Vertical Economies of Scope for Organic and Conventional Dairy Farms in the United States

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Abstract

Studies of dairy farm structure have neglected issues of vertical organization of the farm. In this study we model and measure the potential for dairy farms to reduce costs of production through vertical integration. We estimate a multi-stage, multi-output cost function to assess vertical economies of scope in organic and conventional dairy farms. We model the cost of producing grains and forages, which are then used as inputs in the production of milk. We find negligible vertical economies of scope for conventional dairy farms. In contrast, we find significant vertical economies of scope in organic dairy production, suggesting that there is an economic incentive for vertical integration 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.

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 2006; 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

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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 study extends the economic literature on dairy 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 product produced in a first stage transferred within the firm as an input for the subsequent stage. In contrast, specialized firms are strictly involved in distinct production stages, so that downstream firms acquire inputs through market transactions. If the internal transfer of the intermediate product is less costly than the market exchange, there exist economies of vertical integration or vertical economies of scope (Perry 1989). Vertical source economies may arise through any of three sources: technological economies, market imperfections, and transactional economies (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 transactions may increase costs for non-integrated firms.

Most agricultural production processes can be viewed as multi-stage production processes, and increasing vertical coordination is a stylized fact in U.S. agriculture. However, little research has addressed vertical economies of scope. To our knowledge, Azzam and Skinner (2007), in an application to hog production in the Midwest region of the United States, is the only study that assesses vertical economies of scope in U.S. agriculture. They find significant vertical economies of scope across different combinations of farrow-to-feeder production and feeder-to-finish production. The current paper makes two key contributions to this literature. First, we provide the first estimates of vertical scope economies 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.

This study utilizes 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.

Modeling Vertical Economies of Scope in Dairy Farming

A dairy farm may be involved in farm enterprises beyond milking cows and selling milk (Sumner and Wolf 2002). Grain crops, forage crops, and pasture may be raised on the farm as a feed source for the milking herd. Heifers may also be raised on the farm to replace the cows that are culled from milk production. In terms of cost share of these intermediate inputs, feed represents the highest share of operating expenses of a dairy farm (Tozer and Heinrichs 2001). 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 to assess vertical economies of scope. Azzam (1998) used a mean comparison 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. To create the hypothetical costs, a farrow-to-feeder farm was matched to feeder-to-finish farm in terms of size, and the costs of production were then added. 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 multi-stage technology in hog production. In contrast to the mean comparisons, Azzam and Skinner (2007) found significant vertical economies of scope.

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 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

(1) $C(y_1, 0, 0) + C(0, y_2, 0) + C(0, 0, y_3) > C(y_1, y_2, y_3)$

where $C(.)$ is the cost function, 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

(2) $VES = \dfrac{[C(y_1,0,0) + C(0,y_2,0) + C(0,0,y_3) - C(y_1,y_2,y_3)]}{C(y_1,y_2,y_3)}.$

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 three products i, where $i = j$. There are two intermediate products, grains and forages, and a final product, milk.

The estimated cost function is

(3) $C(y_k) = \alpha_0 + \sum_i \boldsymbol{\beta}_i D_i + \sum_i \boldsymbol{\alpha}_i y_i + \dfrac{1}{2} \sum_i \sum_j \boldsymbol{\alpha}_{ij} y_i y_j + \sum_l \boldsymbol{\delta}_l d_l$

where the term α_0 denotes the parameter for a common fixed cost for all three farm enterprises, $\boldsymbol{\beta}_i$ denotes a vector of parameters for fixed cost specific to grain production, fixed cost specific to forage production, and fixed cost specific to milk production. The dummy variables D_1, D_2, and D_3 are nonzero when any grain, forage, or milk products are produced respectively. The vector of parameters $\boldsymbol{\alpha}_i$ captures the main effects of quantity of products on the cost of production. The vector of parameters $\boldsymbol{\alpha}_{ij}$ captures the interaction effects, i.e. any complementary effects of jointly raising different products. I also include l dummy variables to control for location and reliance on a pasture-based technology. The vector of parameters $\boldsymbol{\delta}_l$ captures the dummy variable effects. Two dummy variables d_1 and d_2 are included for dairy farms located in the East and the Cornbelt

region of the United States. The farms in the Upper Midwest serve as the benchmark. The location variables are included to assess any cost differences due to climate, soil or price variability by region. We also include a dummy variable d_3 to address potential technology differences by farms which provide forages through pasturing instead of through harvested forages. We define farms that allow their cows to obtain more than 50% of their forage needs from pasture to have a pasture-based technology.

