## Production Costs and Structural Change in Hog and Milk Production[11]

Industries grow and expand in different areas largely because of cost advantages associated with production in each area. Because of the importance of costs of production as a determinant of industry structure, the relationship between farm structural and performance characteristics and the costs of production is examined in each structural change area. Regression analysis is used to measure the relationship between production costs and the characteristics of hog and dairy operations. Results of the regression analysis should demonstrate the relative economic incentives available to producers in each set of counties. These incentives can then be used to guide speculation about structural change in hog and milk production.

Structural differences among the areas are identified by testing for differences between the coefficients estimated for each area. A t-test for the equivalency of two regressions is used to measure structural differences (see appendix). These t-statistics indicate whether the estimated coefficients in an area are different from the estimated coefficients in other areas. A significant difference between coefficients suggests that variables affect production costs differently in each area. Nonsignificant coefficients mean that the effects are much the same regardless of the area.

The regression analysis provides information about the direction and magnitude of influence each variable has on production costs, but does not indicate the relative importance of variables in explaining why costs vary among livestock operations. Therefore, the sample variation of unit cost is decomposed into the portion attributable to each variable in order to determine the degree of influence each variable exerts on cost (see appendix). The coefficient of separate determination is used to show the extent to which each explanatory variable alone contributes to unit-cost variation, relative to other variables. These coefficients are also used to compare each variable's contribution to unit-cost variation among the structural change areas.

[11]Much of this section was taken from McBride, W.D., *Structural Change in Hog and Milk Production, 1969-92*, a paper presented at the 1997 meetings of the American Agricultural Economics Association, Toronto, ON, Canada, July 1997.

### Model Specification

Production costs include costs of cash expense items and capital replacement, measured per cwt of live weight gain for hogs and per cwt of milk sold for dairies. Cash expense items include farm "out-of-pocket" expenses incurred during the production of each commodity. Included are both variable costs, such as feed, veterinary and medicine, and fuel, and the fixed costs of farm overhead, taxes and insurance, and interest. Capital replacement cost is the amount that must be set aside each year so that capital items can be replaced over time and the farm can continue producing. Capital replacement costs need not be paid each year, but eventually must be met in order for the farm to stay in business. Variables used to explain the variation in cash and capital replacement costs include measures of size of the livestock operation, specialization in livestock production, input efficiency (feed and labor), productivity, and use of debt financing on the farm operation. Similar variables are used in equations for both the hog and dairy industries so that the effects of each characteristic can be compared between the industries, as well as among the structural change areas (fig. 20).

Size of the hog operation is measured by head of sales and/or removals, while size of the dairy operation is measured by head of cows milked. Production costs are expected to be inversely related to size of operation. Although variable costs may be similar among farms of different sizes, larger farms typically have lower total unit costs because costs of fixed inputs, such as machinery, buildings, and equipment, are spread over more units of output. A second-degree term is also included to measure the effect of size on production costs because it is expected that costs will decline with size at a decreasing rate. Thus, the coefficient on the squared term is expected to be positive.

Specialization in hog and milk production is measured as the percentage of the total value of farm production attributed to hog sales and contract removals on hog operations and milk sales on dairy operations. More specialized operations are expected to have lower production costs than more diversified operations. Operators of more specialized operations can devote their time to fewer enterprises and are likely to have developed greater managerial skills and be more aware of cost-saving techniques.

Figure 20
**Variables used in the unit-cost equation for FCRS hog and dairy operations**

| Variable description | Measured among hog operations as | Measured among dairy operations as | Expected relationship with unit production costs |
|---|---|---|---|
| Unit production costs | Cash plus capital replacement costs | Cash plus capital replacement costs | na |
| Size | Head of hogs and pigs sold or removed | Head of cows milked | Negative |
| Size squared | Head of hogs and pigs sold or removed squared | Head of cows milked squared | Positive |
| Specialization | Percent of farm sales from hogs | Percent of farm sales from milk | Negative |
| Feed efficiency | Pounds of feed fed per cwt of gain | Pounds of feed fed per cwt of milk sold | Positive |
| Labor efficiency | Hours worked per cwt of gain | Hours worked per cwt of milk sold | Positive |
| Productivity | Number of pigs sold/removed per litter farrowed | Pounds of milk produced per cow milked | Negative |
| Debt financing | Debt-to-asset ratio | Debt-to-asset ratio | Positive |
| Debt financing squared | Debt-to-asset ratio squared | Debt-to-asset ratio squared | Negative |

