**Staff Paper P97-2** **January 1997**

# STAFF PAPER SERIES

## ARE LARGE FARMS MORE EFFICIENT?

**Willis L. Peterson**
**Morse Distinguished Teaching Professor**

**DEPARTMENT OF APPLIED ECONOMICS**
**COLLEGE OF AGRICULTURAL, FOOD AND ENVIRONMENTAL SCIENCES**
**UNIVERSITY OF MINNESOTA**

ABSTRACT

ARE LARGE FARMS MORE EFFICIENT?

Accurate estimates of returns to scale require that inputs and output are measured without error and that environmental and managerial differences among firms of varying sizes are taken into account. Measurement problems affecting estimates of returns to scale in agriculture include: (1) combining the farm dwelling with capital inputs, (2) correlation of environmental and management characteristics with size and (3) the effect of off-farm employment on small farm output and production costs. Estimates of long run average total cost curves for farms in the corn belt reveal that after the above factors are taken into account, estimated scale economies in agriculture disappear, while there is evidence of diseconomies as farm size increases.

The proposition that large farms are more efficient than small ones, namely that economies of scale exist in U.S. agriculture appears to be widely accepted both by the public and the profession. The growth in size and decrease in number of farms over the past half century is consistent with this hypothesis. Moreover numerous empirical studies have reported scale economies. (See for example, Ahearn, Whittaker, and El-Osta; Batte and Sonka; Cooke and Sundquist; Griliches; Hallem; Hayami and Ruttan; Kumbhakar, Biswas, and Bailey; Madden and Partenheimer; Moschini).

Recently, questions have been raised about the validity of the scale economies hypothesis (Kislev and Peterson, 1996). We are reminded here that scale economies must be a temporary, disequilibrium phenomenon since, according to Euler's theorem, payments to factors will exceed output. Obviously this situation cannot persist indefinitely. Yet conventional estimates of returns to scale in U.S. agriculture have not decreased over the past 40 years. Moreover, returns to scale estimates did not decline during the 10-year period mid 1970s to mid 1980s even though farm size remained relatively constant during this time. It is argued, therefore, that estimates of returns to scale have been biased upward.

Accurate estimates of returns to scale require that inputs and output be measured without error and that environmental and managerial differences which may exist for firms of varying sizes are taken into account. Labor quality is often cited as a source of bias. If large farms are managed by more capable people, as seems likely, and this is not reflected in the labor measure, the labor input on large farms will be understated causing an upward bias of returns to scale estimates. Use of covariance analysis to account for management or labor skills differences among farms has resulted in reduced estimates of returns to scale (Kislev; Mundlak). The evidence also suggests that education, a proxy for managerial ability, is associated with larger farm size (Sumner and Leiby).

The overall objective of this study is to assess the impact of several measurement problems inherent in agricultural census data. Much of what we know about returns to scale in agriculture is based on these data. These problems include (1) the addition of the farm dwelling to capital inputs, (2) differences among farm sizes in land and management quality, and (3) differences in off-farm employment.

## MEASUREMENT PROBLEMS

1. Farm dwelling. To estimate the value of land and buildings on farms, the agricultural census asks respondents to report the value of land and *all* buildings, including the value of the farm dwelling. As a result, the service flow, or implicit rental value of the house, does not show up as farm output but the house is included among the inputs. More importantly, the house accounts for a larger share of the inputs on small farms than on large farms. The house also accounts for a larger share of output on small farms. Indeed, for small part-time and hobby farms the service flow of the house and yard probably is the main output of the farm, i.e. the reason for living there. Since the upward bias of inputs, and downward bias of output, increase as farm size decreases, inclusion of the house in capital inputs leads to an upward bias of estimated returns to scale, at least using census or other data where the house and yard are included in the value of land and buildings.

2. Land Quality. As indicated in the next section, yields on large farms are substantially higher than on small farms. This should be cause for concern; a plant or an animal does not know if it is growing on a large or small farm. Under similar management and environmental conditions,

biological efficiency should not vary among size groups. Differences in yields are likely to stem mainly from land quality differences. And evidence will be presented which seems to indicate large farms are situated on higher quality land than small farms, at least in the corn belt. Failure to take into account land quality will make it appear that large farms are more productive than small farms, i.e. that economies of scale prevail, when in fact we may be observing economies of better quality land and higher yields.