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

$$(4) \quad VES = \frac{2\alpha_0 - \frac{1}{2}\alpha_{12}y_1y_2 - \frac{1}{2}\alpha_{13}y_1y_3 - \frac{1}{2}\alpha_{23}y_2y_3}{C(y_1, y_2, y_3)}.$$

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 data have no specialized grain and forage producers, i.e. farms which exclusively produce only grains or only forages. Thus the fixed cost specific to milk production becomes an implicit part of the constant term which represents the common fixed cost. Since the common fixed cost α_0 cannot be disentangled from the estimated coefficient, we follow Kwoka (2002) and focus solely on the complementarity effects of jointly producing grains, forages, and milk. The scale-free measurement of vertical economies of scope estimated in this study is

$$(5) \quad VES_c = \frac{-\frac{1}{2}\alpha_{12}y_1y_2 - \frac{1}{2}\alpha_{13}y_1y_3 - \frac{1}{2}\alpha_{23}y_2y_3}{C(y_1, y_2, y_3)}.$$

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

We test for and model heteroscedasticity by positing Harvey's model of multiplicative heteroscedasticity (Harvey 1976), which specifies variance as

(6) $\quad \sigma_i^2 = \exp(\mathbf{z}_i'\boldsymbol{\gamma})$,

where z_i is the set of variables suspected to affect the variance, and $\boldsymbol{\gamma}$ are parameters to be estimated. We include a constant and the natural logarithm of herd size in z_i.

Data

We use data on U.S. dairy farms from the 2005 Agricultural Resource Management Survey (ARMS) Dairy Costs and Returns Report. 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.

Milk is the primary output of dairy farms. But there is also secondary 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 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 his family. The operating interest cost represents the opportunity cost of money spent on the variable costs of production. The opportunity cost of money is equal to 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.

We present summary statistics for the variables included in this study in table 1. 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,

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.

Figure 1 presents kernel density estimates of the distribution of percent of grains and forages that are homegrown, for organic and conventional farms. A lower percentage of grains are homegrown compared to forage for both organic and conventional dairy farms. More conventional dairy farms are producing their own grains compared to organic dairy farms. In the case of forage production, more organic dairy farms are producing their own forage compared to conventional dairy farms.

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 variances of costs of production.

We present the estimated cost function for organic production and conventional production in table 2. Both models have explanatory power with statistically significant effects for some variables. For the organic production model we find a statistically significant, positive fixed cost specific to forage production. The fixed cost specific to grain production is negative and statistically insignificant. The imprecise estimate of the fixed cost specific to the grain production stage may be due to the lack of data needed to be able to estimate the cost of production at the origin. We find an increasing marginal cost of production for grains, forages, and milk. The only product interaction that is statistically significant is the joint production of forages and milk. The negative sign of this interaction points to cost complementarities, i.e the marginal cost of jointly producing forages and milk is less than the sum of marginal costs of producing each. Location and pasture-based technology have no statistically significant effects on cost of production.

For the conventional production model, we find a statistically significant increasing marginal cost of production for forages. We find statistically significant linear and quadratic effects for grain and milk production. The marginal cost of production for grains increases at a decreasing rate. The marginal cost of production for milk increases at an increasing rate. We find statistically significant cost complementarities for the joint production of grains and forages. The interaction effect for grains and milk is statistically significantly positive. The marginal cost of jointly producing grains and milk is greater than the sum of the marginal costs of producing each.

In table 3 we present estimates of VES_c 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

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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 and milk price, small organic and conventional dairy farms would consist of approximately 100 milking cows or less. Except for the small size category, the actual herd sizes 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 VES_c 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 vertical economies of scope 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. Thus organic dairy farms have an economic incentive to integrate into feed production.

In contrast, we find negligible vertical economies of scope (i.e., VES_c values close to zero) for conventional dairy farms of all sizes. These results show that on average, conventional dairy farms have little economic incentive to integrate into feed production.

Conclusion

Economies of scale have been singled out as a driver for the consolidation of livestock farming into fewer and larger farms in the United States (MacDonald et al. 2007; MacDonald and McBride 2009). The vertical dimension of farm structure has been neglected from these

studies of structural change. Besides descriptions of vertical integration in the different livestock industries in the United States (Ward 1997; Sumner and Wolf 2002), only one study has assessed economies of integration in the livestock industries, specifically the hog industry (Azzam and Skinner 2007). We extend the analysis to the vertical dimension of farm structural changes in the dairy industry. We assess economies of integration of feed and milk production in the traditional dairy regions of the United States. 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 then 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 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. We include accounting costs as well as the economic cost of capital resources and the labor provided by the operator and his family.

