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ECONOMIES OF SCALE AND OUTPUT FLEXIBILITY IN NORTHEASTERN U.S. DAIRY

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ABSTRACT

This paper argues that even with strong economies of scale, all farm sizes could have similar adjusted average costs and be equally competitive because the advantages of flexibility on small farms tend to offset those of economies of scale on large farms. Evidence from Northeastern U.S. dairy farms suggests that capital intensity and specialization increase with size, flexibility decreases with size, and small and large farms are equally viable despite slight economies of scale.

Key Words: Output flexibility, dairy farm size, economies of scale, risk, specialization, capital intensity.

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Agricultural economists generally argue that increasing returns to scale (IRS), which are more easily realized with capital intensive and specialized technologies, could make large farms more efficient than small farms. The coexistence of small and large farms in some agricultural subsectors have been attributed to constant returns to scale (CRS). The economies of scale argument has been used to justify the recent withdrawals of some government programs designed to preserve small family farms.

Recent studies in the industrial organization field, however, suggest that in industries characterized by IRS, small and large firms can coexist because small firms are more output flexible (flexibility theory). Flexibility theory argues that the greater specialization and capital intensity of large firms, which makes them more efficient when prices are stable, also makes them less output flexible when prices are unstable (Oi, 1981, 1983; Mills; Stigler; Mills and Schumann). The advantages of economies of scale, which only accrue when prices are stable, are said to be offset by the disadvantages of inflexibility. Agricultural economists argue that the tendency over time in U.S. agriculture towards larger and fewer farms, increased mechanization and capital intensity, reduced reliance on labor, and increased machinery and product specialization (Kislev and Peterson) could lead eventually to more efficient farms and lower real food prices. Flexibility theorists, however, would argue that real food prices and efficiency will not change in the long-run because the advantages and disadvantages to larger size balance out.

To investigate the true benefits of size, this paper summarizes flexibility theory and examines its validity in the Northeastern U.S. dairy sector. The findings could reshape opinions offered by economists to policy makers on farm consolidation, specialization and capital intensive technologies.

THE FLEXIBILITY THEOREM

The economies of scale hypothesis suggests that if the long-run average cost (LRAC) for a competitive industry is declining, all firms would be identically large in the long-run. However, heterogeneous technology will be possible under this scenario when LRAC is flat bottomed (CRS). This theory ignores differences in flexibility among firms and variability in prices.

The flexibility theory, however, suggests that when prices are unstable, differences in output flexibility among farms of different sizes help to explain heterogeneous technology. The explanations are as follows. First, (1) because a small firm is less capital intensive, its short-run average cost (AC_i) and marginal cost (MC_i) curves are flatter (Stigler, Merschak and Nelson), its AC_i has a higher minimum (Mills) and its short-run supply elasticities (n_i) is larger than that of a large firm. Second, a large firm is less flexible when prices vary (Stigler) but is more efficient when price is stable (economies of scale). Third, when price is not stable, the trade-off between flexibility and economies of scale makes realized production costs (AC_i^{**}) equal for firms of different sizes thus making heterogeneous technology possible (Mills and Schumann). Fourth, risk increases with size and inflexibility.

An illustrative proof of the flexibility theory, as found in Mills and Schumann, is presented next. In addition, the cost of inflexibility (CIF_i), which has been ignored in literature, is derived. It is also shown that the LRAC curve is irrelevant when prices are unstable and that the relevant costs are realized or adjusted costs (Adj. LRAC) which are more similar for firms of different sizes. Adj. LRACs account for differences in CIF_i among firms.

Proof and Illustration

Following Mills and Schumann, assume that the short-run total cost function of the i^{th} firm is $C_i = a_i + b_i Q_i + (1/2e_i)Q_i^2$ where C_i and Q_i are total cost and output; the intercept (a_i) is fixed cost; and b_i and e_i are coefficients of variable cost. $AC_i = a_i Q_i^{-1} + b_i + (1/2e_i)Q_i$, AC_i minimizing level of output (Q_i^*) is $(2a_ie_i)^{\frac{1}{2}}$, minimum AC_i (AC_i^*) is $b_i + (2a_i/e_i)^{\frac{1}{2}}$ and the supply curve is $Q_i^+ = ei(P - b_i)$ where $P > b_i$ (Mills and Schumann).

