Vertical Economies of Scope in Dairy Farming

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Abstract

With the exception of Azzam and Skinner (2007), the economic literature on farm structure has largely neglected issues of vertical organization of the farm. In this article we estimate a multi-stage, multi-output cost function in order to measure vertical economies of scope in organic and conventional dairy farms. In particular, we model the integration of production of grains and forages on dairy farms. We find negligible vertical economies of scope for conventional dairy farms but significant vertical economies of scope in organic dairy production. The large vertical economies of scope for organic dairy farms are consistent with higher costs of obtaining organic feed through market transactions associated with an underdeveloped market for organic feeds.

KEYWORDS: vertical economies of scope, vertical integration, dairy

*This research has been supported by a Cooperative Agreement with USDA/ERS and by the Agricultural Experiment Station at Purdue University. The authors thank Ken Foster and Mike Schutz for constructive comments on earlier versions of this research.
1. Introduction

Economies of scale and higher technical efficiency of larger dairy farms have put smaller dairy farms at a cost disadvantage in the United States, thus contributing to a shift in farm structure towards larger farms (Mosheim and Lovell 2009; Tauer and Mishra 2006; MacDonald et al. 2007). From 1998 to 2007, the number of U.S. dairy farms with fewer than 100 cows decreased by 44 percent, the number of dairy farms with 100–499 cows decreased by 30 percent, and the number of dairy farms with 500 cows or more increased by 39 percent. These changes in farm structure have raised questions about the future of small dairy farms in the United States (Tauer and Mishra 2006).

Small dairy farms have adopted management strategies to enhance revenues and become more cost competitive with larger dairy farms. Some small dairy farms have opted for product differentiation, targeting specialty, niche markets such as organic dairy production. High price premiums for organic milk make this market attractive for dairy farmers (McBride and Greene 2007). Yet the presence of increasing returns to scale in organic dairy farming in the United States may lead to an organic farm structure that follows the same trend towards large farms observed in conventional milk production (Mayen, Balagtas, and Alexander 2009). There is some indication that some small dairy farms have adopted cost management strategies to offset economies of scale and be competitive with larger dairy farms (Tauer and Mishra 2006; MacDonald et al. 2007). Although specific cost reduction strategies have not been identified, the higher degree of vertical integration of small dairy farms may play an important role (Sumner and Wolf 2002). This article extends the economic literature on farm structure by modeling and measuring the potential for dairy farms to reduce costs of production through vertical integration.

In multi-stage production processes a vertically integrated firm is involved in two or more adjacent production stages, with the output from a first stage transferred within the firm as an input for the subsequent stage. In contrast, specialized firms acquire inputs and sell outputs through market transactions. If the internal transfer of the intermediate product is less costly than the market exchange, there exist vertical economies of scope (Perry 1989). Vertical economies of scope may arise through technological economies, market imperfections, or reduced transactions costs (Perry 1989; Kaserman and Mayo 1991). Technological economies exist when less of the intermediate products are required to produce the same final product due to integration of the upstream stage. Market failures, for example market power exercised in pricing of the intermediate product, may result in higher costs of production for non-integrated firms. Similarly, transactions costs associated with market exchanges may increase costs for non-integrated firms.
Although most agricultural production processes can be viewed as multi-stage production processes, and increasing vertical coordination is a stylized fact in U.S. agriculture, the economic literature on U.S. farm structure is largely absent of empirical estimates of vertical economies of scope. In a notable exception Azzam and Skinner (2007) estimate vertical economies of scope in U.S. hog production and find significant vertical economies of scope across different combinations of farrow-to-feeder production and feeder-to-finish production. The present article makes two key contributions to this literature. First, we provide what are to our knowledge the first estimates of vertical economies of scope for U.S. milk production. Second, we make a methodological contribution by extending the framework adopted by Azzam and Skinner (2007) to include two intermediate products and allow for heteroscedasticity.

We utilize a multi-stage, multi-output cost function framework to assess vertical economies of scope on organic and conventional dairy farms. We model the cost of jointly producing two first-stage products, grains and forages, which are then used as inputs in milk production. We use the 2005 Agricultural Resource Management Survey–Dairy Costs and Returns Report which provides nationally representative data on production costs of organic and conventional dairy farms in the United States.