We find negligible vertical economies of scope in conventional production, suggesting that there is little economic incentive for integration into feed production. This finding implies that there must be other non-pecuniary drivers for the higher degree of vertical integration in small, conventional dairy farms (Sumner and Wolf 2002). In contrast, we find significant vertical economies of scope in organic dairy production. The relative cost savings of vertical integration on organic dairy farms increase with herd size. An organic dairy farm with 55 milking cows may reduce the cost of production by 17 percent by vertically integrating into grain and forage production. Organic dairy farms with 143 milking cows may reduce costs of production by 68. Organic dairy farms have a strong economic incentive to integrate into feed production. The

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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

Azzam, A. 1998. "Testing for Vertical Economies of Scope: An Example from Hog Production." *Journal of Agricultural Economics* 49: 427–533.

Azzam, A., and C.S. Skinner. 2007. "Vertical Economies and Structure of U.S. Hog Farms." *Canadian Journal of Agricultural Economics* 55:349–364.

Benson, A.F. 2008. "Organic Dairy Updates." Available at http://www.organic. cornell.edu/organicdairy/News.html. (accessed on April 15, 2009).

El-Osta, H.S. and M.C. Ahearn. 1996. *Estimating the Opportunity Costs of Unpaid Labor for U.S. Farm Operators*. Washington, DC: U.S. Department of Agriculture, Economic Research Service. Technical Bulletin No. 1848, March.

Foley, R.C., D.L. Bath, F.N. Dickinson, and H.A. Tucker. 1972. *Dairy Cattle: Principles, Practices, Problems, Profits*. Philadelphia: Lea and Febiger.

Frank, G. "Cost of Production versus Cost of Production." University of Wisconsin. Center for Dairy Profitability. August 1998.

Harvey, A.C. 1976. "Estimating Regression Models with Multiplicative Heteroscedasticity." *Econometrica* 44: 461–465.

Kaserman, D.L., and J.W. Mayo. 1991. "The Measurement of Vertical Economies and the Efficient Structure of the Electric Utility Industry." *Journal of Industrial Economics* 39: 483–502.

Kwoka, J.E. 2002. "Vertical Economies in Electric Power: Evidence on Integration and its Alternatives." *International Journal of Industrial Organization* 20:653–671.

MacDonald, J.M., E.J. O'Donoghue, W.D. McBride, R.F. Nehring, C.L.Sandretto, and R. Mosheim. 2007. *Profits, Costs, and the Changing Structure of Dairy Farming*. Washington, DC: U.S. Department of Agriculture, Economic Research Service. Economic Research Report No. 47, September.

Macdonald, J.M. and W.D. McBride. 2009. The Transformation of U.S. Livestock Agriculture. Washington, DC: U.S. Department of Agriculture, Economic Research Service. Economic Information Bulletin No. 43, January.

Mayen, C., J. Balagtas, and C. Alexander. 2009. "Technology Adoption and Technical Efficiency: Organic and Conventional Dairy Farms in the United States." Working paper.

McBride, W.D., and C. Greene. 2007. "A Comparison of Conventional and Organic Milk Production Systems in the U.S." Selected Paper presented at AAEA annual meeting, Portland, OR, 29–31 July.

McGregor, C.A. 1989. *Directory of Feeds and Feed Ingredients*. Wisconsin: W.D. Hoard and Sons Co.

Mosheim, R., and C.A. Knox Lovell. 2006. "Economic Efficiency, Structure and Scale Economies in the U.S. Dairy Sector." Paper presented at AAEA annual meeting, Long Beach, CA, 23–26 July.

Perry, M.K. 1989. "Vertical Integration: Determinants and Effects." In Schmanelsee, R. and Willig, R. (eds.). *Handbook of Industrial Organization*. New York, NY: North Holland.

Sumner, D.A., and C.A. Wolf. 2002. "Diversification, Vertical Integration, and Regional Pattern of Dairy Farm Size." Review of Agricultural Economics 24:442–457.

Tauer, L.W., and A.K. Mishra. 2006. "Can the Small Dairy Farm Remain Competitive in US Agriculture?" *Food Policy* 31:458–468.

Tozer, P.R. and A.J. Heinrichs. 2001. "What Affects the Costs of Raising Replacement Heifers: A Multiple-Component Analysis." *Journal of Dairy Science* 84: 1836–1844.

Ward, C.E. 1997. "Vertical Integration Comparison: Beef, Pork, and Poultry." Paper presented at WAEA annual meeting, Reno, NV, 13–16 July.