The profit of the i^{th} firm (Π_i) is $PQ_i^+ - C_i = [\frac{e_i}{2}][P - b_i]^2 - a_i$. Assuming a distribution of price such that its mean and variance are $\overline{P}$ and σ_P^2, this expression can be transformed into a polynomial function by a Taylor's series expansion around $\overline{P}$ as $\Pi_i = (\frac{1}{2})e_i(\overline{P} - b_i)^2 - a_i + e_i(\overline{P} - b_i)(P - \overline{P}) + (\frac{1}{2})e_i(P - \overline{P})^2$. $\overline{P}$ which is the simple average price is less relevant to the producer than the realized or weighted average price over a given time frame (P_i^{**}) which is weighted by output. The distribution of output for a particular firm determines its P_i^{**}. The expected profit $[E(\Pi_i)]$ is $(1/2)e_i(\overline{P} - b_i)^2 - a_i + (1/2)e_i\sigma_P^2$. Expected profit must be zero for each firm at long-run competitive equilibrium regardless of size (Dreze and Gabszewicz). Hence, the following long-run condition: $(\overline{P} - b_i)^2 + \sigma_P^2 = (2a_i/e_i)$, and the following expression for AC_i^* at long-run competitive equilibrium:

$$AC_i^* = b_i + [(\overline{P} - b_i)^2 + \sigma_P^2]^{\frac{1}{2}}. \tag{1}$$

Equation (1) shows that when prices are stable at $\overline{P}$ $(\sigma_P^2 = 0)$, long-run competitive equilibrium implies that $AC_i^* = \overline{P} = P^{**} = \overline{AC}_i = AC_i^{**}$ where $\overline{AC}_i$ is mean value of average cost and AC_i^{**} or P_i^{**} is the weighted average value of average cost or price (weighted by output). Consistent with the economies of scale hypothesis, firms with the lowest AC_i^* will survive and technology would be homogeneous (Sheshinski and Dreze) unless the static long-run average cost function is flat bottomed. Equation (1) also shows that when prices are unstable ($\sigma_P^2 \neq 0$), $AC_i^* > \overline{P}$. The divergence increases with the degree of price uncertainty. Market price uncertainty lowers $\overline{P}$ below AC_i^* but all firms remain equally viable. The cost of inflexibility to producers (CIF_i) is $AC_i^{**} - AC_i^*$.

Evaluated at $\overline{P}$, the elasticity of supply (n_i) is $(\partial Q_i^+/\partial P)(P/Q_i^+) = \overline{P}/(\overline{P}-b_i) > 0$. Based on the above, Mills and Schumann showed that as farm size increases, AC_i^* falls, fixed cost (a_i) increases, variable cost (b_i) falls, flexibility (n_i) increases, and capital intensity (a_i/e_i) increases. Note that AC_i^{**} stays the same for all farms. They also showed that $V[Q_i^+(P)] = \sigma_{Q_i}^2 = e_i^2\sigma_P^2$, that $CV_{Q_i} = n_i CV_P$ where $V() = \sigma_{()}^2 =$ variance of () and $CV_{()}$ is the coefficient of variation of (), and that $\sigma_{\Pi_i}^2 \approx (Q_i^+)^2\sigma_P^2$. These imply that more flexible smaller producers are more price responsive and that uncertainty of profit (risk) increases with size but decreases with flexibility.