3. Off-Farm Employment. This activity which is more prevalent on small farms has several effects on the farm operation. Because the principal operator and/or family members now have less time to allocate to the farm, there can be an economic decision to shift towards a less intensive management level. Management is not only knowing what to do and when to do it, but it also has an opportunity cost. For example, more timely planting and harvesting that jeopardizes the off-farm job, or results in a reduction in off-farm earnings in excess of what is gained on the farm, will not be economically justified. Like other inputs, there is an optimal level of management for each farm depending on its cost and returns. A lower level of economically justified management on small, part-time farms along with lower quality land can explain their apparent lower level of technical efficiency, and apparent scale economies. This does not mean that off-farm work of small farm operators is socially wasteful. As long as what is gained from off-farm work exceeds what is given up on the farm, which must be the case if willingly done, there is a net gain to society by off-farm work.

This is not to say that managerial ability, however defined, of small farm operators is equal to those who operate large commercial operations. Presumably large farms are more difficult to manage than small ones. In the long run, a manager will increase the size of the farm until the long run average total cost curve begins to turn up. For better managers this quantity will be larger than it is for their less skillful counterparts. Moreover, one would expect the payoff to investment in acquiring management skills to be greater among capable managers of large farms than it is for their less capable, small farm counterparts. More investment in human capital will take place by those who reap a higher return. The less skillful managers can maximize income by keeping the farm small while supplementing earnings from off-farm employment where management decisions are made by someone else.

Family background also makes a difference. The operator who takes over or inherits a family farm consisting of 1000 acres of prime cropland is more likely to end up with a large commercial farm then one whose parents owned 160 acres of marginal land. The latter will more likely be a part-time farmer, at least if jobs are available within commuting distance. Both could be of equal managerial ability. Where one ends up depends a lot on where one starts.

## Data and Methodology

Agricultural census data, Volume II, "Government Payments and Value of Sales," (1987) are employed to measure efficiency differences among size classes. Nine sales classes are reported for each state ranging in size from $500,000 and above to $2500 and below. These data are well suited for measuring returns to scale because of the large variation in farm size. Also, cross-section data depict long run relationships and returns to scale is a long-run concept.

Ten Corn Belt states are included in the sample making a total of 90 observations: IL, IN, IA, MI, MN, MO, NE, OH, SD, and WI. Data are from the 1987 agricultural census. Because 1987 was not an atypical year for prices or production, abnormal costs and/or inventory changes should not be major problems, especially among size groups.

Returns to scale are defined by the long run average total cost (LRATC) curve. A negative relationship between LRATC and output implies economies of scale while a positive relationship implies diseconomies. Because farms produce and sell a variety of products, output is measured in monetary terms. Thus LRATC is dollar(s) per dollar of output.

The data are available for nine size classes based on sales. Each size class is represented by a 0-1 dummy; the middle size is the reference dummy. This allows the estimated LRATC curve to take on any shape dictated by the data. Use of continuous data with a specific functional form can yield results contingent on that form. The flexible dummies allow for any shaped LRATC curve including a horizontal line, a ski-jump shaped line, a U-shaped curve, or any combination of these.

The LRATC curve is estimated by the following equation:

$$\mathbf{LRATC = f(S_1,...S_4,\ S_6...S_9,X_1,\ X_2)}$$

Size group $\mathbf{S_1}$ is the smallest ($2500 sales and less) and $\mathbf{S_9}$ is the largest ($500,000 sales and over). Variables $\mathbf{X_1}$ and $\mathbf{X_2}$ represent two characteristics defined later, that can influence LRATC other than size.

**Size Characteristics**

To facilitate presentation of the data in Table 1, the nine size classes are aggregated into three groups with three classes in each. The large group includes farms with $100,000 of sales and over, while the small group's farms have sales of less than $10,000.

Although no direct information is available on land quality and topography in the census, indirect evidence suggests that large and small farms operate in different geographic environments, at least in the corn belt. As shown in Table 1, small farms have a smaller proportion of land in crops and exhibit lower yields. Because of the relatively small percent of land in harvested crops, small farms appear to be located in areas where woods, hills, and sloughs are more common. Generally these correlate with lighter forest soils and a topography of hills and small, odd-shaped fields. In contrast, areas where cropland is a large percent of the total tend to be characterized by relatively level or, gently rolling terrain, heavier prairie soils, and large square or rectangular fields, at least in the states included in this study.