na=Not applicable.
Source: Variables are taken from the 1992 Farm Costs and Returns Survey data for hogs and the 1993 Farms Costs and Returns Survey data for dairy.

Major inputs used in hog and milk production include feed, labor, and capital. Feed cost accounts for about 60 percent of total cash costs. Feed efficiency is measured as the pounds of feed used to produce 100 pounds of gain for hogs and 100 pounds of milk sold for dairies. Unit costs are expected to rise with feed consumption. Likewise, production costs are expected to increase as more labor is used. Labor efficiency is the hours worked per cwt gain for hogs and cwt milk sold for dairy. Improved labor efficiency often results from investments in capital intensive production facilities and methods that tend to lower unit production costs. Because of the high correlation between labor and capital use, a measure of capital use efficiency is not included in the model to avoid problems associated with collinearity.

Productivity on hog operations is measured by the number of hogs sold/removed per litter farrowed. On dairy operations, milk sold per cow is used to measure productivity. Both measures indicate animal performance and should have a negative relationship with production costs. These variables also indicate the level of managerial ability.

The effect of debt financing on the cost structure of hog and dairy farms is examined by including the farm debt-to-asset ratio. Two reasons producers may finance their operations with debt are: (1) to meet short-term financial obligations, and (2) to make long-term investments in production facilities and equipment, most likely expanding the size of the operation. In both cases, the use of debt financing will likely increase production costs through added interest payments. However, for producers expanding their operation with added debt, the cost advantages associated with greater production will likely offset some of the added interest cost. For these reasons, a second-

degree polynomial is used to model the relationship between the debt-to-asset ratio and production costs. Production costs should increase with the debt-to-asset ratio at a decreasing rate, thus the coefficient on the squared term is expected to be negative.

## Regression Results Among Hog Producers

Regression coefficients and their significance for hog production in each structural change area are presented in table 12. Also included are the t-statistics that test for structural differences among the areas. For example, the t-statistic between areas 1 and 3 concerning the coefficients on labor efficiency shows a significant difference. This means that the influence of labor efficiency on production costs is different in area 1 than in area 3.

Coefficients on the two size variables in each area have the expected sign, suggesting that hog production costs decline with size at a decreasing rate. However, size is a significant determinant of production costs only in area 3 where hog production costs decline with size toward a minimum on operations with about 6,500 head of sales/removals. Also, the effects of size on production costs do not vary among the areas as any differences between coefficients in each area are insignificant. The degree of farm specialization in hog production is not significant in any of the areas.

The positive sign on coefficients for the feed and labor efficiency variables indicate that production costs increase as more units of each input are required to produce 100 pounds of pork. Both input efficiency measures are significant in all areas. Each additional pound of feed adds 5-6 cents to per cwt hog production costs with no significant differences between the areas. This means that feed efficiency affects hog production costs much the same way regardless of where the hogs are produced. In contrast, the influence of labor efficiency on production costs varies by area (fig. 21). The effect of labor efficiency on production costs is significantly greater in area 3 where each additional labor hour adds about $5 to per cwt production costs. In both areas 1 and 2, another hour of labor adds only $3 or less to per cwt costs.

Variation in productivity, both within and between areas, does not significantly affect per cwt production costs. Coefficients are insignificant in each area regression as well as in tests between areas. The debt financing variables have a significant impact on hog production costs only in area 3, where increasing the debt-to-asset ratio causes per cwt costs to rise at a decreasing rate. Debt financing also has a significantly larger impact on costs in area 3 than in either areas 1 or 2.

