Forage Outsourcing in the Dairy Sector: The Extent of Use and Impact on Farm Profitability

Jeffrey Gillespie, Richard Nehring, Carmen Sandretto, and Charles Hallahan

The extent of forage purchasing behavior in milk production and its impact on profitability are analyzed using data from the 2000 and 2005 dairy versions of the Agricultural Resource Management Survey. Forage outsourcing is more common with hay than with silage and haylage, and is more prevalent in the western United States. Though silage and haylage outsourcing is found to impact profitability, the major profitability drivers appear to be farm size and efficiency. Evidence of significant forage contracting is found in the western United States.

Key Words: forage, input purchasing, outsourcing, contracting, milk production

As U.S. milk production has shifted location to non-traditional production areas such as the American West, larger dairy farms have emerged in those areas—farms that rely less on home-grown and more on purchased forages. These farms are not only less likely to produce their own forage, but also less likely to utilize grazing as a primary source of nutrition for dairy animals, allowing more animals to be carried on fewer acres. This represents a move away from the traditional production of the feed input and the final product, milk, on the same farm (vertical integration) and a move toward specialization in milk production and outsourcing the forage input. The goals of this study are to determine the types of dairy farmers opting to outsource rather than produce their own forages, and to determine the impact of these decisions on farm profitability. A secondary goal is to provide insight into factors influencing the types of business arrangements that specialized forage producers are using to sell their forage. A pooled dataset including years 2000 and 2005 of the Agricultural Resource Management Survey (ARMS) is used to examine structural change in this industry.

Ruminants such as dairy cows require substantial forage. The daily estimated forage requirement of a 1,300-pound Holstein milking cow is about 26 pounds of dry matter or 29.25 pounds of hay-equivalent (Amaral-Phillips and McAllister 2007). This can be met using one of a continuous set of combinations of hay, silage, and/or pasture. Farmers choose a forage ration depending upon a number of factors, three of which are profitability, management preferences, and forage availability. Regardless of the chosen feeding system and whether forages are outsourced or produced on-farm, provision of forages and other feedstuffs constitutes about 50 to 60 percent of the cost of producing milk (Amaral-Phillips and McAllister 2007).

Forage Outsourcing versus Vertical Integration with the Forage Segment in Milk Production

A wealth of literature has addressed the "make or buy," "produce or purchase," or "vertically integrate versus outsource" firm decision (Coase 1937, Williamson 1975, 1979, 1985, Grossman and Hart 1986, Grossman and Helpman 2002). Vertical coordination in agriculture has also re-

Jeffrey Gillespie is Martin D. Woodin Endowed Professor in the Department of Agricultural Economics and Agribusiness at Louisiana State University Agricultural Center in Baton Rouge, Louisiana. Richard Nehring, Carmen Sandretto, and Charles Hallahan are economists at the Economic Research Service, U.S. Department of Agriculture, in Washington, D.C.

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ceived significant attention (Barry, Sonka, and Lajili 1992, Hobbs 1997, Davis and Gillespie 2007). Less work, however, has been devoted to understanding vertical coordination in dairy production than in other livestock sectors, with exceptions such as Sumner and Wolf (2002), who found significant relationships between dairy farm size, vertical integration, specialization, diversification, and region using 1993 USDA Farm Costs and Returns Survey data. The present study focuses on the forage input segment, where we find significant relationships between farm size, region, forage purchasing behavior, and farm profitability.

Considerable effort has been devoted to the development of economic theory to identify those parameters most relevant for deciding whether to produce or outsource inputs. Williamson (1975, 1985) and Grossman and Hart (1986) emphasize the roles of asset specificity and transaction costs in determining whether a firm should vertically integrate or outsource inputs. The presence of costly assets highly specific to a particular function and significant transaction costs tends to encourage well-defined, complete contracts or vertical integration.

Grossman and Helpman (2002) expand the economic theory of the firm's "produce or outsource" decision, citing the roles of transaction costs, competition, and the holdup problem. They conclude that in highly competitive markets, outsourcing must lead to a significant cost advantage to offset the transaction costs associated with searching for a reliable input source and the costs associated with holdup. With milk production, the large number of firms producing the commodity is indicative of a competitive market, suggesting that the magnitude of transaction and holdup costs is particularly important in the decision. Grossman and Helpman (2002) further suggest that in cases where production costs are highly sensitive to specific characteristics of the input (such as input quality), the viability of outsourcing will be reduced.

What characteristics specific to U.S. milk and forage production would influence the forage outsourcing versus vertical integration decision? In areas with well-developed forage markets, the long-run cost associated with purchasing forage might be expected to be competitive with the cost of growing it, including a charge for the operator's labor. The corn silage market price would be determined by the market price for corn grain, bushels of corn per ton of silage, harvest costs, and adjustments for quality. Whether to produce or outsource forage would depend primarily upon managerial factors such as the benefits associated with specialization and debt concerns. Specialization in producing either milk or forage allows the operator to develop expertise by concentrating effort on one enterprise. *Net of transaction costs*, the improved management associated with a specialized milk-producing farm and a second specialized forage-producing farm potentially allows each to produce milk or forage at lower cost per unit than would one farm producing both products. Furthermore, resource constraints would allow the farm to produce more of either milk or forage through specialization than could be produced if both were being produced, leading to greater scale economies in either of the enterprises and, hence, lower cost per unit produced. The relationship between larger-scale dairies and lower levels of vertical integration into feed and replacement heifer production has been previously shown by Sumner and Wolf (2002).

Another incentive for milk producers to purchase forage is the lower initial investment associated with the operation relative to growing forages. Equipment purchases associated with forage planting, harvesting, and other field operations such as plowing and fertilizing require substantial start-up costs, perhaps requiring credit. Barry, Sonka, and Lajili (1992) cite financial constraints as a reason for farmers to enter contracts with upstream or downstream firms supplying inputs or output marketing services versus vertically integrating. This may be particularly important for new farmers who are credit-constrained and/or desire to limit debt.

Boucher and Gillespie (2007) estimate the resource use and costs of field operations associated with forage production. For corn silage production, the total estimated cost of purchasing new implements and tractors is \$105,830 and \$138,288, respectively. Establishment and production of alfalfa hay involves a total estimated cost of purchasing new implements and tractors of \$81,782 and \$48,371, respectively. Land cost associated with growing the forage must be added to the fixed costs for both of these enterprises. Of these fixed expenses, implements such as hay balers and silage choppers are likely to represent the assets that are most specific to forage production.

