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Dairy Resource Management: A Comparison of Conventional and Pasture-Based Systems

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Abstract: Facing rapid and significant change in the sector, U.S. dairy production trends from 1993-2005 were tracked and performance measures (scale and technical efficiency and returns on assets) were estimated for conventional and pasture-based dairy farms using data from USDA's Agricultural Resource Management Survey. Comparisons of relative economic performance of dairy farms by size and type are made.

Key Words: *dairy operations, pasture-based systems, technical efficiency*

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Background

The U.S. dairy sector is experiencing rapid change characterized by several economic and institutional trends that have implications for dairy producers and environmental quality. U.S. dairy farms are becoming larger, but fewer in number with more animals per cropland acre, and more scale efficient. This increased concentration creates potential for associated manure management problems, particularly in urban influenced areas. For example, the supply of nutrients in manure on farms or within a geographic unit, e.g. county, increasingly exceeds the nutrient requirements of crops grown there. Consequently, dairy producers face increased manure management costs due to the imposition of new animal feeding operation regulations (Ribaud et al).

Another is an expansion of “urban influences” into formerly rural traditional dairy producing areas that can increase production costs and impose other constraints that impact dairy producers’ efficiency. It is also true that urban expansion in some of the “nontraditional” areas in the West, particularly in California, is increasing costs and lowering competitiveness. From 1994 to 2004, the number of U.S. farms with dairy cows decreased from 148,690 to 78,295, while total milk production increased from 154 billion pounds to 171 billion pounds (USDA-National Agricultural Statistics Service). Increased concentration can lead to potential water pollution that may offset recent gains derived from improvements in commercial fertilizer management practices.

It has been argued that one way these concerns can be partially addressed is through the use of pasture-based dairy operations, where animals are allowed to graze, reducing the quantity

of manure accumulated in confined areas and potentially reducing odor problems. Though often characterized by lower milk production per cow, pasture-based operations are perceived to be more “natural” and environmentally friendly than are conventional systems.

The largest dairies that have emerged are generally “conventional dairies,” conventional referring in this case to capital-intensive, high-input, high-output, confinement dairies that rely minimally on pasture grazing for animal nutrition. These types of operations are referred to by Taylor and Foltz as “stored feed operations,” and generally rely on a total mixed ration (TMR) for animal nutrition. Pasture-based production, on the other hand, relies heavily on forage from pasture for nutrition. Using ARMS (Agriculture Resource Management Survey) data for 1993, 2000, and 2005, this study compares the performance measures (scale and technical efficiency and returns on assets) of pasture-based operations with conventional operations. Using these results, we then draw conclusions regarding competitiveness of pasture-based dairy production in the U.S. We use the 2005 ARMS survey to predict forage reliance for the 1993 FCRS and the 2000 ARMS because the 2005 ARMS survey asked questions on forage reliance that were not in the earlier surveys. For 2005 we find that close to 33 percent of farms and 12 percent of production occur on forage or semi-forage reliant farms.

Among pasture-based operations, a broad spectrum of degree of dependence on pasture exists, with Taylor and Foltz breaking this group into “management intensive grazing” and “mixed feed” operations. Management-intensive grazers use pasture as the primary forage source during the grazing period, while mixed feed operators obtain part of their forage rations from pasture but rely primarily on stored feed. A “rule of thumb” definition of pasture-based grazing commonly heard in the industry involves the milk cow receiving at least 50 percent of its nutritional needs from pasture during the grazing season. In selecting a sample of Pennsylvania

dairy farms for a survey of grazers, Hanson et al. required that the animals had to obtain at least 40% of their forage needs during the summer months from pasture. Dartt et al. defined a “management intensive grazing operation” as one where at least 25 percent of the annual forage requirement was obtained via pasture. The animals were to have been grazed for at least four months. Thus, the actual percentage of pasture required for an operation to be legitimately termed “pasture-based” seems to vary depending upon the assumptions of those doing the studies.

Pasture-based production varies by region, as forage availability from pasture depends partially upon climate. In the United States, the grazing season may range from as short as four or five months in the Upper Midwest to year-round in the Southeast. For purposes of the current study, operations (based on grazing season data) may be categorized as one of the following: (1) conventional, meaning that either no pasture is used or less than 25 percent of forage needs are met by pasture during the grazing season, (2) semi-forage reliant, meaning that between 25 and 50 percent of forage needs are met by pasture during the grazing season, and (3) forage reliant pasture-based, meaning that at least 50 percent of forage needs are obtained via pasture during the grazing season. Conventional, semi-forage reliant, and forage-reliant pasture-based operations would roughly correspond respectively to the stored feed, mixed feed, and management intensive grazing systems referred to by Taylor and Foltz, or TMR, daytime pasture with TMR at night, and pasture-based systems examined by Tozer, Bargo, and Muller. As discussed later in this study, non grazing season use of high energy feed stuffs such as corn silage or other concentrates may alter our assessment of the level of **annual** forage reliance.