Land quality and topography are expected to influence unit production costs. The per acre cost of tillage, planting, weed control, and harvesting does not vary in proportion to yields. Thus high quality land will entail lower costs per unit of output., Moreover, there is less travel and turning time per acre when fields are large and rectangular shaped. This also reduces unit costs. Because of the positive correlation of farm size with soil fertility and favorable topography for crop production, part of what appears to be economies of scale can instead be economies of fertile soil and large, level fields.

Cropping patterns between large and small farms also differ. Corn and soybeans account for about two-thirds of harvested cropland on large farms, and only about one-third on small farms. The proportion of harvested cropland in small grains and hay is the opposite--almost two-thirds on small and one-fourth on large farms. Since corn and soybeans are high value crops, the difference in cropping patterns can make it appear that large farms are more productive. In part, the difference in cropping patterns may stem from difference in land quality.

In spite of the likelihood of higher quality land on large farms, per acre value of land and buildings is highest on small farms (Table 1). This could be due to the higher proportion of the house in total assets of small farms. Also one might expect small farms to be located closer to population centers where off-farm employment is more readily available but where land prices are relatively high. Higher land prices that are unrelated to land quality for agricultural purposes also will make small farms appear less efficient.

Information on days of off-farm work is available for principal operators only. Income from this source was estimated form manufacturing wages in each state. Although income from off-farm work typically is not added to the farm's output or sales, the separation of the two is not strictly correct. Because part-time farmers have less time to carry out non-routine tasks such as repairs and maintenance, animal health care, and harvesting, the purchase of professional services to perform such tasks will be more prevalent among small farms. These inputs add to the costs but off-farm earnings that require and help pay for these services are deleted from measured output, again biasing the results in favor of economies of scale. This phenomenon is similar to homemakers who work outside the home and use part of their earnings to purchase child care services, labor-saving appliances, convenience foods, and restaurant meals.

The fact that repairs and maintenance expense per dollar of sales is nearly four times higher on small than large farms supports the contention that the latter rely more heavily on purchased services. Part of this difference could be due to the use of older machinery by small farms. By purchasing lower cost used machines and spending proportionately more on repairs and maintenance, small farms are able to convert fixed cost to variable cost, thereby diminishing the importance of lumpy inputs as a factor causing scale economies. Considering this added element of flexibility, machines can be purchased in an array of fixed and variable costs.

**TABLE 1**
**SIZE CHARACTERISTICS**
**TEN CORN BELT STATES**

| | Large | Medium | Small |
|---|---|---|---|
| **LAND AND CAPITAL PER FARM** | | | |
| Acres | 1359 | 326 | 94 |
| Percent harvested cropland | 63 | 50 | 26 |
| Crop yields | | | |
| Corn (bu./acre) | 126 | 100 | 85 |
| Soybeans (bu./acre) | 39 | 35 | 28 |
| Hay (tons/acre) | 2.7 | 2.2 | 1.6 |
| Percent of harvested cropland in: | | | |
| Corn and soybeans | 66 | 58 | 34 |
| Small grains and hay | 25 | 37 | 64 |
| Land and buildings ($1000) | 1023 | 208 | 80 |
| Per Acre ($) | 752 | 638 | 851 |
| Machinery and equipment ($1000) | 171 | 52 | 21 |
| **INCOME AND EXPENSES PER FARM ($1000)** | | | |
| Total sales | 518 | 36.8 | 3.7 |
| Income from off-farm work | 2.1 | 7.0 | 12.1 |
| Government payments | 31.8 | 4.8 | .32 |
| Out-of-pocket expenses | 411 | 28.8 | 5.3 |
| Percent repairs and maintenance | 5.7 | 9.3 | 11.7 |
| Per dollar of sales ($) | .045 | .073 | .168 |

**Source: Census of Agriculture, 1987, Vol. II, "Government Payments and Value of Sales".**

Psychic income adds another element of bias against small farms. Presumably such income is more important per dollar of sales for small, part-time and hobby farms than it is for large commercial enterprises. The cost of producing this income is counted among the inputs but not among the output. Psychic income is an attractive source of utility because it cannot be taxed while the cost of producing this utility can be written off against other income. This could in part explain the relative growth of part-time and hobby farms in recent times.