Labor required for field operations to establish alfalfa is estimated at 1 hour, 4 minutes per acre, and for harvesting, 6 hours, 54 minutes per acre. The labor requirement for corn silage field operations is 4 hours, 19 minutes per acre. For the dairy farmer deciding whether to produce or purchase forage, the significant capital, labor, management, and asset specificity associated with growing and harvesting the forage must be considered.

The arguments made for producing forage and milk on separate farms do not consider the benefits of vertical integration, as discussed by Williamson (1979)—thus, the conditional phrase mentioned earlier, "net of transaction costs."[1] If transaction costs associated with acquiring forage are significant, they could alter the relative profitability associated with producing or outsourcing forage. In addition, risk is expected to change with specialization, as the milk producer must be assured of a steady supply of quality forage from a separate firm; thus, relationships between buyer and seller, such as strategic alliances and contracts, would be expected to arise.

The shift of milk producers away from producing forage is akin to, but less extensive than, shifts in the hog and broiler industries. Hog producers feed less home-produced feedgrain than in years past. Given dairy forage requirements and expected quality variability, some forage contracting would be expected, as has evolved with feed in the hog and broiler industries. Though limited data show the distribution of forage transactions under contract versus spot markets, it is apparent that forage contracting is becoming more common with respect to corn silage (Tranel et al. 2003). Extension publications assist corn silage producers in determining a fair price for corn silage (e.g., Tranel et al. 2003, Stellato 2008, Rankin 2008), with some focus on determining a fair contract price. Evidence gleaned from extension specialists, farmers, and popular press suggests forage contracting to be a common procurement strategy of dairy farmers.

[1] What is seen in the case of larger, often more "industrialized" milk production firms is a movement away from "vertical integration" and toward outsourcing with regard to feed. This suggests that, as opposed to popular usage of the term "vertical integration" to imply industrialization, a movement toward industrialization in livestock is not necessarily associated with a movement toward vertical integration of all upstream and downstream production stages.

Modeling the Forage Purchase Decision and Its Impact on Farm Profitability

The produce versus outsource forage choice could influence farm profitability in a number of both positive and negative ways, with potential influential factors including management specialization, economies of size, economies of scope, transaction costs, holdup costs, and others. Though our dataset does not allow for full assessment of the individual influences of each of these factors due to the indivisibility of inputs, we can determine which farms among those that produce versus outsource forages are the most profitable, providing an assessment of the influence of outsourcing on overall firm performance.

A model for estimating the impact of outsourcing forage on farm profitability for firm i, π_i, assumes that profit is a linear function of the extent of forage purchasing, F_i, and a vector of other explanatory variables, X_i. The equation can be written as

$$(1) \qquad \pi_i = X_i'\beta + \Omega F_i + e_i,$$

where e_i is a random error term. Vector X_i represents farmer and farm characteristics hypothesized to influence farm profitability other than forage purchasing, such as region, farm size, diversification, and demographics. Forage purchasing decisions are also likely to depend on farm and farmer characteristics, so the outcomes are not expected to be random, but rather based on the farmer's self selection. As such, in the spirit of Heckman (1990) and as used by dairy economics studies such as McBride, Short, and El-Osta (2004) and Foltz and Chang (2002), instrumental variables for F_i are appropriate for estimating their impact on profit. The equation used for estimation of an instrumental variable F_i^* for forage purchasing intensity is

$$(2) \qquad F_i^* = Z_i'\gamma + \psi_i,$$

where F_i^* represents an unobservable difference in utility associated with purchased versus homegrown forage, measured as the percentage of forage that is purchased. The term $Z_i'\gamma$ represents estimates of utility using farm characteristics Z_i, and ψ_i is the error term. Because the range of proportions of forage produced on the farm is bounded at zero and 100 percent, with substantial numbers either producing or outsourcing 100 percent of their forage, the distribution for equation (2) is truncated at the zero and 100 percent levels, suggesting an estimator that appropriately models this truncation: the two-limit tobit. For this model, if F_i is the observed dependent variable, then, according to Maddala (1983, p. 161):

$$(3)\qquad \begin{aligned} F_i &= L_{1i} \text{ if } F_i \le L_{1i} \\ F_i &= F^*_i \text{ if } L_{1i} < F^*_i < L_{2i} \\ F_i &= L_{2i} \text{ if } F^*_i \le L_{2i}\,. \end{aligned}$$

In this model, the upper and lower limits are represented by L_{1i} and L_{2i}, respectively. As such, the tobit model can be estimated as

$$(4)\qquad E[F_i \mid F_i = F_i^*] = E[F_i^* \mid 0 < F_i^* < 100]\,.$$

Given the estimation of the instrumental variables, the impact on profitability from equation (1) can be expressed in similar manner as that in Foltz and Chang (2002):

$$(5)\qquad \begin{aligned} E[\pi] = X_i{}'\beta + \Omega\{&E[F_i \mid F_i = F_i^*]*\Pr(F_i = F_i^*) \\ &+ E[F_i \mid F_i = 0]*\Pr(F_i = 0) \\ &+ E[F_i \mid F_i = 1]*\Pr(F_i = 1)\}. \end{aligned}$$

In sum, this model can be estimated using (i) the tobit model to estimate the percentage of forages outsourced, and (ii) ordinary least squares (OLS) to estimate the impact of outsourcing and other factors on profitability. Specific variables used in each of the equations, as well as the data used, are discussed in the following section.

Data and Explanatory Variables

Data used for this analysis were collected via USDA's Agricultural Resource Management Survey (ARMS), an annual comprehensive survey of U.S. farms. In selected years, versions of the Phase III survey are conducted with additional questions to collect detailed data on specific enterprises. In 2000 and 2005, dairy farms were targeted, resulting in a sample of 870 usable dairy observations for 2000 and 1,814 for 2005, for a combined total of 2,684. Weights included in the dataset allow the sample to be expanded to the population of U.S. dairy farms.