Pasture-based dairying has increasingly gained attention in the United States in recent years. Several positive attributes of pasture-based dairying are generally cited as reasons to

consider it: (1) it is less damaging to the environment, (2) animal welfare is improved, as animals are confined for shorter periods, (3) pasture-based operators are generally happier with their lifestyle (Taylor and Foltz), and (4) if well-managed, pasture-based production can be competitive with conventional production, as lower milk production is offset by lower production costs. Furthermore, growth of organic milk demand and supply have increased in recent years, and organic dairy production is generally associated with access to pasture (though rules on degree of access to pasture with dairy operations are currently being considered). Some current pasture-based operations may qualify as certified organic producers by meeting USDA specified standards.

Though today's definition and practice of organic milk production is relatively "new," the pasture-based technology is not new, as pasture-based systems can be argued to have been the traditional production method. Pasture-based dairying remains the most common production technology used in several subregions of the southeastern United States, as well as in New Zealand and Ireland. Verkerk provides an extensive review of the state of the New Zealand dairy industry, discussing the challenges of pasture-based production, including the need to breed over a short time period and the difficulties associated with applying embryo technologies. Thus, while pasture-based production is generally lower-cost, there are significant challenges associated with the adoption of other cost-reducing technologies.

Previous Studies Addressing the Economics of Pasture-Based Dairy Operations

Economic analyses of pasture-based versus conventional dairy production systems have produced mixed results, but the majority of these studies have found pasture-based operations to be the more profitable. Parker, Muller, and Buckmaster used linked spreadsheet models to compare Pennsylvania pasture-based dairy production with a typical conventional "dry lot"

situation. The 200-acre pasture-based farm with 53 cows and 48 replacements generated a higher gross margin than found with conventional dairy production. The authors did not, however, expect to see an increase in pasture-based dairying until producers became confident that production could be maintained at levels competitive with confined production.

Elbehri and Ford used a simulation model to examine forage systems for a representative 60-cow Pennsylvania dairy farm. They found that an intensive grazing pasture-based operation stochastically dominated a conventional system, but that if milk yields in the pasture system dropped by only four to six percent, the pasture system would no longer be preferred.

Based upon a two-year University of Minnesota experiment station field trial in northern Minnesota, Rust et al. compared an intensive rotational grazing pasture-based dairy system with a conventional confinement system. They found that, due to lower feeding, facilities, labor, and equipment costs, net returns per cow were higher for the pasture-based than the conventional system, despite lower milk production in the pasture-based system.

Hanson et al. surveyed 53 Pennsylvania dairy farms, and found that those using intensive grazing pasture-based systems were profitable. They also found, however, that increased use of pasture was associated with higher debt relative to assets and negative cash flows, suggesting that debt and significant financial constraints may provide an incentive to increase grazing intensity.

Dartt et al. conducted a survey of 35 management-intensive grazing (pasture-based) and 18 conventionally managed dairy farms in Michigan. Average dairy herd sizes in the sample were approximately 70 cows and 80 cows for the pasture-based and conventional farms, respectively. Results showed that the pasture-based farms experienced greater economic profit than did the conventional dairies. The authors caution, however, against extrapolation of results

to a wider region because the farms in the sample were not located in Michigan's "dairy belt."

Tucker, Rude, and Wittayakun conducted an experiment in Mississippi to evaluate the performance of dairy cows on a TMR diet versus rotational grazing of annual ryegrass during March-May. Daily milk production declined on the ryegrass diet, though income over feed costs were higher for the pasture treatment.

Soder and Rotz simulated a representative 250-acre Pennsylvania dairy farm, varying grazing rate and amount of concentrate fed. Regardless of whether annual milk sales, the number of animals, or available acreage for grazing was held constant, the model farm utilizing pasture with a high concentrate supplement level had greater associated net return to management than did the farm using conventional technology. Generally, increasing concentrate supplement level increased profitability and nutrient balance of pasture-based farms.

White et al. conducted a four-year experimental study of conventional and pasture-based systems in North Carolina. Results showed that cow health was better on the pasture-based operation. They concluded that pasture-based production had the potential to be economically competitive, as significant differences for income over feed costs between the systems were not found.