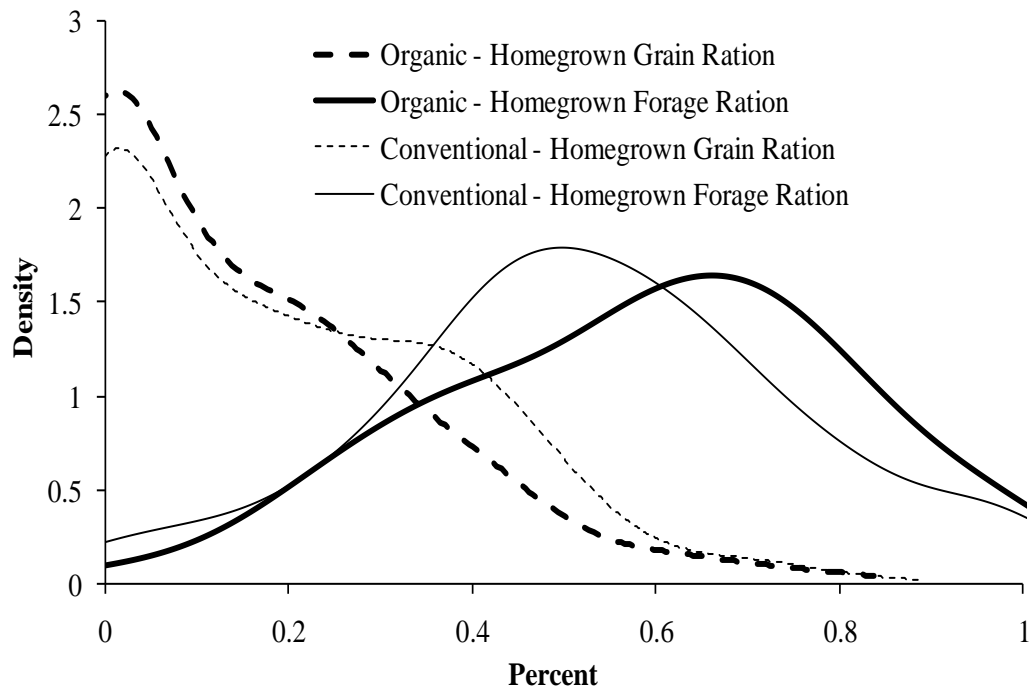**Figure 1. Kernel Density Estimates of the Percentage of Homegrown Grains and Forages on Organic and Conventional Dairy Farms**

Table 1. Summary Statistics for Organic and Conventional Dairy Farms

	Organic Production (N = 205)		Conventional Production (N = 527)	
	Mean	SE	Mean	SE
Milking Cows	63.6	2.4	102.9	7.3
Grains (1,000 cwt)	1.55	0.18	5.50	0.44
Forages (1,000 cwt)	4.97	0.34	8.21	0.55
Milk (1,000 cwt)	8.98	0.39	22.19	1.84
Grain Production (1/0)	0.56	0.03	0.70	0.02
Forage Production (1/0)	0.98	0.01	0.98	0.01
Upper Midwest (1/0)	0.50	0.04	0.48	0.02
Cornbelt (1/0)	0.09	0.02	0.17	0.02
East (1/0)	0.41	0.03	0.35	0.02
Pasture (1/0)	0.59	0.03	0.14	0.02

Table 2. Cost Functions for Organic and Conventional Dairy Production

Cost Model	Organic Production		Conventional Production	
	Coefficient	S.E.	Coefficient	S.E.
Constant	13.114	26.246	56.662	20.047***
Grain Production [a]	–7.159	8.275	–3.417	6.115
Forage Production [b]	43.904	25.855*	3.170	20.067
Grains [c]	8.847	4.648*	7.434	0.830***
Grains × Grains	–0.880	1.943	–0.068	0.037*
Forages [c]	7.851	3.203**	8.874	0.992***
Forages × Forages	–0.063	0.280	–0.039	0.056
Grains × Forages	0.167	1.023	–0.273	0.119**
Milk [c]	15.851	3.211***	9.646	0.402***
Milk × Milk	0.658	0.483	0.006	0.003**
Milk × Grains	0.116	1.206	0.098	0.047**
Milk × Forages	–1.244	0.582**	–0.022	0.025
East	–9.467	7.197	1.472	6.159
Cornbelt	3.438	14.339	–9.706	6.363
Pasture	–6.510	6.496	–0.001	6.247
Heteroscedastic Model				
Constant	0.212	0.585**	1.549	0.875***
Logarithm Herd Size	1.777	0.225***	1.095	0.058***

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.

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

Farm Type and Herd Size	Mean Input Use			$VES_c{}^c$
Organic Farms	Grains[a]	Forages[a]	Milk[b]	
55 cows	1.30	4.10	7.77	0.174
64 cows	1.55	4.97	8.98	0.217
143 cows	3.79	12.70	19.69	0.679
Conventional Farms				
55 cows	2.91	4.88	10.74	0.009
103 cows	5.504	8.21	22.19	0.011
230 cows	12.32	17.00	52.34	0.017

[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 5.