Percentage of Purchased Forage

Tobit models [equation (2)] are estimated to determine types of farmers more likely to outsource versus produce hay and straw, and silage and haylage. The first model estimates percentage of hay and straw purchased, including alfalfa and all other hay. The second estimates percentage of silage and haylage purchased, including corn and sorghum silage and haylage. In the ARMS dairy survey, there are categories for "alfalfa hay," "other hay," and "straw," so these were grouped together as dry forage. Likewise, there are categories for "corn silage," "sorghum/milo silage," and "other silage and haylage," all of which were grouped together. Separate equations are estimated for dry and ensiled forages due to their inherent differences in production and bulkiness, as well as the fact that differences were noted in the percentages of each that were purchased, as shown in Table 1.

Region has been shown to be a significant determinant of whether firms vertically integrate or outsource (e.g., Chinitz 1961). Regional factors expected to influence the percentages of hay and straw, and silage and haylage, purchased are represented by regional variables: *Southeast, Lake States, Appalachia, Southern Plains, West, Corn Belt,* and *Pacific*, with the base region being the *Northeast*.[2] These are the major U.S. farm production regions, as designated by the USDA's Economic Research Service, with substantial dairy production. It is expected that greater percentages of forage would be outsourced in the Southern Plains, West, and Pacific states. Reimund, Moore, and Martin (1977) show that changes in the nature of transactions between upstream and downstream firms are often accompanied by changes in production location. States in the western regions such as Idaho and New Mexico are relative

[2] Regions and states included in the ARMS Phase III dairy survey include the Northeast (Maine, New York, Pennsylvania, and Vermont), Lake States (Michigan, Minnesota, and Wisconsin), Corn Belt (Illinois, Indiana, Iowa, Missouri, and Ohio), Appalachia (Kentucky, Tennessee, and Virginia), Southeast (Georgia and Florida), Southern Plains (Texas), West (Arizona, Idaho, and New Mexico), and Pacific (California, Oregon, and Washington). The ARMS Phase III survey (non-enterprise specific) includes all states surveyed in the ARMS.

Table 1. Means of Independent and Dependent Variables

Variable	Units	N	Weighted Mean
Portion purchased hay & straw	%/100	1680	0.2864
Portion purchased silage & haylage	%/100	2040	0.0737
Net farm income	$	2684	74955.7400
Net farm income per cow	$	2684	697.4570
Net farm income per cwt milk	$	2684	4.5186
Southeast	0-1	2684	0.0085
Lake	0-1	2684	0.3882
Appalachia	0-1	2684	0.0527
Southern Plains	0-1	2684	0.0158
Corn Belt	0-1	2684	0.1827
West	0-1	2684	0.0420
Pacific	0-1	2684	0.0501
Acres	No.	2684	387.2251
Cows	No.	2684	129.7053
College	0-1	2684	0.1283
Off-farm hours	No./Yr	2684	111.9245
Operator age	Yrs	2684	49.9748
Portion of farm income from milk	%/100	2683	0.8859
Graze	0-1	2684	0.6681
Year 2005	0-1	2684	0.4228
Milk price	$/cwt	2684	13.6902
Milk per cow	Cwt/Cow/Yr	2684	161.5351

newcomers in large-scale milk production. Sumner and Wolf (2002) show regional differences in vertical integration within the U.S. dairy sector.

Farm size variables include numbers of cows and acres. As dairy enterprise size increases, constrained resources including but not limited to management are expected to move from forage to milk production, leading to greater forage outsourcing. A squared term on *Cows* allows for nonlinearities associated with dairy size and forage outsourcing. Greater acreage, on the other hand, would indicate increased resources potentially available for forage production.

The influence of off-farm work is explored via *Off-farm hours*, the number of hours per year the operator works off the farm. Off-farm work is expected to increase forage outsourcing, given additional constraints placed on the operator. Off-farm employment may signal significant opportunity cost associated with operator labor being allocated to forage production. The utilization of grazing as a forage source for dairy cattle is included as a dummy variable, *Graze*. Forage grazing would substitute for hay, haylage, and/or silage.

Demographic variables include operator age and whether a 4-year college degree is held. A dummy variable, *Year 2005*, is included to determine changes in forage outsourcing between 2000 and 2005. *Year 2005* is expected to have a positive sign.

The appropriateness of pooling 2000 and 2005 data was tested using the likelihood ratio test, where the unrestricted model included all independent variables plus each of the independent variables interacted with *Year 2005*. The restricted model did not include the interaction terms. Results indicated the inappropriateness of pooling 2000 and 2005 data without interaction terms, which would result in biased estimates. Interaction terms for the pooled model are designated as *Year** [...], where * is followed by the independent variable of interest. Inclusion of interaction terms allows for more extensive analysis of structural change over the period of study. Significant estimates suggest nonstationarity of estimates, indicating that the influence of a particular independent variable on outsourcing behavior has changed over time, an expected result in the presence of changing technology and shifting consumer demand.

Second-Stage Profit Estimation

The second-stage estimation of equation (1) determines the influence of forage outsourcing on two whole-farm profit measures: (i) net return per hundredweight of milk produced to operator and land, and (ii) net return per hundredweight of milk produced, including opportunity costs of operator labor and land. Net farm income, a whole-farm concept, is constructed as (gross cash farm income adjusted by changes in inventory, estimated value of home-consumed products, and rental value of dwellings on the farm) less total operating expenses, including interest payments and depreciation on capital stock. In addition, profit measure (ii) includes the opportunity cost for operator labor, determined as the total hours of operator labor multiplied by the wage rate for hired agricultural labor in the state where the farm is located, and a land opportunity cost. The land opportunity cost is determined using the quality-adjusted land measure developed by Nehring, Ball, and Breneman (2002). Land value is based upon its agricultural productivity and distance to market using a hedonic pricing model. Value is adjusted using 2002 values by state. Quality-adjusted land values for 2000 and 2005 are adjusted depending upon the relative land values reported by the USDA's National Agricultural Statistics Service (USDA 2000–2006). The two profitability measures are used, in the case of (i), to account for the situation where operator labor and land are costless, and in the case of (ii), to consider the significant operator labor and land required for producing homegrown forage. Whole-farm profitability measures are preferred to enterprise measures for this study, given the indivisibility of inputs used for both forage and other crop and livestock production.

Independent variables include regional variables, size of operation, specialization, demographic variables, technology variables, forage purchase variables, and data year. The regional variables included in the first-stage equations are used in this stage. Regional and year variables allow for consideration of price differences, as well as production relationships over time and space. Regional differences in dairy farm profitability have been found by previous researchers (e.g., McBride, Short, and El-Osta 2004).