2. Modeling Vertical Economies of Scope in Dairy Farming

Dairy farms may be diversified into a range of production enterprises, including grain crops, forage crops, and pasture (Sumner and Wolf 2002). As well, replacement heifers may be raised on the farm or sourced from specialized heifer operations. Incentives to diversify into feed production may be particularly strong because feed costs account for a large share of dairy operating expenses (Tozer and Heinrichs 2001). Thus, in this study we focus on the potential for dairy farms to reduce costs of production by integrating feed production.

Two methodologies have been used in the agricultural economic literature to assess vertical economies of scope. Azzam (1998) used a difference in means test to compare the actual costs of production of vertically-integrated hog farms to the hypothetical costs of production if two separate, specialized farms produced the same output. Azzam and Skinner (2007) used the same data but instead utilized an econometric approach to assess vertical economies of scope. They used a multi-stage cost function framework similar to the analyses of vertical economies of scope in the electric industry (Kaserman and Mayo 1991; Kwoka 2002). They found this methodology more appropriate than the mean comparison test because the cost function provides more economic information about the

We adopt the multi-stage cost function framework to assess the degree of vertical economies of scope in the dairy industry. We extend previous analyses of vertical economies of scope which have analyzed the case of a single intermediate product (Kaserman and Mayo 1991; Kwoka 2002; Azzam and Skinner 2007) by including two intermediate products. For a firm which produces two intermediate products and a single final product, vertical economies of scope exist if the cost of jointly producing the intermediate products and the final product is lower than the cost of producing the three products separately. Stated formally, vertical economies of scope exist if the following inequality holds

\[
C(y_1, 0, 0) + C(0, y_2, 0) + C(0, 0, y_3) > C(y_1, y_2, y_3)
\]

where \(C(.)\) is the cost function and \(y_1\) and \(y_2\) are intermediate products used as inputs in the production of \(y_3\).

A scale-free measure of vertical economies of scope (VES) is

\[
VES = \frac{[C(y_1, 0, 0) + C(0, y_2, 0) + C(0, 0, y_3) - C(y_1, y_2, y_3)]}{C(y_1, y_2, y_3)}
\]

This measure represents the percentage increase in costs of production on specialized firms relative to costs on a vertically-integrated firm. Vertical economies of scope exist if \(VES\) is greater than zero.

Kwoka (2002) and Azzam and Skinner (2007) estimate a multi-stage quadratic cost function, which allows the inclusion of outputs with quantity of production equal to zero. We extend the cost function to include two intermediate products, grains \((y_1)\) and forages \((y_2)\), and a final product, milk \((y_3)\). (In the following, we use subscript 1 to denote grains, subscript 2 to denote forages, and subscript 3 to denote milk.)

We specify the cost function \(C(y_1, y_2, y_3)\) as

\[
C(y_1, y_2, y_3) = \alpha_0 + \beta_1 D_1 + \beta_2 D_2 + \beta_3 D_3 + \alpha_1 y_1 + \frac{1}{2} \alpha_{11} y_1^2 + \alpha_2 y_2 + \frac{1}{2} \alpha_{22} y_2^2 + \alpha_3 y_3 + \frac{1}{2} \alpha_{33} y_3^2 + \frac{1}{2} \alpha_{12} y_1 y_2 + \frac{1}{2} \alpha_{13} y_1 y_3 + \frac{1}{2} \alpha_{23} y_2 y_3 + \delta_{East} d_{East} + \delta_{Cornbelt} d_{Cornbelt} + \delta_{pasture} d_{pasture}
\]

where \(D_i, i \in (1,2,3)\), are dummy variables equal to one for a farm engaged in enterprise \(i\) to allow for the enterprise-specific fixed costs of production; \(d_{East}\) and \(d_{Cornbelt}\) are regional dummy variables (farms in the Upper Midwest are the
benchmark group); and $d_{\text{pasture}}$ is a dummy variable equal to one for farms obtaining more than 50 percent of their forage needs from pasture; and $\alpha$s, $\beta$s, and $\delta$s are parameters to be estimated. The cost function in (3) allows fixed costs that are common across all three enterprises, $\alpha_0$, as well as enterprise-specific fixed costs. As well, the interaction effects in (3) permit complementarity in variable costs of jointly producing any pair of the three products. For example, the marginal cost of producing milk,

$$
\frac{\partial C(y_1, y_2, y_3)}{\partial y_3} = \alpha_3 + \alpha_{33}y_3 + \frac{1}{2}\alpha_{13}y_1 + \frac{1}{2}\alpha_{23}y_2,
$$

may be decreasing (or increasing) in production of grains or forages.