Tozer, Bargo, and Muller analyzed three experimental treatments in Pennsylvania: a TMR non-grazing system, a TMR system combined with pasture in the daytime hours, and a pasture-based system. Using partial budgeting to compare net incomes among the treatments, they showed the TMR conventional system to be the most profitable. The authors acknowledge that their results run counter to other studies, explaining that several things need to be considered in comparing the studies. First, they used "high-yielding Holstein cows grazing high-quality pastures in the northeast United States for a limited grazing season," versus the year-round

grazing used by White et al. No differences in mastitis rates were found in the Tozer, Bargo, and Muller study. The authors state that their results are consistent with those of Elbehri and Ford's assertion that pasture-based systems could not expect to be competitive with conventional systems if their milk yields were more than six percent lower. The Tozer, Bargo, and Muller study found that milk yields were 25% and 16% lower for the pasture-based and TMR with daytime grazing treatments, respectively.

Assuming pasture is used in a dairy operation, two studies are of particular interest in analyzing grazing intensity. Fales et al. found that, in Pennsylvania, increasing the stocking rate on rotationally grazed pastures led to an increase in profit per acre, but a decrease in profit per cow. Winstein, Parsons, and Hanson surveyed pasture-based dairy farmers in Virginia, Vermont, and Pennsylvania to determine differences in characteristics of dairy farmers by grazing system. Farmers were divided into continuous, traditional, moderately intensive, and intensive grazers. Numbers of cows in the study ranged from 69 with intensive grazing to 74 with traditional grazing. Intensive grazers operated smaller farms, were younger, had more formal education, were more satisfied with a number of aspects of their farm businesses, and had lower milk production per cow.

Several observations are made with respect to previous studies conducted on the economics of pasture-based versus conventional dairy production. First, the studies have been experimental in nature, have used simulation techniques, or have resulted from surveys of relatively small numbers of small farms in specific regions. Analyses have compared relatively small conventional farms with relatively small pasture-based operations, with none fully addressing the increasingly common 250+ cow operation. With the emergence of much larger-scale operations, the majority of which are likely to be conventional, it is of use to compare

efficiencies that cover the full range of operation sizes. In order to survive economically, smaller, non-organic pasture-based operations will need to remain competitive with larger, conventional operations.

According to ARMS, What Is a Pasture-Based Farm and Where Are The Farms Located?

Literature on the economics of pasture-based systems typically defines the level of intensity of such systems as: (1) relative to the proportion of forage requirements obtained from pasture during the grazing season, as in Tozer, Barg and Muller, or (2) annually, as in Dartt et al. European dairy pasture systems are commonly discussed in terms of stocking rates (Shallo et al. and IFOAM EU Regional Group). In this study, information from the 2005 Agricultural Resource Management Survey (ARMS) is used to identify factors associated with forage reliance from pasture during the grazing season. For these operations, we regressed forage reliance, measured as the percentage of forage nutrients obtained from pasture during the grazing season, on seven factors conditioned on regional dummies for the North and South: (1) the dairy pasture to beef pasture ratio, (2) the dairy pasture to total acres ratio, (3) the corn silage to total harvested acres ratio, (4) the ratio of total hay acres to harvested acres, (5) a population accessibility score, (6) pasture acres per cow, and (7) reported annual milk production per cow. It was found that, for 2005 data, the percentage of forage reliance from pasture is positively associated with the dairy pasture to acres ratio, the ratio of total hay acres to harvested acres, and dairy pasture acres per cow, while the percentage of forage reliance from pasture is negatively associated with the dairy pasture to beef pasture ratio and the corn silage to total harvested acres ratio. Percentage of forage reliance from pasture is not significantly associated with reported annual milk production at the national level.

Based on our preliminary regression results the main drivers of forage reliance from

pasture among operations reporting grazing are the ratio of dairy pasture acres to beef pasture acres, the ratio of total hay acres to total harvested acres, the ratio of dairy pasture acres to harvested acres and the ratio of dairy pasture acres to cows (the stocking rate). It was found that for all 2005 dairy operations, including grazers and non grazers, a 10 percent increase in pasture acres relative to total acres is associated with a 6.6 percent increase in forage reliance from pasture, while a 10 percent increase in the stocking rate is associated with a 0.2 percent increase in forage reliance from pasture. A 10 percent increase in the hay acres per harvested acres is associated with a 0.3 percent increase in forage reliance from pasture, and a 10 percent increase in the dairy pasture to beef pasture ratio is associated with a 0.8 percent decrease in forage reliance from pasture. These results should be interpreted in light of the fact that the regression results explain only one-third of forage reliance and our current specification relies on preliminary ARMS cost of production data that cannot be easily used to identify home grown versus purchased feed items known to be important in pasture based operations (Dratt et al.). While no significant relationship was found between pasture forage reliance and annual milk production per cow at the national level, regression results limited to only the Corn Belt, Lake States and Northeast reveal a significant inverse relationship between forage reliance from pasture and annual milk production per cow.