Size variables include *Cows* and *Acres*. With scale economies, average cost would decrease with size, as shown by Tauer and Mishra (2006a) with dairy farms. This would yield higher net farm income per cow or hundredweight of milk produced. An enterprise specialization variable is *Percent of farm income from milk*. Farm income from sources other than the dairy would be expected to increase net farm income per unit of output.

Demographic variables include *College* and *Age*. It is expected that more highly educated farmers would realize greater net farm income due to superior managerial ability. Foltz and Chang (2002) found higher profitability among more highly educated Connecticut dairy farmers. The impact of age is explored. Tauer and Mishra (2006b) found age to be associated with higher cost dairy operations, which would imply lower net farm income. On the other hand, older farmers might realize higher net farm income due to experience.

A proxy for technology use is *Milk per cow*, measured as the hundredweight of milk produced per cow per year. The use of advanced technologies is expected to yield greater net farm income if used on sufficiently large operations to spread the fixed costs over more cows. *Milk per cow* is a proxy for technologies and management strategies that would influence cow productivity such as breed type, use of recombinant bovine somatotropin, record-keeping, and others. *Milk price*, the average price of milk received per hundredweight, is included.

Decisions involving whether to outsource or produce forages are included in the models as two instrumental variables estimated using equation (2)—*Pr-percentage purchased hay and straw* and *Pr-percentage purchased silage and haylage*—which represent the predicted percentages of hay or straw and silage or haylage purchased, derived from the first-stage estimates. In the spirit of

Heckman (1990), these are considered valid instruments if the independent variables used in the tobit models to predict them provide reasonable predictors of forage purchasing behavior. Similar to the tobit analyses, interaction terms are included as *Year** to test the null hypothesis that effects of independent variables on measures of profitability are stationary.

How Are Forage Producers Marketing Their Forage?

Limited data link milk production with specific forage procurement strategies. The ARMS does, however, collect forage production data, including quantities of alfalfa hay, other hay, corn silage, and sorghum silage produced, used on the farm, and sold via contract or spot markets. These data are available via the Phase III ARMS. If contract forage sales were more common relative to spot market sales in regions of greater forage outsourcing by dairy farmers, this would suggest increased forage procurement via contract in these regions. Such results would allow us to extend our knowledge of dairy farmers' outsourcing decisions (demand) to understanding the nature of the outsourcing on the supply side via contract or spot market.

For consistency with the dairy analysis, the 2000 and 2005 ARMS Phase III data were used for the forage analysis, but the data were not limited to dairy farms. These surveys include 10,309 and 22,843 observations, respectively, to determine the types of producers who produce hay or silage (i) for only their own animals' consumption, (ii) for sale via spot markets, and (iii) for sale via production or marketing contract. A fourth option is that the farmer does not produce hay or silage. The primary objective is to determine where most of the hay and silage sold under contract is produced and the types of farmers producing it. In similar manner to Davis and Gillespie's (2007) analysis of business arrangement selection in U.S. hog production, the multinomial logit model, expressed in equation (6), which follows Greene (2000, p. 859), is used:

$$\text{(6)} \qquad \text{Prob}(Y=j) = \frac{e^{\beta_j' x}}{\sum_{k=0}^{3} e^{\beta_k' x_i}}, \; j = 0,...,3.$$

With four possible choices, the designation $j = 0, \ldots, 3$ holds. Two separate models are estimated, one for silage and the other for hay.

Independent variables in the multinomial logit model include regional dummy variables *Pacific* and *West*, with the base being all other regions. For the silage analysis, *Southern Plains* is also included. We required the region to have at least 15 observations in each category to be included as a separate regional dummy variable. Other variables in both analyses were *Dairy* (value of dairy production), *Cattle* (value of cattle production), *Acres, Percent value forage* (percentage of farm production value in forage), and *Year 2005.* As in the dairy analysis, weights extend the analysis to the U.S. farm population. Similar to the other analyses in this paper, interaction terms by year allow pooling of the data and testing of the null hypothesis of estimate nonstationarity.

Weighted regression procedures were used to estimate all models. The multi-phase sampling underlying ARMS data provides challenges in estimating variances using classical methods, thus the delete-a-group jackknife estimator is used, as discussed by the Panel to Review USDA's Agricultural Resource Management Survey (2008).[3] A convenient property of the delete-a-group jackknife procedure is that it is robust to unspecified heteroscedasticity.

Results

Table 1 shows weighted means of independent and dependent variables. Table 2 shows comparisons of percentages of hay and straw purchases relative to homegrown of ≥ 50 percent and < 50 percent, and of silage and haylage purchases relative to homegrown of ≥ 50 percent and < 50 percent using weighted means tests for selected variables. Operators with ≥ 50 percent of hay and

[3] The empirical regression results reported in the tables in the results section are derived using farm-level annual data. The data come from a complex survey design (both an area and list frame), not a model-based random sample commonly used in econometric analysis. Hence, a jackknifing procedure is used with 15 replicates to estimate sample variances (to get t-statistics on the coefficients from the base run regressions) in order to make inferences about the population. For a further explanation as to why "nonclassical" econometrics must be employed to achieve sensible inferences about the population of the sample, see *Understanding American Agriculture: Challenges for the Agricultural Resource Management Survey* (National Academies Press, Washington, D.C., 2008). In particular, see Chapter 4 on survey design and Chapter 7 on methods for analysis of complex surveys.