P^{**} for the i^{th} firm (P_i^{**}) is $\sum_{t-1}^{T}(Q_{it}/\sum_{t=1}^{T} Q_{it})P_t$ where Q_{it} is output of the i^{th} firm in the t^{th} year and P_t is price in the t^{th} year. Adelaja derived it as

$$P_i^{**} = AC_i^{**} = \overline{P} + \frac{n_i\sigma_P^2}{\overline{P}} = \overline{P}(1 + n_i CV_P^2) > \overline{P}. \quad (2)$$

From (2), $\partial AC_i^{**}/\partial\sigma_P^2 = n_i/\overline{P} > 0$ which means that as price uncertainty increases, realized average cost increases. Adelaja also derived

$$CIF_i = \frac{[(\overline{P}/n_i)^2 + \sigma_P^2]\left\{[(\overline{P}/n_i)^2 + \sigma_P^2]^{\frac{1}{2}} - [\overline{P}/n_i]\right\}}{(\overline{P}/n_i)[(\overline{P}/n_i) + \sigma_P^2]^{\frac{1}{2}}} > 0. \quad (3)$$

Equations (2) and (3) imply that $AC_i^{**} > AC_i^* > \overline{P}$. Since at competitive equilibrium, all AC_i^{**} are equal, CIF_i decreases as flexibility increases if AC_i^* increases as flexibility increases.

The proofs above suggest that at competitive equilibrium, the economies of scale advantages of large firms, which occurs only when price is stable, is eroded when price is unstable; large firms face greater risk and higher costs of inflexibility; despite economies of scale, the realized unit costs for all producers are equal; and the notion that long-run competitive equilibrium always implies CRS is challengeable.

EVIDENCE FROM NORTHEASTERN U.S. DAIRY

Despite farm consolidation, the evidence on economies of scale in the Northeastern dairy sector is conflicting (Hoque and Adelaja; Wysong; Matulich; Hoque, Adelaja and Ganguly). The sector is characterized by competitive behavior, homogeneous product and heterogeneous technology. Although, dairy prices have been stabilized through price support, not all price variation was eliminated by price stabilization policies.

Panel data on the sector whereby each time series provided data on the average farm in a given size group were used to examine the validity of the flexibility theory. The data were obtained from annual ELFAC reports published by the Cooperative Extension Service of the Northeastern states. The ELFAC sample is divided into three subsamples of small farms (less than 40 milk cows), medium sized farms (40 to 79 milk cows), and large farms (80 or more milk cows). For each of the average farms, annual measures of capital intensity index (CI_i), specialization index (SI_i), output (Q_i), price (P_i), and profit (Π_i) were calculated. Measures of central tendency (based on annual data from 1971 to 1985) of capital intensity index ($\overline{CI}$, σ_{CI}^2 and

CV_{CI}), specialization index ($\overline{SI}$, σ^2_{SI} and CV_{SI}), output ($\overline{Q}_i, \sigma^2_{Q_i}$ and CV_{Q_i}), price ($\overline{P}, \sigma^2_P$ and CV_P), and profit ($\overline{\Pi}_i, \sigma^2_{\Pi_i}$ and CV_{Π_i}) were also computed and compared for each average farm to see if they are correlated with size. In addition, n_i measures econometrically estimated for the average farms were used to determine average positions of AC_i and AC_i^* and were used to calculate average values of Q_i^*, b_i, a_i and e_i. The e_is were calculated as $n_i\overline{Q}_i/\overline{P}$, b_i were be calculated as $\overline{P}-(\overline{P}/n_i)$, a_i were calculated as $e_i[(\overline{P}/n_i)^2 + \sigma^2_P]/2$, AC_i^* were calculated as $b_i + [(\overline{P}/n_i)^2 + \sigma^2_P]^{\frac{1}{2}}$, and Q_i^* were calculated as $(2a_i/e_i)^{\frac{1}{2}}$ based on the equations above. The deflator used for nominal prices and costs was the deflator for Gross National Product (GNP deflator) published in *Economic Report of the President.* Thus, prices and costs are expressed in constant 1971 dollars. The coefficient of variation of prices suggested some price variation despite marketing orders and price support.