Results of the unit-cost decomposition for each area are shown in table 13. Coefficients of separate deter-

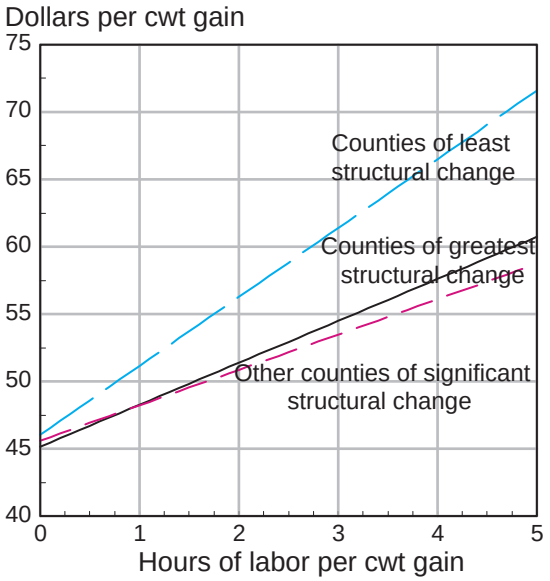
**Table 12—Regression estimates of the unit cost equation for FCRS farrow-to-finish hog farms in each structural change area**

| Variable | Coefficient estimates | | | t-statistics between areas | | |
|---|---|---|---|---|---|---|
| | Counties of greatest structural change (area 1) | Other counties of significant structural change (area 2) | Counties of least structural change (area 3) | area 1 area 2 | area 1 area 3 | area 2 area 3 |
| Intercept | 22.55238334** | 18.96616561** | 13.20161521** | 0.29 | 0.81 | 0.77 |
| Size | -0.00438329 | -0.00159539 | -0.00267397** | -0.61 | -0.39 | 0.49 |
| Size squared | 0.00000076 | 0.00000022 | 0.00000020** | 0.95 | 1.11 | 0.07 |
| Specialization | 0.00726050 | 0.00332870 | -0.00384469 | 0.06 | 0.17 | 0.14 |
| Feed efficiency | 0.05155645** | 0.06002404** | 0.05112888** | -0.70 | -0.04 | 1.28 |
| Labor efficiency | 3.10914649** | 2.62294363** | 5.10818337** | 0.26 | -1.77* | 2.01** |
| Productivity | 0.25703416 | -0.05720108 | 0.56805690 | 0.33 | -0.34 | -0.81 |
| Debt financing | 13.74620724 | 9.80491317 | 49.92185892** | 0.14 | -1.66* | - 2.45** |
| Debt financing squared | -45.84375424 | 4.71430784 | -55.81238616** | -1.07 | 0.20 | 2.95** |
| F | 11.57** | 24.34** | 78.44** | | | |
| $R^2$ | 0.5650 | 0.5735 | 0.6787 | | | |

**significant at the 5-percent level; *significant at the 10-percent level.
Source: Compiled by ERS using 1992 Farm Costs and Returns Survey data.

Figure 21

**Estimated relationship between hog production costs and labor efficiency in each structural change area**




Source: Compiled by ERS using Farm Costs and Returns Survey data.

mination indicate the portion of cost variation explained by the regression model that can be attributed to each explanatory variable. Feed efficiency has the greatest individual effect on unit-cost variation, accounting for more than half of the total explained variation in all areas. However, feed efficiency is relatively more important for explaining unit-cost variation in area 1 than 2, and in area 2 than 3. In contrast, labor efficiency has a relatively larger impact on unit-cost variation in area 3 than in the other areas. Labor efficiency accounts for about 37 percent of explained variation in area 3 compared with about 20 percent in area 2 and less than 10 percent in area 1.

## Regression Results Among Milk Producers

Regression coefficients and their significance for milk production in each structural change area are presented in table 14, along with the t-statistics that test for structural differences among the areas. A significant t-statistic indicates a significant difference of coefficients between areas. For example, the significant t-statistic on operation size between areas 1 and 3 means that the influence of size on production costs is different in area 1 than it is in area 3.