Table 2. Differences in Means of Selected Variables

	Hay and Straw Purchase		Silage and Haylage Purchase	
Variable	≥ 50%	< 50%	≥ 50%	< 50%
Age	48.76[A]	50.61[B]	46.90[A]	50.30[B]
Acres	349.0[A]	407.2[B]	285.5[A]	398.0[B]
Debt-asset ratio	0.20[A]	0.16[B]	0.23[A]	0.17[B]
Milk per cow (cwt/cow/year)	167.86	158.22	172.73[A]	160.35[B]
College	0.15	0.12	0.19[A]	0.12[B]
Off-farm hours	101.45	117.41	144.62	108.46
Cows	186.91[A]	99.76[B]	280.81[A]	113.73[B]
Percent of farm income from milk	87.4[A]	82.9[B]	91.5[A]	83.7[B]
Net farm income ($)	569,313[A]	316,911[B]	853,015[A]	356,157[B]
Net farm income / cow ($)	524[A]	631[B]	537	589
Net farm income / cwt ($)	2.82[A]	3.68[B]	2.81	3.36
Region				
Southeast	0.01	0.01	0.01	0.01
Northeast	0.24	0.27	0.30	0.26
Appalachia	0.04[A]	0.06[B]	0.03[A]	0.06[B]
Southern Plains	0.03[A]	0.01[B]	0.03[A]	0.01[B]
Corn Belt	0.18	0.18	0.10[A]	0.19[B]
Lake States	0.30[A]	0.43[B]	0.25[A]	0.40[B]
West	0.08[A]	0.02[B]	0.12[A]	0.03[B]
Pacific	0.12[A]	0.01[B]	0.15[A]	0.04[B]

Note: Letters A and B indicate significant column difference tests based on pairwise two-tailed delete-a-group jackknife t-statistics at a 90 percent confidence level or higher with 15 replicates and 28 degrees of freedom. Tests pertain *only within each of the two groupings* on the first row of the table.

For region variables, numbers in each column sum to 1.

straw, and silage and haylage, being outsourced were younger, farmed fewer acres, held greater debt, milked more cows, received a higher percentage of farm income from milk, and realized higher total net farm income. In addition, purchasers of silage and haylage were more likely to hold college degrees, and purchasers of hay and straw were more likely to realize lower net farm income per cow and per hundredweight of milk produced. Regional differences in the weighted means are striking, with *Appalachia*, *Corn Belt*, and *Lake States* dairy farmers relying less heavily, and *West, Pacific*, and *Southern Plains* dairy farmers relying more heavily on outsourced forage.

Differences in weighted means are valuable in that they show whether outsourcing behavior varies with one particular variable, providing insight as to whether there is a simple correlation between purchasing behavior and the variable, phenomena which are often observed in the industry. However, these statistics provide limited capability to analyze the relationship between the variables; thus, a multivariate analysis is required for fuller understanding of the factors influencing outsourcing. Tobit results show that a number of factors influence the decision of whether to outsource or produce forages for the dairy operation (Tables 3 and 4). As expected, region was important. *Southern Plains & West* and *Pacific* dairy producers were more likely and *Lake States* dairy producers less likely to purchase hay and straw than were those in the *Northeast. Southern Plains & West* dairy producers were more likely and *Lake States* and *Corn Belt* dairy producers less likely to purchase silage and haylage than were those in the *Northeast*. These results, coupled

Table 3. Tobit Results for Portion of Purchased Hay and Straw

Variable	Estimate β	Std. Error
Constant	0.1983	0.4126
Southeast	0.1575	0.2663
*Year*Southeast*	0.1744	1.7489
Lake	-0.4986***	0.1762
*Year*Lake*	0.7486***	0.2356
Appalachia	-0.2741	0.1757
*Year*Appalachia*	0.2267	0.2798
Southplains&west	0.7599***	0.1807
*Year*Southplains&west*	-0.0941	0.2689
Corn Belt	0.0113	0.1927
*Year*Corn Belt*	0.1491	0.2469
Pacific	1.3566***	0.2587
*Year*Pacific*	-0.2750	0.4727
Acres	-0.0004*	0.0002
*Year*Acres*	0.0001	0.0006
Cows	0.0015*	0.0009
*Year*Cows*	0.0001	0.0014
Cows squared	-3.68E-7	3.73E-7
*Year*Cows squared*	1.20E-7	4.20E-7
College	0.2698	0.2193
*Year*College*	-0.4669	0.2967
Off-farm hours	-0.0003*	0.0002
*Year*Off-farm hours*	0.0004*	0.0002
Operator age	-0.0107*	0.0060
*Year*Operator age*	0.0039	0.4451
Graze	0.0363	0.1786
*Year*Graze*	0.0299	0.2557
Year 2005	-0.3298	-0.5716
Sigma	0.9320***	0.0797
N	2368	
Log likelihood	-84986	

Note: ***, **, and * indicate significance at the 1 percent, 5 percent, and 10 percent levels, respectively, using the delete-a-group jackknife variance estimator with 15 replicates.

with the differences in weighted means tests, suggest that the transition from vertically integrated forage and milk production to production by separate firms has been more pronounced in the *Southern Plains & West* and *Pacific* regions, and less so in the traditional *Corn Belt, Lake States*, and *Northeast* regions. This is consistent with Reimund, Moore, and Martin's (1977) thesis that changes in the relationship between upstream and downstream firms (toward contracting) generally occur in new production regions. It is also consistent with Sumner and Wolf's (2002) results showing regional differences in vertical integration on U.S. dairy farms. Chinitz (1961) was among the early economists to point out that organizational structure of industries and firm size often differ among regions, citing potential reasons and calling for greater work in the area.

Older producers—those expected to use traditional technologies and business arrangements—were less likely to outsource hay and straw. Producers working more off-farm hours were more likely to outsource silage and haylage. Results of the off-farm hours variable were mixed for purchases of hay and straw, as the sign on *Off-farm hours* was positive but the sign for *Year*Off-farm hours* was negative, suggesting that the effect of off-farm employment depended on year. Holding a college degree led to increased outsourcing of silage and haylage.

The positive coefficient on the *Cows* variable for percentage of purchased hay and straw suggests that larger dairies are more likely to outsource hay and straw.[4] As the dairy enterprise becomes larger, the firm specializes by concentrating management in milk production. Increased acreage, however, was associated with reduced forage outsourcing.

Outsourcing of hay and straw, and silage and haylage, is not shown to have increased from 2000 to 2005. Significant interaction terms, however, show that the coefficients were non-stationary over the period. Specifically, the *Year*Lake States* and *Year*Corn Belt* variables are positive and significant in the hay and straw, and silage and haylage, runs, respectively, suggesting relatively greater movement toward forage purchasing in those regions relative to the *Northeast*.

Factors Influencing Net Farm Income

As expected, region and milk price influenced both measures of net farm income (Table 5). The

[4] The negative and significant estimate for *Cows squared* suggests a decreasing effect on forage purchasing with size. The estimate would suggest the percentage purchased is maximized at 3,200 cows, though one cannot place much confidence in this since there would be relatively few observations from which to draw in the very large range.