Using equation (3), the scale-free measurement for vertical economies of scope in equation (2) is

$$
VES = \frac{2\alpha_0 - \frac{1}{2}\alpha_{12}y_1y_2 - \frac{1}{2}\alpha_{13}y_1y_3 - \frac{1}{2}\alpha_{23}y_2y_3}{C(y_1, y_2, y_3)}.
$$

Vertical economies of scope exist if the numerator is positive, i.e. if the sum of a common fixed cost plus a scaled measure of cost complementarity is positive. The common fixed cost $\alpha_0$ cannot be econometrically identified due to the nature of our data. In particular, all farms in the data set are involved in milk production, i.e. the dummy variable for milk production $D_3$ in cost specification in equation (3) is always equal to one. Since the common fixed cost $\alpha_0$ cannot be disentangled from the estimated intercept coefficient, we follow Kwoka (2002) and assess the complementarity effects of jointly producing grains, forages, and milk. Thus, we estimate a scale-free measure of vertical economies of scope due to cost complementarities as

$$
VES_C = \frac{-\frac{1}{2}\alpha_{12}y_1y_2 - \frac{1}{2}\alpha_{13}y_1y_3 - \frac{1}{2}\alpha_{23}y_2y_3}{C(y_1, y_2, y_3)}.
$$

Because we drop the shared fixed costs, which are by definition non-negative, we interpret $VES_C$ as a lower bound of vertical economies of scope. Actual vertical scope economies are larger than indicated by $VES_C$ if shared fixed costs are strictly positive.

In addition to equation (6), we also estimate an upper bound of vertical economies of scope $VES_{CU}$ by adding the estimate of the constant term, which accounts for the common fixed cost plus the fixed cost specific to the dairy enterprise ($\alpha_0 + \beta_3$), to the numerator of equation (6). Inclusion of $\alpha_0 + \beta_3$ in the VSE measure is appropriate if the milk-specific fixed cost of production is zero,
so that the intercept measures only the common fixed cost. To the extent that milk-specific fixed costs are non-zero, $VES_{CU}$ overstates the vertical economies of scope.

Appending an error term to the cost function in (3) yields our econometric cost specification

$$C(y_1, y_2, y_3) = \alpha_0 + \beta_1 D_1 + \beta_2 D_2 + \alpha_1 y_1 + \frac{1}{2} \alpha_{11} y_1^2 + \alpha_2 y_2 + \frac{1}{2} \alpha_{22} y_2^2 + \alpha_3 y_3 + \frac{1}{2} \alpha_{33} y_3^2 + \frac{1}{2} \alpha_{12} y_1 y_2 + \frac{1}{2} \alpha_{13} y_1 y_3 + \frac{1}{2} \alpha_{23} y_2 y_3 + \delta_E d_{East} + \delta_{Cornbelt} d_{Cornbelt} + \delta_{pasture} d_{pasture} + \varepsilon.$$  

where the disturbance terms $\varepsilon$ are independently and normally distributed with zero means and variance $\sigma^2$. We test for and model heteroscedasticity by positing Harvey’s model of multiplicative heteroscedasticity (Harvey 1976), which specifies variance as

$$\sigma^2 = \exp(z' \gamma),$$

where $z$ is the a vector of variables suspected to affect the variance and $\gamma$ is a vector of parameters to be estimated. We include a constant and the natural logarithm of herd size in $z$.