Annual measures of SI were calculated as revenue from dairy activities divided by total revenue multiplied by 100. Variable costs of milk production for the average farms were calculated as the deflated or real values of (SI/100) times the sum of the expenses on all variable inputs (including hired labor). Total costs of milk production (in real terms) were measured as the sum of total fixed and total variable costs (in real terms). Components of the former included the user costs of land, buildings, equipment and livestock. Annual capital intensity indexes (CI) were then measured as total fixed cost divided by total cost times 100. To obtain real measures of revenues, total nominal dairy related revenues were also deflated. Real total profit (Π) was measured as real value of total farm revenue minus real value of total farm cost. The measures of $\bar{Q}$, $\bar{CI}$, $\bar{SI}$, $\bar{\Pi}$, σ^2_Q σ^2_{CI}, σ^2_{SI}, σ^2_{Π}, CV_Q, CV_{CI}, CV_{SI}, and CV_{Π} reported in Table 1 were obtained from the generated time-series on each of the average farms.

Realized producer prices (P_i^{**}) were calculated as the weighted average real prices of milk over the 15 year period. The realized average costs of milk (AC_i^{**}) were obtained as the weighted "average" average cost. The weights used are each year's share of total 15 year output. The values of P^{**} reported in Table 1 are quite similar to those of AC_i^{**} as implied by the equilibrium condition (Dreze and Gabszewicz).

The following Koyck distributed lag supply model was used to estimate n_i for the average farm in each group:

$$\ell n Q'_{it} = \lambda_{iO} + \lambda_{iP} \ell n P_{it} + \lambda_{iF} \ell n F_{it} + \lambda_{iB} \ell n B_{it} + \lambda_{iL} \ell n Q'_{it-1} + U_{it} \tag{4}$$

where Q'_{it} is mean output of the average farm times the number of dairy farms in the i^{th} group in the t^{th} period, P_{it} is real price received for milk by farmers in the i^{th} group in the t^{th} period, F_{it} is the real price paid by farmers in the i^{th} group for feed and concentrates in the t^{th} period (F_{it} is the same for all farm groups in any given period), B_{it} is the real price received by farmers in the i^{th} group for beef (a substitute product) in the t^{th} period, Q'_{it-1} is the lagged value of Q'_{it}, U_{it} is an error term and the λs are coefficients of the model. Nominal values of F_{it} and B_{it} were obtained from Agricultural Prices (USDA). All nominal prices were deflated by the GNP deflator to obtain the real prices.

The model imposes similar lag structures on impacts of causal variables for farms in a given group while lag structures vary across farm size groups. Note that $\lambda_{iP} = n_i$ while $\lambda_{iP}/(1 - \lambda_{iL}) = N_i$. The instrumental variable method suggested by Johnston and Fuller was used to estimate the models. Details of estimates of equation (4) are not reported here. All relevant coefficients, however, were significant at the 5 percent level.

RESULTS

Statistically, the $\overline{CI}$ measures are all significantly different at the 5 percent level and are consistent with the expectation that capital intensity increases with farm size. The $\overline{SI}$ measures for small and medium sized farms, and small and large farms were also significantly different at the 5 percent level while the $\overline{SI}$ measures for medium and large farms were not. The $\overline{SI}$ measures suggest that specialization increases with farm size up to a point. As expected, Profit ($\overline{\Pi}_i$) also increases with farm size. The coefficients of variation of profit ($CV_{\Pi i}$), however, suggest that the degree of risk or income instability increases with farm size. Consistent with the argument of Mills and Schumann and the findings of Caves and Yamey, these suggest that continued farm consolidation may lead to higher risks and greater income instability.

The calculated values for AC_i^{**} and P_i^{**} are practically equal at about 6.781 for all farms. These values suggest that even if economies of scale advantages do accrue to larger farms, the flexibility of smaller farms compensate to make the realized costs (or prices) equal. Estimated short-run price elasticities of supply (n_i) and the long-run price elasticities of supply (N_i) reported in Table 1 suggest that small farms are most flexible in the short-run ($n_i = .5204$), followed by mid-sized farms ($n_i = .2665$) and by large farms ($n_i = .2311$). However, large farms are most flexible in the long-run ($N_i = .7585$) followed by small farms ($N_i = .6785$). Mid-sized farms are the least flexible both in the short- and long-run.

The relative magnitudes of n_i and N_i are consistent with expectations. Short-run flexibility comes from the ability to vary variable inputs which small farms have more of due to low capital intensity (Chavas and Klemme).