Table 4. Weighted Tobit Results for Portion of Purchased Silage and Haylage

Variable	Estimate β	Std. Error
Constant	-0.6749	0.7999
Southeast	0.8376	0.7113
*Year*Southeast*	-0.3149	0.9246
Lake	-0.9782***	0.3398
*Year*Lake*	0.7051	0.4375
Appalachia	-0.2185	0.4461
*Year*Appalachia*	-0.2904	0.6643
Southplains&west	1.6392***	0.5547
*Year*Southplains&west*	-0.1617	0.9843
Corn Belt	-1.1287***	0.2793
*Year*Corn Belt*	1.0867**	0.4403
Pacific	0.2271	0.5485
*Year*Pacific*	0.6300	1.1452
Acres	-0.0022***	0.0006
*Year*Acres*	0.0019	0.0018
Cows	0.0023	0.0019
*Year*Cows*	-0.0014	0.0025
Cows squared	-7.55E-7	8.93E-7
*Year*Cows squared*	6.51E-7	9.55E-7
College	0.8429***	0.3177
*Year*College*	-0.8647	0.5604
Off-farm hours	0.0007***	0.0002
*Year*Off-farm hours*	-0.0004	0.0004
Operator age	-0.0114	0.0143
*Year*Operator age*	-0.0074	0.0188
Graze	-0.2245	0.2768
*Year*Graze*	0.1420	0.2991
Year 2005	-0.0002	1.4635
Sigma	1.5321***	0.1311
N	2040	
Log likelihood	-36640	

Note: ***, **, and * indicate significance at the 1 percent, 5 percent, and 10 percent levels, respectively, using the delete-a-group jackknife variance estimator with 15 replicates.

most profitable farms had larger dairy herds when opportunity costs for land and operator labor were included. The farm size variable, *Acres*, had mixed effects on farm profitability, with interaction terms *Year*Acres* being significant in both cases and opposite in sign of the *Acres* variable, indicating differing effects by year. Differences by year were expected, likely the result of different input and output prices other than milk between the two years. More profitable farms generally derived greater additional income from other farm enterprises. Age had mixed effects on profitability, depending upon year. As expected, farms realizing greater milk production per cow were more profitable when opportunity costs were considered, but mixed effects by year were found when opportunity costs were not considered.

Controlling for other factors that could influence farm profitability, the only forage outsourcing variable that was significant was *Pr-percent purchased silage & haylage*, indicating that farms outsourcing a higher percentage of silage and haylage were less profitable than those outsourcing less. These numbers, however, must be viewed with caution, as the *Year*Pr-percent purchased silage & haylage* coefficients are larger and opposite in sign of the *Pr-percent purchased silage & haylage* coefficients for one of the regressions, and "close" for the other, but non-significant. This likely explains the lack of significance for any of the percent purchased variables in the restricted (no *Year** interaction terms) models that are not reported here. Results, however, suggest that the benefits to outsourcing rather than growing one's own silage and haylage do not improve the representative farm's total profitability or its profitability per unit of input or output, which helps to explain why only 7.4 percent of silage and haylage was purchased over the period of study. It is of interest that the *Pr-percent purchased silage & haylage* coefficients were significant, while those for the *Pr-percent purchased hay and straw* coefficients were not. The coefficients are larger and the standard errors smaller for the former than the latter, suggesting a consistently greater impact of outsourcing of silage and haylage than hay and straw on profitability. This may be partially the result of transportation and subsequent storage costs for silage being greater than those costs for hay, suggesting on-farm production being lower-cost. At the least, these results suggest that, for the representative farm, profitability associated with producing one's own forage is not exceeded by the profitability associated with purchasing it.

Table 5. Ordinary Least Squares Regressions for Net Farm Income (NFI)

	NFI / cwt		NFI Less Opportunity Costs / cwt	
Variable	β	Std. Error	β	Std. Error
Constant	11.37***	0.09	-26.95***	0.13
Southeast	-1.73***	0.22	3.10***	0.47
*Year*Southeast*	0.51	2.48	-1.39	1.99
Lake	1.05***	0.01	3.81***	0.01
*Year*Lake*	0.89***	0.05	-3.16***	0.05
Appalachia	1.29***	0.01	4.73***	0.01
*Year*Appalachia*	-2.74***	0.03	-4.44***	0.01
Southern Plains	-0.61	0.82	6.47***	1.45
*Year*Southern Plains*	-1.82*	1.10	-3.75***	1.34
Corn Belt	0.96***	0.01	1.80***	0.02
*Year*Corn Belt*	-0.15*	0.08	-0.84***	0.05
West	-1.82**	0.73	4.06***	1.47
*Year*West*	0.58	0.84	-2.46*	1.34
Pacific	-1.36	1.55	4.44*	2.67
*Year*Pacific*	1.61	1.85	-3.46	2.91
Cows	00.0	0.00	0.01***	0.00
*Year*Cows*	-00.0	0.00	-0.00***	0.00
Portion of farm income from milk	-9.09***	0.03	6.25***	0.06
*Year*Percent of farm income from milk*	3.62***	0.14	-1.75***	0.12
Operator age	0.01***	0.00	0.02***	0.00
*Year*Operator age*	-0.02***	0.00	-0.01*	0.00
Acres	0.00***	0.00	0.00	0.00
*Year*Acres*	0.00***	0.00	-0.00***	0.00
Pr-percent purchased hay & straw	0.58	1.78	-1.71	3.01
*Year*Pr-percent purchased hay & straw*	-2.16	2.25	2.72	3.27
Pr-percent purchased silage & haylage	-1.81**	0.71	-4.10***	1.02
*Year*Pr-percent purchased silage & haylage*	4.71	5.46	3.48	3.81
Milk price	0.12***	0.11	0.35***	0.01
*Year*Milk price*	0.05***	0.01	0.25***	0.01
Milk per cow	-0.01***	0.00	0.07***	0.00
*Year*Milk per cow*	0.01***	0.00	0.02***	0.00
Year 2005	-4.71***	0.18	-4.20***	0.34
N	2683		2683	

Note: ***, **, and * indicate significance at the 1 percent, 5 percent, and 10 percent levels, respectively, using the delete-a-group jackknife variance estimator with 15 replicates.