### 3. Data

We use data on U.S. dairy farms from the 2005 Agricultural Resource Management Survey (ARMS) Dairy Costs and Returns Report. ARMS is a multi-frame, probability-based survey in which farms are randomly selected from groups of dairy farms stratified by value of sales. Each sampled farm represents a number of farms that are of similar value of sales; this number represents the survey expansion factor, or weight. Weighting is recommended for descriptive and econometric analyses when inferences are made of the population of interest (Dubman 2000). In this study we use the ARMS farm weights to weigh the means analysis and the maximum likelihood function when estimating the multiplicative heteroscedastic cost functions. Since ignoring stratification in the estimation of variances is not likely to cause substantial biases, we use the traditional variance estimators to test for statistical significance in the mean comparison tests and econometric models (Carrington et al. 2000).\(^1\) Traditional variance estimators

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\(^1\) There are two alternative procedures for estimating variances when using ARMS data: the delete-a-group jackknife variance estimator proposed by Dubman (2000) and the probability-
have been used by other researchers when estimating econometric models using ARMS data (Fernandez-Cornejo, Hendricks, and Mishra 2005).

We restrict this analysis to farms in the traditional dairy regions of the United States: Cornbelt region (Illinois, Indiana, Iowa, Missouri, Ohio), East region (Maine, New York, Pennsylvania, Vermont), and the Upper Midwest region (Michigan, Minnesota, Wisconsin). These regions have a higher degree of vertical integration than farms in the west and southeast (Sumner and Wolf 2002).

The usable sample with complete observations for all variables used in this analysis consists of 205 organic dairy farms and 527 conventional dairy farms. After we apply the respective weights, the weighted sample represents approximately 505 organic dairy farms and 29,461 conventional dairy farms in the United States.

Although the primary revenue source for farms in our sample is milk, they also may receive revenue from cattle sales, cooperative dividends, and manure sales. The costs associated with the secondary revenue-generating items cannot be separated from the cost of producing milk. Thus to more accurately take into account the added cost due to higher secondary revenues, we utilize a production equivalent which consists of hundredweight (100 pounds) of milk necessary to provide the same level of income from milk sales and secondary revenue (Frank 1998). That is, secondary revenue is divided by the per hundredweight price of milk, and is then added to farm milk production.

Dairy farms use different types of feed inputs in milk production. We aggregate grains and forages produced on the farm based on total digestible nutrients (TDN). TDN is directly related to the feed’s nutrient content, as reported in the Directory of Feeds and Feed Ingredients (McGregor 1989). For quantity of grains we include corn, barley, sorghum, wheat, soybeans, and oats. For quantity of forages we include alfalfa hay, all other hay, corn silage, and sorghum silage. We approximate TDN of grazed forage by assuming that the maximum voluntary intake of forage by cows is 2.5 pounds of dry matter per day per hundredweight of body weight (Foley et al. 1972). We do not have complete information on the quality and type of grazed pasture thus we assume that grazed forages consist of 50 percent of TDN. To obtain the annual consumption of grazed forage we utilize weighted bootstrapping technique as proposed by Goodwin and Mishra (2004). A disadvantage of the former procedure is that the when using a subset of the overall sample, the jackknife approach may not be valid since the replicate weights provided with the ARMS data set would be distorted when certain data observations are not included (Goodwin, Mishra, and Ortalo-Magne 2003). A disadvantage of the latter is that the weights on organic dairy farms are so small that the likelihood of selecting organic farms to conform to the pseudo-sample is very small. Without organic farms being selected, the comparison between organic and conventional dairy farms would be impossible.
the survey data on the reported months of the year that the cows are grazing, and the percent of forage needs that are obtained from pasturing.

The cost of producing grains, forages, and milk includes accounting and economic costs. The accounting costs include expenditures on seeds, fertilizer, agricultural chemicals, livestock, leasing of livestock, purchased feed, purchased bedding and litter, medical supplies, fuels and oils, electricity, other utilities, farm supplies, repairs and maintenance, renting of land for raising crops and grazing, total cash wages paid for hired labor, contract labor, custom work, non-real estate property taxes and insurance, and other general business expenses. The economic costs include operating interest, opportunity cost of capital, and opportunity cost of labor by the operator and family members. Operating interest is calculated as the variable cost of production times the interest rate of a 6 month Treasury bill in 2005 (3.4 percent). The cost of capital includes the depreciation and interest paid on farm assets (machinery, buildings, and livestock), the opportunity cost of land owned by the farm which is used to raise crops and house the dairy facility, and the opportunity cost of money spent on capital assets. The opportunity cost of owned land is equivalent to average state rental rates for acres of land used to raise crops and for grazing. The opportunity cost of capital assets is equal to a charge of 3.4 percent on the 2005 market value of farm assets which includes the inventory of inputs and crops, breeding livestock, farm machinery, and buildings. For the opportunity cost of labor, we obtain the amount of time worked by the operator and family members on the farm directly from the survey. The wage rate for the operator is estimated by ERS’s cost of production estimates which utilize the opportunity cost of farm operator labor employed off-farm, estimated from an econometric model of off-farm labor supply and wages (El-Osta and Ahearn 1996). For family labor, we utilize average state hourly rates for farm work and minimum wage rates for employees less than 16 years of age.