Beyond the short-run, flexibility comes from the ability to expand the scale of production (increase herd size) which large firms have more of due greater ability to raise required capital (Chavas and Klemme). Total long-run flexibility, the sum of short-term plus the "beyond the short-term" flexibility, is thus largest for large farms. The mid-sized farms seem to be neither flexible enough in the short-run or financially capable enough in the long-run to expand output.

Because n_i is the estimate of short-run supply elasticity for the average farm at average yield levels, the values of a_i, e_i and b_i obtained from η_i are the implied cost function parameters associated with average yield. These values are reported in Table 1. The a_i measures support the hypothesis that fixed costs increases as size increases while the b_i measures support the hypothesis that variable costs are inversely related to size.

The implied values of minimum average cost when demand is static (AC_i^*), for the average small, medium and large farms are, respectively, \$6.753, \$6.740 and \$6.746 per cwt. of milk. They suggest almost constant returns to scale and that the LRAC curve (when demand is static) is, at best, very slightly decreasing. Unfortunately, it is difficult to determine if the AC_i^* measures are significantly different for the different samples.

On comparing AC_i^*, AC_i^{**} and $\overline{P}$, it is apparent that AC_i^{**} are higher than AC_i^* by between 3 and 4 cents while the AC_i^*s are higher than $\overline{P}$ by between half a cent and one and a half cents. These serve to illustrate the argument that when prices are unstable ($\sigma_P^2 \neq 0$), mean price falls below minimum average cost. Note that $AC_i^* - \overline{P}$ and $AC_i^{**} - \overline{P}$ both increase with σ_P^2. The small gap found in this study is because dairy prices have been stabilized via price support policies ($\sigma_P^2 = 0.322$ while $CV_P = 8.413$ percent).

A graphical illustration of the cost structure of ELFAC farms is depicted in Figure 1.

CONCLUSION

This paper argues that the benefits of economies of scale to producers seem to accrue only when prices are stable. The fact that the weighted average costs (AC_i^{**}s) and the weighted average prices (P_i^{**}s) for Northeastern dairy farms of various sizes were higher and more equal than the minimum average costs (AC_i^{*}s) suggests that costs of inflexibility (CIF_i) may preclude Northeastern dairy producers from realizing full cost potentials from economies of scale and that there may be no real benefits to size. Because risk increases drastically as size increases, it is concluded that farm consolidation in Northeastern dairy may not contribute much to efficiency but will result in higher risk, greater income instability, and greater output inflexibility. It is difficult to justify public policies to encourage increased farm size when such policies could lead to greater risks with no offsetting benefits to producers or consumers.

There are, perhaps, several subsectors of agriculture where returns to scale possibilities are greater than in the Northeastern U.S. dairy sector. In such subsectors computed AC_i^{*} measures would be rather divergent, the LRAC curve would be rather steep, and the CIF_i measures would be rather divergent. For such subsectors, in the absence of price stabilization policies, the coexistence of various sizes of farms could still be possible and the large benefits of economies of scale could still elude producers.

Figure 1: Realized Producer Prices, Minimum Average Costs and Market Price in Northeastern Dairy.