Where Is Forage Contracting Occurring?

Results of the forage contracting multinomial logit model are shown in Tables 6 and 7 and indicate that silage contracting is more prevalent in the *West* and *Pacific* regions relative to the rest of the United States. Relative to other regions, *Pacific* and *West* farmers were more likely to have marketing contracts for their hay than to produce for on-farm use or to produce no hay. Relative to other regions, *Pacific* and *West* farmers were more likely to have marketing contracts for their

Table 6. Multinomial Logit Results for Hay Production in the United States, n = 31,313

	On-Farm Use vs. No Hay	Hay Sale vs. No Hay	Hay Contract vs. No Hay	Hay Sale vs. On-Farm Use	Hay Contract vs. On-Farm Use	Hay Contract vs. Hay Sale
Constant	-0.4177***	-1.7204***	-10.4473***	-1.3027***	-10.0294***	-8.7310
	(0.0486)	(0.1050)	(0.7852)	(0.1104)	(0.7872)	(7.8308)
Pacific	-2.0911***	-0.9910***	3.3765**	1.1000*	5.4673***	4.3696
	(0.2803)	(0.3920)	(0.0486)	(0.5704)	(1.5107)	(6.2860)
*Year*Pacific*	-0.0499	-1.9752	-2.9341	-1.9253	-2.8840	-0.9609
	(0.2901)	(1.3939)	(1.8763)	(1.4611)	(1.9091)	(7.2313)
West	-0.6975**	-0.0095	4.1434***	0.6880**	4.8407***	4.1536
	(0.3211)	(0.2977)	(0.8546)	(0.3242)	(0.8861)	(6.2092)
*Year*West*	0.0644	-0.2107	-2.5691	-0.2751	-2.6333	-2.3591
	(0.4399)	(0.3693)	(1.7612)	(0.4280)	(1.6895)	(7.2313)
Dairy	1.45E-6***	8.69E-7***	-0.0003	-5.78E-7**	-0.0007	-4.21E-5
	(3.14E-7)	(1.84E-7)	(0.0055)	(2.46E-7)	(0.0036)	(0.0003)
*Year*Dairy*	-1.08E-6***	-5.19E-7**	0.0004	5.59E-7**	0.0007	4.10E-5
	(3.41E-7)	(2.44E-7)	(0.0055)	(2.42E-7)	(0.0036)	(0.0003)
Cattle	2.45E-8	3.45E-8	6.32E-8	1.01E-8*	3.88E-8	2.87E-8
	(4.63E-8)	(4.69E-8)	(6.90E-8)	(6.09E-9)	(3.02E-7)	(7.72E-6)
*Year*Cattle*	3.69E-8	3.68E-8	7.94E-10	-5.52E-11	-3.61E-8	-3.60E-8
	(4.97E-8)	(5.08E-8)	(2.14E-6)	(1.06E-8)	(2.16E-6)	(8.95E-6)
Acres	3.07E-6	6.03E-6	1.02E-5	2.95E-6	7.12E-6*	4.18E-6
	(1.29E-5)	(1.13E-5)	(1.13E-5)	(4.09E-6)	(4.17E-6)	(0.0002)
*Year*Acres*	1.39E-5	1.34E-5	1.12E-5	-5.04E-7	-2.74E-6	-2.25E-6
	(2.63E-5)	(2.77E-5)	(2.75E-5)	(4.95E-6)	(8.06E-6)	(0.0003)
Percent value forage	15.9778	38.2085**	38.9629**	29.3586**	30.1129**	0.7571
	(0.5539)	(15.7249)	(15.7061)	(12.2260)	(12.5870)	(2.8780)
*Year*Percent value forage*	-50.1399**	4.1186	1.9850	54.2585**	52.1249*	-2.1364
	(20.6163)	(28.7380)	(28.5832)	(25.8882)	(26.8882)	(3.5927)
Year 2005	0.0623	-0.9670***	1.9195**	-1.0293***	1.8569**	2.8905
	(0.0761)	(0.2794)	(0.9450)	(0.2849)	(0.9464)	(9.1352)

Note: ***, **, and * indicate significance at the 1 percent, 5 percent, and 10 percent levels, respectively, using the delete-a-group jackknife variance estimator with 15 replicates.

Table 7. Multinomial Logit Results for Silage Production in the United States, n = 31,313