**The Farm Dwelling**

There are two ways to handle the farm dwelling. One is to subtract its estimated value from the total of land and buildings reported in the census. Second, an estimate of its implicit rental value can be added to farm output. To be consistent with Department of Commerce estimates of GDP, which includes the implicit rental value of owner-occupied housing as well as the value of food produced and consumed on farms, the second option is chosen. A figure of $400 per month ($4800 per year) per house is added to per farm output. While this figure probably was a lower bound of rental charges for country homes in 1987, it makes a substantial difference to the measured output of the smallest farms. Because partnership farms tend to have two houses, the rental figure is adjusted according to the proportion of partnerships in each size class. This adjustment affects mainly the larger farms. The USDA state average estimate of food produced and consumed on farms also is added as an adjustment to the output of each farm, although this is not a major adjustment, $385 per farm for the 10 state average.

**LRATC Estimates**

Total cost in LRATC is defined as out-of-pocket expenses less interest payments and property taxes plus a charge for capital. To convert capital cost to a flow, the capital charge is set equal to .10 of land and buildings plus .20 of machinery and equipment. Two LRATC curves are shown in Table 2. In Column 1, value of output is defined as sales plus government payments plus other farm related income plus value of food produced and consumed on farms. This is a conventional measure of output in LRATC. The figures in Column 1 show the results of averaging LRATC for each size class over the ten states.

The figures in Column 1 clearly depict substantial economies of scale. Average total cost per dollar of output ranges from over $5 in the smallest size group to 86 cents for the very largest farms.

The LRATC figures in Column 2 show the results of adding the implicit rental value of the farm dwelling to output. Now the difference between the small and large farms is reduced, but there is still evidence of scale economies.

A statistical test for scale economies of the figures in Column 2 is shown in Column 3. Positive coefficients on the size dummies imply that LRATC for the corresponding size group is higher than the mid-size reference group. Conversely, negative coefficients imply lower costs than the mean.

As shown in Column 3, the addition of the implicit rental value of the farm dwelling to output reduces but does not eliminate estimated scale economies. The smallest three groups exhibit positive and significant coefficients at the .01 level whereas the coefficients on the largest three groups are negative and significant implying economies of scale even at the very largest sizes. The three mid size groups exhibit constant costs.

The Column 4 regression includes two additional variables intended to account for environmental and managerial differences among the farms in the various size classes: corn

**TABLE 2**

**LRATC AND REGRESSION COEFFICIENTS**

| | **LRATC ($)** | | ***Regression Coefficients** | |
|---|---|---|---|---|
| **Size Class** | **(1)** | **(2)** | **(3)** | **(4)** |
| Constant | | | .964 (32.1) | .862 (10.6) |
| $S_1$ | 5.01 | 1.04 | .405 ( 9.54) | -.037 (-.409) |
| $S_2$ | 2.40 | .85 | .175 ( 4.12) | -.151 (-2.10) |
| $S_3$ | 1.76 | .87 | .126 ( 2.96) | -.131 (-2.16) |
| $S_4$ | 1.33 | .86 | .060 ( 1.41) | -.084 (-1.83) |
| $S_5$ | 1.10 | .84 | | |
| $S_6$ | .95 | .76 | -.075 (-1.76) | .082 ( 1.73) |
| $S_7$ | .89 | .75 | -.104 (-2.44) | .180 ( 2.76) |
| $S_8$ | .86 | .75 | -.115 (-2.72) | .228 ( 3.07) |
| $S_9$ | .86 | .82 | -.108 (-2.54) | .236 ( 3.19) |
| Corn Yields | | | | -.003 (-3.98) |
| Days of Off-Farm Work | | | | .005 ( 5.02) |
| $R^2$ | | | .767 | .830 |
| N | | | 90 | 90 |

***Figures in parenthesis are t-ratios.**

yields and days of off-farm work per farm by the principal operator. Since corn is the major crop in these ten states, average corn yield in each of the 90 size class observations is used as a proxy for land quality. This variable might also pick up LRATC variation due to field size and topography since yields tend to be higher where fields are large and nicely shaped for tillage and harvesting. Corn yields also could reflect managerial differences between large and small farms. Possibly better managers on large farms are able to coax higher yields by better management practices, or by applying higher doses of fertilizer and chemicals closer to the profit maximizing margin.