When assessing vertical economies of scope all costs need to be net of expenditures on purchases of the intermediate products to avoid double counting (Kwoka 2002; Azzam and Skinner 2007). In our case, all costs are net of expenditures on purchased grains and forages. For a vertically-integrated farm there are no expenditures to be deducted, whereas for a farm which specializes in milk production the entire expenses on feed purchases are deducted from the cost of production. With this correction to the costs of production we implicitly correct for any potential pricing above marginal cost of the intermediate product. This adjustment in the cost allows the comparison of cost differences between making and purchasing feed.

In table 1 we report means, standard errors, and statistical significance of the mean comparison tests between organic and conventional farms for the variables included in this study. A striking difference between organic and conventional dairy farms is farm size as measured by number of milking cows.
Average herd size on organic dairy farms is approximately 64 cows, whereas the average herd size on conventional dairy farm is 103 cows. On organic farms,

<table>
<thead>
<tr>
<th>Table 1. Mean Comparisons of Production and Farm Characteristics for Organic and Conventional Dairy Farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Production</td>
</tr>
<tr>
<td>(N = 205)</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Milking Cows</td>
</tr>
<tr>
<td>Grains (1,000 cwt)</td>
</tr>
<tr>
<td>Forages (1,000 cwt)</td>
</tr>
<tr>
<td>Milk (1,000 cwt)</td>
</tr>
<tr>
<td>Grain Production (1/0)</td>
</tr>
<tr>
<td>Forage Production (1/0)</td>
</tr>
<tr>
<td>Upper Midwest (1/0)</td>
</tr>
<tr>
<td>Cornbelt (1/0)</td>
</tr>
<tr>
<td>East (1/0)</td>
</tr>
<tr>
<td>Pasture (1/0)</td>
</tr>
</tbody>
</table>

Note: For each variable we tested the hypothesis that organic and conventional means were equal. Asterisks denote statistical significance of the test statistic at the 10 percent (*), 5 percent (**), and 1 percent (***)) levels.

average annual grain production is approximately 1,550 cwt of TDN from grains, average annual forage production is 4,970 cwt of TDN from forages, and average annual milk production is 8,980 cwt. On conventional farms, average grain production is approximately 5,500 cwt of TDN, average forage production is 8,210 cwt of TDN, and average milk production is 22,190 cwt. Grain production
occurs in 56 percent of organic dairies and 70 percent of conventional dairies. Forage production occurs in 98 percent of organic and conventional dairy farms. The sample contains more organic and conventional dairy farms in the Upper Midwest, than in the East, followed by the Cornbelt region. Approximately 59 percent of organic dairy farms obtain more than 50 percent of their forage needs from pasture, whereas only 14 percent of conventional dairy farms do.

4. Estimation, Results, and Discussion

We use a likelihood ratio test to reject the hypothesis of homoscedasticity, i.e. $\gamma = 0$, for the organic production cost model (p-value $< 0.01$) and the conventional production cost model (p-value $< 0.01$). For both cost models we find that herd size has a statistically significant, positive effect on the variance.

We present the estimated cost functions for organic production and conventional production in table 2. Both models have explanatory power with statistically significant effects for certain variables. For the organic production model we find a statistically significant, positive fixed cost specific to forage production and a statistically insignificant fixed cost specific to grain production. The imprecise estimate of the fixed cost specific to organic grain production stage may be due to the lack of data needed to estimate the cost of production at the origin. We also find statistically significant positive linear effects of grains, forages, and milk on the cost of organic production. The marginal costs for grain production, forage production, and milk production are positive and constant with respect to their own output. The only statistically significant interaction term is for the joint production of organic forages and milk. The negative sign of this interaction points to cost complementarities. The marginal cost of milk is decreasing in forage output and the marginal cost of forage is decreasing in milk output.