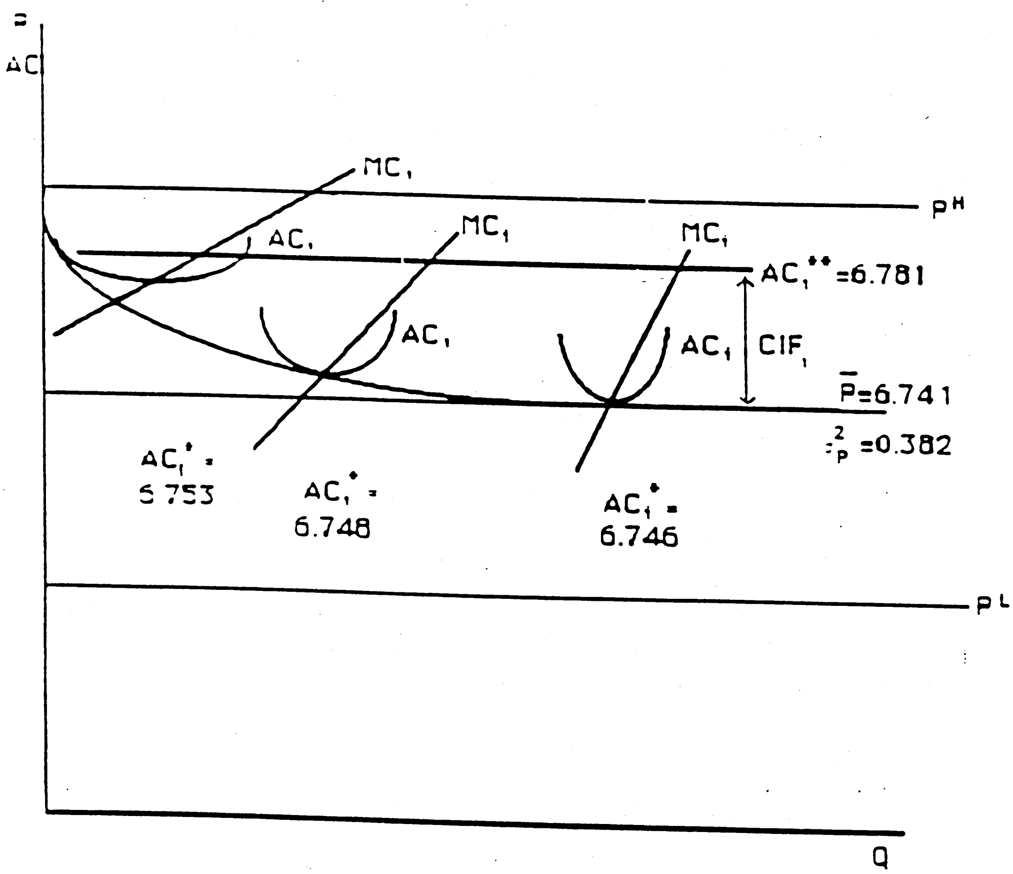

Diagram not drawn to scale.

Table 1: Implied Cost Function Parameter for ELFAC Dairy Farms.

Measure of	Measured as	Farm Size Categories		
		Small Sized	Medium Sized	Large Sized
Flexibility[a]	n_i	0.5204	0.2665	0.2311
Large-Run Supply Elasticity[a]	n_i	0.6785	0.3814	0.7585
Inverse of Slope of Supply[b]	e_i	340.716	302.662	586.632
Coefficient of Fixed Cost[b]	a_i	28639.751	96872.530	249659.930
Coefficient of Variable Cost[b]	b_i	−6.213	−18.554	−22.428
Cost Minimizing Output[b]	Q_i^*	4417.697	7657.628	17114.818
Minimum AC_i (Static)[b]	AC_i^*	6.753	6.748	6.746
Realized AC_i (Unstable)[c]	AC_i^{**}	6.781	6.782	6.781
Realized Price[c]	P_i^{**}	6.781	6.781	6.781
Unweighted Price[c]	$\overline{P}$	6.741	6.741	6.741
Variance of Price[c]	σ_P^2	0.322	0.322	0.322
Coef. of Var. of P[c]	CV_P	8.413	8.413	8.413
Cost of Inflexibility	CIF_i	0.028	0.034	0.035
Mean Capital Intensity[c]	$\overline{CI}_i$	0.172	0.202	0.223
Mean Specialization Index[c]	$\overline{SI}_i$	92.521	94.231	93.756
Mean Profit[c]	$\overline{\pi}_i$	2898.312	4048.480	6413.629
Coef. of Var. of π_i[c]	$CV_{\pi i}$	79.809	94.046	106.276
Mean output[c]	$\overline{Q}_i$	4413.465	7655.771	17111.572
Coef. of Var. of Q_i[c]	CV_{Qi}	9.163	7.056	11.060

a Econometrically estimated.

b Implied from n_i estimates.

c Calculated from data.

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