Size of the dairy operation is a significant determinant of unit production costs in areas 1 and 3, but not in area 2. In accord with prior expectations, milk production costs in areas 1 and 3 decline with size at a decreasing rate. However, the degree to which size influences production costs is significantly different between areas 1 and 3. Per cwt production costs decline with size much more gradually in area 1 and reach a minimum on operations of about 4,500 cows (fig. 22). In contrast, production costs are much more responsive to size of operation at lower herd levels in area 3 with the relationship declining to about 1,400 cows.[12] The degree of farm specialization in milk production is significant only in area 2.

As with hog production, feed and labor efficiency are significant determinants of milk production costs in all areas. Coefficients on the feed and labor efficiency variables indicate that production costs increase as more units of each input are required to produce 100 pounds of milk. Each additional pound of feed adds 2-4 cents to per cwt milk production costs. An additional hour of labor increases production costs by $7-$10 per cwt of milk. The impact of neither input efficiency measure is significantly different among the structural change areas.

The coefficient on the productivity variable is significant in areas 2 and 3, but not area 1. In both areas 2 and 3, unit costs decline by about 3 cents for each additional 100 pounds of milk produced per cow. The average productivity of cow herds is higher in area 1 and the significance of coefficients in other areas suggests that incentives exist to raise the level of productivity in these counties.

Increasing the debt-to-asset ratio causes higher per cwt costs in all areas. Estimated coefficients are significant for the linear term on the debt-financing variables in all areas, but significant for the quadratic term only in area 3. The impact of debt financing on unit production costs does not appear to vary significantly by area.

The decomposition of unit costs for each area is shown in table 15. Each explanatory variable contributes a portion to the total explained variation of unit costs as indicated by its coefficient of separate determination. Feed efficiency has the greatest individual effect on unit-cost variation in area 1, account-

[12]Nearly all of the dairy operations in area 3 had fewer than 1,000 cows, and little can be concluded about production costs on operations larger than 1,000 cows in this area. The increasing portion of the cost relationship shown in figure 22 results mainly from the best fit of the curve through operations with fewer than 1,000 cows.

**Table 13—Contribution of factors to unit-cost variation for FCRS farrow-to-finish hog farms in each structural change area**

| Variable | Coefficients of separate determination[1] | | |
|---|---|---|---|
| | Counties of greatest structural change (area 1) | Other counties of significant structural change (area 2) | Counties of least structural change (area 3) |
| Size | 0.0941 | 0.0248 | 0.0249 |
| Size squared | -0.0493 | -0.0131 | -0.0059 |
| Specialization | -0.0042 | -0.0000 | 0.0009 |
| Feed efficiency | 0.4627 | 0.4200 | 0.4056 |
| Labor efficiency | 0.0521 | 0.1185 | 0.2497 |
| Productivity | -0.0048 | 0.0009 | -0.0014 |
| Debt financing | -0.0192 | 0.0143 | 0.0069 |
| Debt financing squared | 0.0336 | 0.0082 | -0.0021 |
| Total (explained variation) | 0.5650 | 0.5735 | 0.6787 |
| Unexplained variation | 0.4350 | 0.4265 | 0.3213 |

[1]See appendix for derivation of the coefficient of separate determination. Negative coefficients indicate that these variables do not help to explain variation in unit production cost.
Source: Compiled by ERS using 1992 Farm Costs and Returns Survey data.