Variable	On-Farm Use vs. No Silage	Silage Sale vs. No Silage	Silage Contract vs. No Silage	Silage Sale vs. On-Farm Use	Silage Contract vs. On-Farm Use	Silage Contract vs. Silage Sale
Constant	-2.6262***	-4.3185***	-8.9201***	-1.6924***	-6.2939***	-4.6015***
	(0.0471)	(0.1234)	(0.4840)	(0.14)	(0.5012)	(0.4430)
Pacific	-3.7527***	-1.7052*	1.5375	2.0475**	5.2902***	3.2427**
	(0.6127)	(0.8943)	(1.0043)	(0.9137)	(1.3186)	(1.5344)
*Year*Pacific*	-0.6036	2.0545*	0.6472	2.6581*	1.2508	-1.4073
	(0.8941)	(1.2294)	(1.3317)	(1.3579)	(1.5539)	(2.0644)
West	-1.1440	-0.6647*	2.7231**	0.4793	3.8671*	3.3878***
	(1.1926)	(0.3736)	(1.3640)	(1.2383)	(2.2901)	(1.4159)
*Year*West*	-0.9157	1.3233	-0.3627	2.2390***	0.5531	-1.6859
	(0.8017)	(0.8120)	(1.7766)	(1.0007)	(2.2320)	(1.9602)
Southern Plains	-2.6048	-2.2346	0.3690	0.3702	2.9738	2.6036
	(3.1036)	(2.4647)	(1.9070)	(3.7482)	(3.6581)	(3.0446)
*Year*Southern Plains*	-3.1461	-0.2321	0.8902	2.9140	4.0363	1.1223
	(3.1384)	(2.6339)	(2.1803)	(3.89)	(4.2188)	(2.6566)
Dairy	1.05E-5***	9.53E-6***	7.16E-6	-9.82E-7**	-3.35E-6	-2.37E-6
	(1.45E-6)	(1.30E-6)	(0.0015)	(4.81E-7)	(0.0015)	(0.0007)
*Year*Dairy*	-3.77E-6**	-4.29E-6***	-2.58E-6	-5.14E-7	1.19E-6	1.71E-6
	(1.91E-6)	(1.60E-6)	(0.0015)	(7.44E-7)	(0.0015)	(0.0007)
Cattle	6.44E-8***	5.55E-8**	-3.93E-7	-8.88E-9	-4.57E-7	-4.48E-7
	(2.63E-8)	(2.76E-8)	(5.08E-5)	(1.09E-8)	(5.08E-5)	(5.80E-5)
*Year*Cattle*	1.88E-7**	1.61E-7**	5.30E-7	-2.71E-8	3.42E-7	3.69E-7
	(7.66E-8)	(7.86E-8)	(5.08E-5)	(2.22E-8)	(5.08E-5)	(5.08E-5)
Acres	1.07E-5	1.08E-5	8.18E-6	1.15E-7	-2.50E-6	-2.62E-6
	(8.24E-6)	(9.63E-6)	(6.23E-5)	(3.95E-6)	(5.92E-5)	(6.22E-5)
*Year*Acres*	2.29E-6	-5.39E-7	1.97E-6	-2.83E-6	-3.29E-7	2.50E-6
	(2.14E-5)	(1.90E-5)	(6.70E-5)	(4.69E-6)	(5.89E-5)	(6.14E-5)
Percent value forage	-2.5542**	1.4415***	0.8616	3.9957***	3.4158**	-0.5799
	(1.2056)	(0.2617)	(1.0062)	(1.1466)	(1.6243)	(1.0982)
*Year*Percent value forage*	-0.0286	0.8982**	0.9302	0.9268	0.9587	0.0320
	(1.2410)	(0.4187)	(1.0113)	(1.2008)	(1.6227)	(1.0871)
Year 2005	0.0814	-1.0496***	-0.1234	-1.1311***	-0.2049	0.9262
	(0.0603)	(0.1462)	(1.0933)	(0.1732)	(1.0831)	(1.0940)

Note: ***, **, and * indicate significance at the 1 percent, 5 percent, and 10 percent levels, respectively, using the delete-a-group jackknife variance estimator with 15 replicates.

silage than to sell it via spot markets, produce it for on-farm use, or in the case of the *West,* to produce no silage. These results are consistent with other results reported in this paper showing these regions to be the most likely for producers to outsource silage or haylage and hay or straw. Expected results were also found for the *Acres, Dairy,* and *Percent value forage* variables. Though several of the *Year 2005* coefficients are significant, further research should be conducted to flush out whether the results represent a trend or simply are a function of the conditions of these two specific years. Likewise, a number of *Year** interaction terms are significant, suggesting that the impact of some of the variables on industry structure was non-constant over time. These results provide evidence that, in the regions where forage outsourcing has been shown to be most prevalent among dairy farmers, the transactions are more likely to be under contract, providing evidence of vertical coordination among dairy farmers and forage producers. Outsourcing via contract would serve to reduce the transaction costs associated with forage producers searching for buyers and dairy farmers searching for suppliers of quality forage, which would be particularly important given the significant capital investments in assets specific to the production of forage or milk.

Conclusions

The way that dairy producers procure forages has evolved significantly over the past two decades, with forage outsourcing becoming more common as dairy farms have become larger and more specialized in milk production. The trend for dairy farms has been to move away from vertically integrated forage and milk production. Through discussion with dairy extension specialists, farmers, extension fact sheets, popular publications, and our analysis of forage contracting, indications are that a substantial portion of purchased forages are procured via contract; however, a better understanding of the variation in specific arrangements of these transactions would be a fruitful area for future research. This paper represents an early attempt to identify those farms most likely to outsource forages, and to develop a better understanding of whether the decision to purchase can be attributed to greater farm profitability or better allocation of management via specialization with a larger dairy.

Significant differences were found in forage purchasing behavior by region—a conclusion that is consistent with Sumner and Wolf's (2002), and Reimund, Moore, and Martin's (1977) original and Gillespie, Karantininis, and Storey's (1997) revised thesis that fundamental changes in the vertical structure of an industry are likely to occur in nontraditional production regions. These authors suggest that as technology is developed and farm size increases, shifts in the location of dairies to new production areas occurs where business arrangements evolve to deal with the increased associated risk and transaction costs. The westward movement of dairy production and the establishment of larger dairies have coincided with greater forage purchasing. Thus, this pattern of structural change appears to be following a trend that would be expected from previous observation of the evolution of agricultural industries. Furthermore, increased contracting of hay and silage is occurring in the relatively new western dairy production regions**,** where there is greater forage outsourcing by dairy farmers. We cannot link this forage contracting specifically to dairy farms, but evidence suggests significant contracting in dairy, considering the extensive demand for outsourced silage and hay in those regions. Given the extensive specific assets associated with both dairy and forage production and significant transaction costs in the sale and procurement of forage, the evolution of contracting is not surprising. Further investigation of the specific types of contracts being utilized is of interest.

Along with size and location influences on the forage outsourcing decision, a number of complementary factors also lend insight into the movement toward outsourcing. Specifically, younger, ostensibly newer producers are more likely to purchase, along with those working more hours off-farm and holding college degrees. Though forage outsourcing was not shown to have increased from 2000 to 2005, it is evident that the factors influencing forage procurement behavior were not constant over time, suggesting structural change. Together, this information suggests that newer, younger producers are establishing larger dairies in non-traditional regions of production, and these producers exhibit a tendency to outsource rather than produce their forage.

This study finds that the forage procurement strategy has a significant influence on dairy farmers' whole-farm net farm income, though it is somewhat unclear whether this could hold over multiple years, as the signs on the year interaction terms were opposite those of the main effect, and the magnitude larger, though non-significant. Thus, caution is urged against reading too much into the main effects. What is clear from the analysis is that forage outsourcing did not result in greater farm profitability. What must be realized, however, is that one of the consistent drivers toward greater profitability was farm size, measured by number of cows, which is positively associated with greater forage purchases. When considered in a multivariate framework, the major drivers of greater net farm income appear to be production location, farm size, farm diversification, technology, farmer demographics, and milk price. Forage purchasing releases management time, so the farm can expand to a larger size, diversify into other enterprises, and limit debt, hence allowing the farm to realize greater profit.

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