacing the capital used for livestock housing, feed and manure storage structures and handling equipment, milking facilities, tractors, and trucks, as well as the return that the capital could have earned in an alternative use. Survey respondents report the type, capacity, and characteristics of different types of equipment and structures in the enterprise. ERS analysts add secondary information on acquisition prices and useful lives of various types of capital, and interest rates, to estimate annual capital replacement costs.

ERS reports gross returns and total costs, per cwt of milk for dairy and per cwt of liveweight gain for hogs. Total costs are sorted into operating and overhead costs. Operating costs are further sorted into feed and other costs, while allocated overhead includes labor, capital recovery, the implicit rental rate of land, taxes and insurance, and general farm overhead. Further details, and data, are available at www.ers.usda.gov/Data/CostsAndReturns/

are a second: modern free-stall barns allow large operators to realize lower housing costs per cow. Large, automated manure removal and storage systems also appear to reduce costs of manure handling, per ton, compared to smaller and less automated systems. These facilities allow larger operations to greatly economize on labor and capital costs, per pound of milk produced, by intensively utilizing their equipment and structures. On many small dairy farms, facilities are utilized at less than full capacity, especially if the facilities are nearing the end of their useful life or if the operator is nearing retirement, with no succession plans.

Small farms tend to be located in regions with higher milk prices, so they realize slightly higher average gross returns to milk production than large farms (fig. 6).[11] However, costs still exceeded gross returns, on average, for small farms in 2005, while farms with at least 500 head had gross returns that exceeded their costs.

ERS cost-of-production accounts allow us to assess several different measures of the financial returns to dairy production, and to compare them across farm sizes (fig. 7). Operating costs include expenses for feed, bedding and litter, fuels and electricity, and veterinary services. While farms may fail to realize enough revenue to cover operating expenses over short periods (because of unforeseen emergencies), they won't stay in business for long unless they cover such expenses. No more than 15 percent of farms in each size class failed to cover operating expenses (fig. 7).

A second standard is to compare gross returns to all costs except those for capital recovery. Farms that meet that standard realize enough revenue to cover all operating expenses, all taxes and insurance on the operation, and the opportunity cost of the operator's time. Existing dairy farms have already put their capital structure and equipment in place; if they are not earning enough to pay for the replacement of that equipment, they can still continue

[11] Milk revenues account for 90 percent of the gross returns from dairy production, with most of the remainder coming from byproducts—sales of cows culled from the herd and the value of the manure produced by the herd.

Figure 7
Financial performance, by size of dairy farm

Source: 2005 Agricultural Resource Management Survey, version 4.

operating until the equipment wears out, which can be a long time.[12] Only about 20 percent of farms with fewer than 100 head meet this standard, while 50-70 percent of midsize farms (100-499 head) and 80-90 percent of large farms do (fig. 7). The smallest dairy operations face seemingly strong pressures to exit, as an operator could earn higher returns to his or her labor elsewhere.

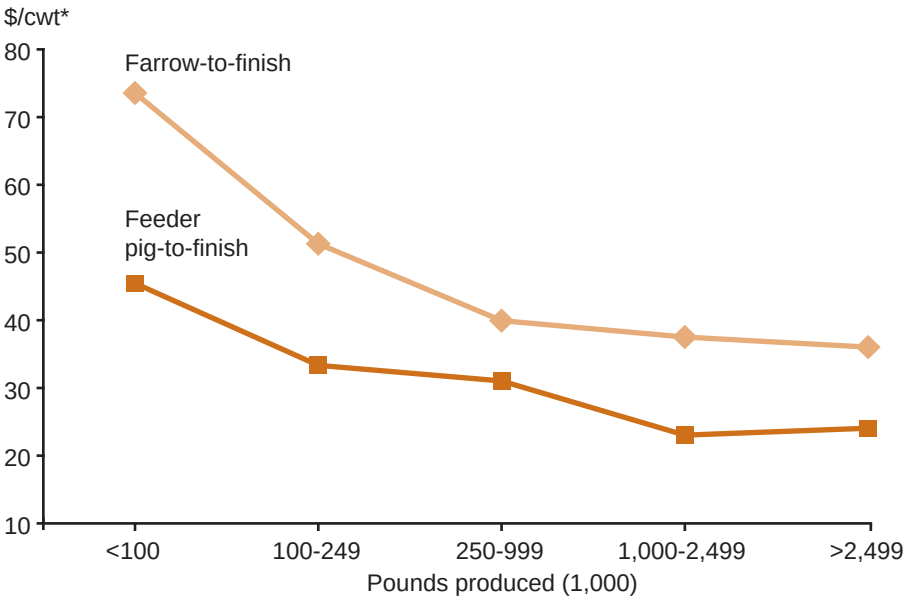
Finally, total costs include capital recovery costs. Farms that cover total costs earn more for their operators' labor than the operators can earn elsewhere, and return more on the farm's capital investment than could be earned elsewhere. Over 70 percent of the largest dairies had gross returns that exceeded total costs, compared to less than 10 percent of small farms and less than 40 percent of midsize farms (fig. 7). That pattern of performance provided strong incentives for existing dairies to expand or to exit, and for producers entering the business to enter at a large size.

Hogs

Key and McBride (2007) and McBride and Key (2003) provide a comprehensive overview of hog production costs and productivity. In 1998, large hog operations had substantial productivity advantages over smaller operations—they used much less feed, labor, and capital for every hundred pounds (cwt, again) of hog production.[13] Many of the highest cost operations closed after 1998, and more efficient small operations were still at a productivity disadvantage in 2004.