For the conventional production model, we find a statistically significant linear effect of forages on the cost of conventional production. The marginal cost for forage production is positive and constant with forage output. We find statistically significant linear and quadratic effects of grains and milk on cost of production. Of particular relevance to our analysis of vertical scope economies, we find statistically significant cost complementarities for the joint production of grains and forages, i.e. the marginal cost of grain is decreasing in forage output.
Table 2. Estimated Cost Functions for Organic and Conventional Dairy Production

<table>
<thead>
<tr>
<th>Cost Model</th>
<th>Organic Production</th>
<th>Conventional Production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>S.E.</td>
</tr>
<tr>
<td>Constant</td>
<td>13.114</td>
<td>26.246</td>
</tr>
<tr>
<td>Grain Production</td>
<td>-7.159</td>
<td>8.275</td>
</tr>
<tr>
<td>Forage Production</td>
<td>43.904</td>
<td>25.855*</td>
</tr>
<tr>
<td>Grains</td>
<td>8.847</td>
<td>4.648*</td>
</tr>
<tr>
<td>Grains × Grains</td>
<td>-0.880</td>
<td>1.943</td>
</tr>
<tr>
<td>Forages</td>
<td>7.851</td>
<td>3.203**</td>
</tr>
<tr>
<td>Forages × Forages</td>
<td>-0.063</td>
<td>0.280</td>
</tr>
<tr>
<td>Grains × Forages</td>
<td>0.167</td>
<td>1.023</td>
</tr>
<tr>
<td>Milk</td>
<td>15.851</td>
<td>3.211***</td>
</tr>
<tr>
<td>Milk × Milk</td>
<td>0.658</td>
<td>0.483</td>
</tr>
<tr>
<td>Milk × Grains</td>
<td>0.116</td>
<td>1.206</td>
</tr>
<tr>
<td>Milk × Forages</td>
<td>-1.244</td>
<td>0.582**</td>
</tr>
<tr>
<td>East</td>
<td>-9.467</td>
<td>7.197</td>
</tr>
<tr>
<td>Pasture</td>
<td>-6.510</td>
<td>6.496</td>
</tr>
<tr>
<td>Heteroscedasticity Model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.212</td>
<td>0.585**</td>
</tr>
<tr>
<td>Logarithm Herd Size</td>
<td>1.777</td>
<td>0.225***</td>
</tr>
</tbody>
</table>

Note: Asterisks denote statistical significance at the 10 percent (*), 5 percent (**), and 1 percent (****) levels. a Grain production is a dummy variable equal to 1 when any grains are produced on the farm. b Forage production is a dummy variable equal to 1 when any forage is produced on the farm. c Quantities of grains, forages, and milk are in 1,000 cwt.
and the marginal cost of forage is decreasing in grain output. However, the interaction effect for grains and milk is statistically significantly positive. This means that the marginal cost of grain is increasing in milk output and the marginal cost of milk is increasing in grain output.

In Table 3 we present estimates of $VES_C$ and $VES_{CU}$ for three herd-size categories (small, average, and large) of organic and conventional dairy farms. We define “small” dairy farms as those with 100 cows or less, and farms with more than 100 cows to be large farms. This classification is based on ERS’s farm typology, in which a farm with annual sales less than $250,000 is defined as a small family farm. Given this definition, and with additional assumptions on yield

Table 3. Vertical Economies of Scope for Organic and Conventional Dairy Farms by Herd Size

<table>
<thead>
<tr>
<th>Farm Type and Herd Size</th>
<th>Mean Input Use</th>
<th>$VES_C$</th>
<th>$VES_{CU}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grains$^a$</td>
<td>Forages$^a$</td>
<td>Milk$^b$</td>
</tr>
<tr>
<td>Organic Farms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55 cows</td>
<td>1.30</td>
<td>4.10</td>
<td>7.77</td>
</tr>
<tr>
<td>64 cows</td>
<td>1.55</td>
<td>4.97</td>
<td>8.98</td>
</tr>
<tr>
<td>143 cows</td>
<td>3.79</td>
<td>12.70</td>
<td>19.69</td>
</tr>
<tr>
<td>Conventional Farms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55 cows</td>
<td>2.91</td>
<td>4.88</td>
<td>10.74</td>
</tr>
<tr>
<td>103 cows</td>
<td>5.50</td>
<td>8.21</td>
<td>22.19</td>
</tr>
<tr>
<td>230 cows</td>
<td>12.32</td>
<td>17.00</td>
<td>52.34</td>
</tr>
</tbody>
</table>