**Table 14—Regression estimates of the unit-cost equation for FCRS dairy farms in each structural change area**

| Variable | Coefficient estimates | | | t-statistics between areas | | |
|---|---|---|---|---|---|---|
| | Counties of greatest structural change (area 1) | Other counties of significant structural change (area 2) | Counties of least structural change (area 3) | area 1 area 2 | area 1 area 3 | area 2 area 3 |
| Intercept | 12.33480082** | 14.70176749** | 14.69026038** | 0.54 | -0.66 | 0.03 |
| Size | -0.00199114** | 0.00717563 | -0.01030164** | -1.04 | 2.62** | 1.89* |
| Size squared | 0.00000022** | -0.00000593 | 0.00000357** | 0.98 | -2.82** | -1.66* |
| Specialization | -0.01101320 | -0.05248013* | 0.00584498 | 1.49 | -1.18 | - 1.96** |
| Feed efficiency | 0.03590675** | 0.02603670** | 0.02156782** | 0.71 | 1.07 | 0.81 |
| Labor efficiency | 7.47253200** | 9.49891501** | 8.53600685** | -0.57 | -0.52 | 0.32 |
| Productivity | -0.00029065 | -0.00021606** | -0.00031455** | -0.29 | 0.09 | 0.71 |
| Debt financing | 5.80694695** | 6.17801771* | 5.78993232** | -0.07 | 0.00 | 0.08 |
| Debt financing squared | -4.34394962 | -8.18316604 | -6.03293727** | 0.50 | 0.39 | -0.29 |
| F | 23.86** | 11.39** | 104.11** | | | |
| $R^2$ | 0.4893 | 0.6866 | 0.7434 | | | |

**significant at the 5-percent level; *significant at the 10-percent level.
Source: Compiled by ERS using 1993 Farm Costs and Returns Survey data.

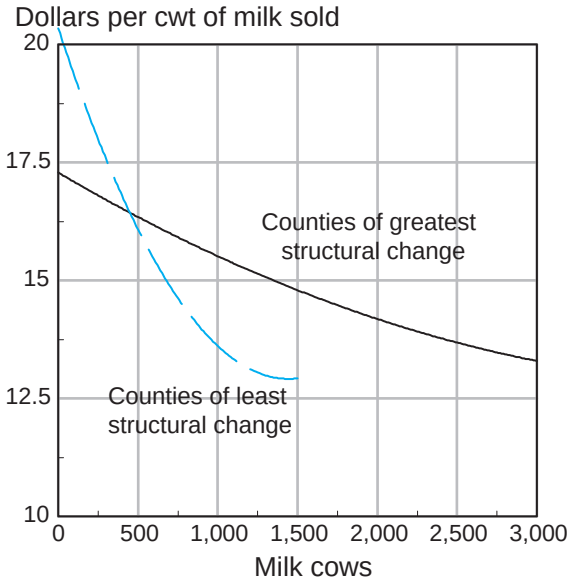
ing for about 45 percent of the total explained variation. However, in other areas labor efficiency is more important. Labor efficiency accounts for about half of the explained variation in areas 2 and 3, while feed efficiency comprises 39 percent in area 2 and 23 percent in area 3. As with hogs, the relative importance of feed efficiency in explaining unit-cost variation is greater in area 1 than 2, and area 2 than 3. Conversely, labor efficiency is more important in area 3 than 2, and area 2 than 1.

## Production Costs and Structural Change: Conclusions

Regression models relating structural and performance characteristics to hog and milk costs of production explain a substantial amount of the variation in cash and capital replacement costs in each structural change area. In counties of greatest change the regression models explain about half the variation in hog and milk production costs, while in other counties nearly 70 percent of cost variation can be attributed to

Figure 22

**Estimated relationship between milk production costs and size of the cow herd in each structural change area**




Source: Compiled by ERS using Farm Costs and Returns Survey data.

the explanatory variables. Also, several explanatory variables were significant in each estimated equation. These findings suggest that the chosen variables are important determinants of hog and milk production costs in each area.

Economic incentives among hog producers in counties of greatest structural change and in other counties of significant structural change are mainly to improve input use efficiency without regard to size of the operation. Significant cost savings appear to be available among producers in these counties through updating facilities, equipment, and production methods that improve feed and labor efficiency. Also, the financial position of these producers does not appear to be a significant obstacle to adding size and modernizing operations.