Productivity differences translate into important cost advantages for larger operations. Production costs, for farrow-to-finish and feed-to-finish operations of different sizes in 2004, are compared in figure 8. Costs are expressed in dollars per cwt of weight gain: for example, a finishing operation that receives 50-pound pigs and feeds them to 250 pounds would realize 2 cwt

Figure 8
Hog production costs in 2004, by size and type of operation



* Production cost per hundred pounds of weight gained while on the farm.
Source: Key and McBride, 2007

[12] A principal reason why structural change occurs over long periods is because it is economic to operate many high-cost farms, as long as revenues still cover variable costs.

[13] On average, feeder-to-finish operations that removed 5,000 or more hogs in 1998 used 247 pounds of feed and 0.12 labor hour for every 100 pounds of hog weight gain, compared to 342 pounds of feed and 0.39 labor hour for operations that removed 500-2,000 hogs (McBride and Key, 2003).

(200 pounds) of gain for each market hog removed. ERS cost-of-production estimates include all costs incurred, whether borne by the integrator or the grower. Feeder pig costs are excluded from the estimates of costs at feeder-to-finish operations, so one should not compare costs across types; instead, the proper comparisons are among different size classes of each type.

Among farrow-to-finish operations, costs fell quite sharply, from over $70 per cwt to just over $40, as annual output expanded from 100,000 pounds of liveweight production to 1 million pounds (or from 400 hogs to 4,000, for 250 pound hogs). Costs continued to fall after that threshold, but more modestly, to $36 among operations with at least 2.5 million pounds of liveweight production (10,000 hogs).

Feeder-to-finish operations also show a strong association between costs of production and the operation's size. Average production costs fell from $45 per cwt, at 100,000 pounds of production, to $23 per cwt at 2.5 million pounds. Beyond that threshold, costs vary little (fig 8).[14] While there is a range of actual costs around the averages, the evidence from the hog surveys indicates that large industrialized hog operations hold substantial cost advantages over smaller farms. The scale effects may be even stronger in more complex statistical analyses that control for location, production practices, and operator characteristics (McBride and Key, 2003: McBride, Key, and Mathews, 2008).

[14] If we assume that a feeder-to-finish operation takes 50-pound pigs and feeds them to 250 pounds, then 1 million pounds of liveweight production will correspond to 5,000 hogs.

Broilers

Broiler production requires a significant investment in physical capital. Farms use specialized broiler houses, which include automated equipment for providing feed and water to the birds as well as sophisticated climate control systems. Modern farms also use mechanized equipment to gather broilers for shipment to processing plants and to remove litter from the houses. Scale economies arise from innovations in the design and utilization of structures and equipment, which also allow for more effective use of labor. While scale economies in poultry processing are large and extensive (Ollinger et al., 2000), those in broiler grow-out are modest, but they have increased over time.

The most common broiler house built in the last decade covers 20,000 square feet (40 feet wide and 500 feet long).[15] Given typical flock turnover, a single house of that size can produce 115,000-135,000 birds in a year, depending on bird size. However, further economies in the use of feeding and watering equipment, as well as litter removal and storage, can be realized by operating houses in pairs, which raises the minimum efficient scale of an operation to 230,000-270,000 birds a year. Few houses built in recent years are less than 20,000 square feet, and an operation with production well below 230,000 head would see noticeably higher costs arising from limited capacity utilization, or from the higher per-unit costs of building smaller facilities.

[15] The measures described are drawn from the 2006 ARMS broiler survey.

Some grow-out operations have up to 18 houses, but the major technology-related scale economies lie in house size and feeding equipment, so most of the available advantages of scale can be realized at what is a modestly sized operation today. Almost all production in the 1950s and 1960s came from much smaller operations than today. The development of new scale econo-

mies in grow-out houses and equipment has driven the gradual increases in broiler farm size.

Beef Cattle

Cattle feeding requires a significant investment in physical capital. Feedlots use mechanized equipment for feed milling, handling, and storage, and for manure removal, storage, treatment, and transport. They use vehicles for transporting animals, pens for holding them, and other specialized structures (Martin, 1979). Equipment and structures are subject to economies of scale from two sources. First, although larger facilities cost more than smaller facilities, their cost per unit of capacity is often lower. Second, once they are built, the fixed costs of the capital can be spread across more animals if the lot can operate near capacity, so that automation favors year-round intensive use of facilities. As a result, commercial feedlots became year-round operations, while farmer-feedlots often operated seasonally.

Krause (1991) reviewed studies of feedlot scale economies that were performed during the industry's transition in the 1960s and 1970s from small farmer-feedlots to large commercial operations. Two findings stand out, and are common to other studies of livestock feeding costs. First, substantial scale economies, up to a threshold size level, derive from more intensive use of equipment, structures, and labor. Second, above the threshold there were a wide range of large sizes over which costs varied modestly, and did not rise. This bears out the wide range of commercial feedlot sizes that we see persisting to this day.

Our best evidence and most complete data—that for hogs and dairy—shows that costs fall sharply as enterprise size increases, up to some threshold level. Technological scale economies, associated with structures and equipment, seem to account for the cost advantages. The broiler and fed-cattle industries also appear to be subject to size-related cost advantages over some range of production. Moreover, none of the livestock industries appear to display a unique optimal size, once scale economies are exhausted. Farms with 2,000 dairy cows have average costs similar to farms with 1,000 cows, as do farms with 12,000 or 5,000 finishing hogs. Farms can get quite large, without realizing scale diseconomies.