$^a$ Quantities of grains and forages are in 1,000 cwt of TDN per year. $^b$ Quantity of milk is in 1,000 cwt per year. $^c$ $VES_C$ represents the percentage increase in costs of production on specialized farms relative to costs on a vertically-integrated farm estimated using equation 6. $^d$ $VES_{CU}$ represents the upper limit of the percentage increase in costs of production on specialized farms relative to costs on a vertically-integrated farm estimated using equation 5 plus the estimate of the intercept term which accounts for $\alpha_0 + \beta_3$. 

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and milk price, small organic and conventional dairy farms would consist of approximately 100 milking cows or less. Mean herd size for the average and large categories for conventional dairy farms are larger than for organic dairy farms. For each type of farm and size category, we evaluate $V_{ES_C}$ and $V_{ES_{CU}}$ at the mean production levels for grains, forages, and milk.

The estimates of vertical economies of scope differ dramatically between organic and conventional dairy farms. For organic farms, we find significant $V_{ES_C}$ for all sizes. For the organic dairy farm with an average-sized herd (approximately 64 milking cows) the total economic costs of vertically-disintegrated production for grains, forages, and milk would be approximately 22 percent higher than for vertically-integrated production. Cost increases due to vertically-disintegrated production would be approximately 17 percent for an organic farm with 55 cows and 68 percent higher an organic farm with 143 cows. As expected, a strictly positive common fixed cost of production results in a higher estimate for $V_{ES_{CU}}$. Thus organic dairy farms appear to have a strong economic incentive to integrate into feed production.

In contrast, we find negligible vertical economies of scope (i.e., $V_{ES_C}$ values close to zero) for conventional dairy farms of all sizes. Integrated production of feed and forage does not lower costs on dairy farms relative to milk production with feed acquired through market transactions. The estimates of $V_{ES_{CU}}$ are significantly higher than vertical economies of scope due to cost complementarities, $V_{ES_C}$, indicating that a strictly positive common fixed cost of production may result in significant vertical economies of scope.

5. Conclusion

Economic analysis of structural change in U.S. animal agriculture has focused almost extensively on consolidation and the associated economies of scale (e.g., MacDonald et al. 2007; MacDonald and McBride 2009). The vertical dimension of farm structure has been largely neglected from economic studies of the structure of livestock production. Aside from descriptive studies of vertical integration in the different livestock industries in the United States (Ward 1997; Sumner and Wolf 2002), only Azzam (1998) and Azzam and Skinner (2007) have attempted to estimate economies of vertical integration in the livestock production. To our knowledge, this article is the first empirical analysis of the vertical dimension of farm structure in the U.S. dairy industry. We assess economies associated with of integration of feed and milk production in the traditional dairy regions of the United States, using data from the 2005 ARMS Dairy Costs and Returns Report. We use a multi-stage, multi-output cost function framework to assess vertical economies of scope in organic and conventional
dairy farms. We model the cost of jointly producing two products, grains and forages, which are used as inputs in milk production. We focus on economies from integrating feed production because feed represents the highest production expense in dairy farming (MacDonald et al. 2007).

We find negligible vertical economies of scope in conventional production due to cost complementarities. But significant vertical economies of scope may exist if the common shared cost of producing all three outputs is sufficiently large. Other non-pecuniary drivers for the higher degree of vertical integration in small, conventional dairy farms may also exist (Sumner and Wolf 2002). In contrast, we find significant vertical economies of scope due to cost complementarities in organic dairy production. The relative cost savings of vertical integration on organic dairy farms increase with herd size. An average-sized organic dairy farm may reduce the cost of production by 22 percent by vertically integrating into grain and forage production, providing organic dairy farms with a strong economic incentive to integrate into feed production. The large vertical economies of scope for organic dairy farms are consistent with higher costs of obtaining organic feed through market transactions associated with an underdeveloped market for organic feeds (Benson 2008).

References