Producers in counties of least structural change appear to have strong incentives to not only improve input efficiency, but also to expand size of the hog operation. Adding size significantly lowers unit production costs among producers in these counties. Likewise, the impact of improved labor efficiency is significantly larger than in the other counties, suggesting greater incentives than in other counties to update and improve the capital stock and production methods. However unlike in the other counties, expansion through added debt appears to come at a significantly greater cost to producers in the counties of least change. Producers in these counties have smaller hog operations and capital may be more expensive because less is borrowed. The effect of higher production costs via debt financing does diminish as more is borrowed.

Milk producers in all counties also have strong economic incentives to improve input use efficiency, but significant cost savings appear to be available to producers in counties of greatest change by expanding the size of the operation. Average herd size is already substantially larger among producers in these counties, and incentives seem to exist for larger, mega-milk production operations of 4,000-5,000 cows. Although the ability to finance expansion through debt may be restricting, this finding suggests that forces underlying structural change in the counties of greatest change will persist.

Incentives for expanded milk production on farms in other counties of significant change are not as apparent. Rather, most significant cost savings appear to be available to producers in these counties through updating facilities, equipment, and production methods that improve feed and labor efficiency. Most of these counties are located in traditional production areas of the North, including the States of Wisconsin, Minnesota, Michigan, and New York. Expanding production in these areas requires greater investment in facilities that house cows during the harsher winter months. Greater economic incentives for producers in these counties appear to be for improving efficiency and productivity without regard to size of operation.

Milk producers in counties of least structural change appear to have several incentives for upgrading their operations, such as improved input efficiency and productivity, and expansion. However, the effect of added size on production costs is significantly different than in counties of greatest change. Producer costs decline much more sharply during expansion at lower herd levels in the counties of least change. Structural change is likely to continue in these counties, but incentives for mega-milk production operations do not exist as in the counties of greatest change. Expansion is also limited by higher costs associated with added debt.

Among hog producers, feed efficiency is the primary factor influencing unit production costs in all areas,

**Table 15—Contribution of factors to unit cost variation for FCRS dairy farms in each structural change area**

| Variable | Coefficients of separate determination[1] | | |
|---|---|---|---|
| | Counties of greatest structural change (area 1) | Other counties of significant structural change (area 2) | Counties of least structural change (area 3) |
| Size | 0.0221 | -0.0074 | 0.0292 |
| Size squared | -0.0027 | 0.0018 | -0.0034 |
| Specialization | 0.0138 | 0.0295 | -0.0065 |
| Feed efficiency | 0.2210 | 0.2679 | 0.1679 |
| Labor efficiency | 0.1589 | 0.3388 | 0.4253 |
| Productivity | 0.0764 | 0.0590 | 0.1241 |
| Debt financing | -0.0128 | -0.0058 | -0.0076 |
| Debt financing squared | 0.0126 | 0.0028 | 0.0146 |
| Total (explained variation) | 0.4893 | 0.6866 | 0.7434 |
| Unexplained variation | 0.5107 | 0.3134 | 0.2566 |

[1]See appendix for derivation of the coefficient of separate determination. Negative coefficients indicate that these variables do not help to explain variation in unit production cost.
Source: Compiled by ERS using 1993 Farm Costs and Returns Survey data.

while its level of importance is highest in counties of greatest structural change. Likewise, feed efficiency is the most important factor influencing milk production costs in counties of greatest structural change. Many of these hog- and milk-producing counties are in nontraditional production areas where feedgrain and forage supplies are more limited. Higher feed prices in these areas place a premium on feed efficiency. Expansion of hog and milk production into areas of limited feed supplies can be costly because of significant costs associated with transporting bulky feedstuffs long distances. Also, risk exposure is greater in these areas due to the greater dependence on purchased feedgrains and forage and their price fluctuations. Despite the disadvantage of less locally available feed, both hog and milk production in nontraditional areas expanded substantially during the study period largely because of the advantages associated with large-scale production and the adoption of feed-efficient production methods.