The days of off-farm work variable also can account for several inherent differences among size classes as discussed previously. First, the economic aspect of management is accounted for. That is, the opportunity cost of performing certain management functions, or performing them on time, may be higher than the expected returns because of off-farm work. This variable also accounts for the output measurement problem which occurs because of allocating part of off-farm earnings to hire professional services that would not otherwise have to be hired, but omitting off-farm earnings from the output measure. Thirdly, this variable also can be a proxy for the relative difference in psychic income among size groups since off-farm work is more prevalent among the smaller, part-time, hobby farms.

The results shown in Column 4 of Table 2 are most revealing. First, as expected, higher corn yields are associated with lower LRATCs while days of off-farm work have the opposite effect. Both coefficients are highly significant. More importantly, the signs on the dummy variables are reversed from what they were in equation (3). Now small farms exhibit smaller LRATC figures than the mid size reference dummy while the LRATCs on the four largest farm size groups are higher -- the largest three significantly higher, implying diseconomies of scale.

Diseconomies of scale does not mean that the long term growth in the average size of farm will cease. The optimal size of full time family farms will increase if off-farm wages increase relative to the cost of farm machinery services. The higher this ratio, the larger the optimal size of farm (Kislev and Peterson, 1982).

## Concluding Remarks

Factors that can influence unit costs in agriculture other than size include quality of land and management, the contribution of the farm dwelling to output, and the impact of off-farm employment on output and production costs. After accounting for these factors, it appears that small family and part-time farms are at least as efficient as larger commercial operations. In fact, there is evidence of diseconomies of scale as farm size increases.

## REFERENCES

Ahern, Mary C., Gerald W. Whittamer, and Hisham El Osta. "The Production Cost-Size Relationship: Issues and Estimates for Three Major Crops," In *Size, Structure and the Changing Face of American Agriculture,* edited by Arne Hallem. Boulder: Westview Press, 1993, pp. 107-49.

Batte, Marvin T. and Steven T. Sonka. "Before and After Tax Size Economies: An Example for Cash Grain Production in Illinois." *American Journal of Agricultural Economics* 67 (Aug. 1985):600-09.

Cooke, Stephen C. and W. Burt Sundquist. "Cost Efficiency in U.S. Corn Production," *American Journal of Agricultural Economics* 71(Nov. 1989):1003-1010.

Griliches, Zvi. "Research Expenditures, Education, and the Aggregate Agricultural Production Function," *American Economic Review.* 54(Dec. 1964):961-74.

Hallam, Arne. "Empirical Studies of Size, Structure, and Efficiency in Agriculture," In *Size, Structure and the Changing Face of American Agriculture,* edited by Arne Hallem. Boulder: Westview Press, 1993, pp. 204-231.

Hayami, Yujiro and Vernon W. Ruttan. *Agricultural Development, An International Perspective.* Baltimore and London: Johns Hopkins University Press, 1985, 2nd edition.

Kislev, Yoav. "Overestimates of Returns to Scale in Agriculture--A Case of Synchronized Aggregation," *Journal of Farm Economics.* 48(Nov. 1966):967-83.

Kislev, Yoav and Willis Peterson. "Economies of Scale in Agriculture: A Reexaminationof the Evidence," In *Essays on Agricultural Economics in Honor of D. Gale Johnson,* Vol. 2, edited by John M. Antle and Daniel A. Sumner. Chicago: University of Chicago Press, 1996.

______. "Prices, Technology and Farm Size," *Journal of Political Economy*. 90(June1982):578-95.

Kumbhakar, Subal C., Basudeb Biswas and DeeVon Bailey. "A Study of Economic Efficiency of Utah Farmers: A System Approach." *Review of Economics and Statistics* 71(Nov.1989):595-604.

Madden, Patrick J. and Earl J. Partenheimer. "Evidence of Economies and Diseconomies of Farm Size." In *Size, Structure, and Future of Farms.*, edited by Gordon A. Ball and Earl O. Heady. Ames: Iowa University Press, 1972.

Moschini, Giancarlo. "Nonparametric and Semi Parametric Estimation: An Analysis of Multiproduct Returns to Scale," *American Journal of Agricultural Economics* 72(Aug.1990):589-96.

Mundlak, Yair. "Empirical Production Function Free of Management Bias." *Journal of Farm Economics* 43(Feb.1961):44-56.

Sumner, Daniel A. and James D. Leiby. "An Econometric Analysis of the Effects of Human Capital, Size and Growth Among Dairy Farms," *American Journal of Agricultural Economics* 69(May1987):465-70.