Factors significantly related to forage reliance (the ratio of dairy pasture acres to beef pasture acres, the ratio of dairy pasture acres to total acres, the ratio of total hay acreage to harvested acres, and dairy pasture acres per cow) were used to identify the level of intensity in the grazing systems **on an annual basis** for 2005 as well as in 1993 and 2000 to achieve a comparison of grazing intensity across regions and over time. More precisely, these factors were used to identify dairy farms by level of forage reliance and by herd size: forage reliant pasture-

based farms, semi-forage reliant farms, small conventional dairies, medium conventional dairies, and large conventional dairies.

The definition of a pasture-based operation is likely to vary somewhat by region of the U.S. The 2005 ARMS data from the Dairy Phase III version are used to examine the prevalence of pasture-based versus conventional dairy farms in 24 States. These comparisons provide insights into the various production practices, by region, that can be considered as “pasture-based.” As shown in Figure 1, forage reliant or extensive dairy operations in the West are concentrated in Idaho. Corn Belt and Lake States dairies are, in general, much smaller than Western dairies with energy intensive, low-pasture operations based on corn silage production dominating, but with significant pockets of pasture-based operations in Western Wisconsin and Southern Missouri.

In the northeast, pasture-based operations cover an even more extensive area, dominating dairy production in Vermont, and in Central and Southeastern New York. The largest concentration of dairy production in the Northeast occurs in Lancaster County, Pennsylvania. There, pasture-based operations are characterized by extensive grazing of cows during the grazing season, reliance on high ratios of dairy pasture to harvested acres, and reliance on alfalfa hay forage needs during the non-grazing months. Such operations are common, as are larger, medium-sized conventional dairies. The Cost of Production Surveys indicate that the greatest reliance on pasture based dairies in terms of proportion of production occurs in the South. A typical pasture based operation in the South relies heavily on relatively low yield dairy pasture and non-alfalfa hay for forage supplements. On such operations, beef operations are often complementary.

This paper presents farm-level technical efficiency rankings by size and type of operation for each of the 24 dairy states with sizeable dairy production as surveyed in the ARMS. The results identify statistically significant differences in economic competitiveness by region and by pasture-based versus conventional production. These preliminary results include all states surveyed in 1993, 2000, and 2005. Because the data are national in scope, the forage reliant definitions are intended to be general enough to allow a comparison of “pasture-based” operations across the U.S. and over time. A priori, it was expected that technical efficiency would vary by region, with states having greater concentration of dairy farms being more technically and scale efficient. Differences in performance measures by pasture-based versus conventional production are explored by identifying characteristics particular to each grouping. Since the 2005 ARMS Dairy Phase III data were released in August, 2006, this study is the first opportunity to analyze the information collected on U.S. dairy farms using these most up-to-date survey results.

Data and Methods

This analysis employs USDA’s farm-level data from the 1993, 2000, and 2005 ARMS Dairy Costs and Returns Reports to identify the extent of pasture use and type of technology used in dairy production and to measure structural change over time. A stochastic production frontier (SPF) model uses farm-level data for the three years to derive measures of technical efficiency, returns to scale, and return on assets. The estimated performance measures are tested for structural change over time. The analysis identifies economic and farm characteristics influencing strong and weak performance by size and type of operation.

The econometric model uses recently developed regression techniques that allow relating several outputs to several inputs (expenditures on six categories of inputs: labor, fuel, fertilizer

and other chemicals, miscellaneous operating expenses, capital services, and land valued at the quality-adjusted price of land for the time period) in a single equation to develop technical efficiency scores by farm. The SPF measurement technique is used to estimate econometrically a translog production function to develop this measure of technical efficiency. Farms are ranked relative to high and low levels of economic performance by size and type of operation.

The parametric SPF was introduced by Aigner, Lovell, and Schmidt, and Meeusen and van den Broeck. Battese and Coelli modified this approach to specify stochastic frontiers for the technical efficiency effects and simultaneously estimate all the parameters involved. In this paper, we follow the model described in Coelli, Battese, and Rao. The stochastic input distance and production frontier approach uses U.S. farm-level data from the 1993, 2000, and 2005 ARMS Phase II/III cost of production surveys (USDA/ERS) for dairy farms. The list and area frame components are incorporated using a system of weights pooled over time (constructed for 1993 by setting up naïve replicates and directly available from the survey for 2000 and 2005). Inferences for states and regions must account for survey design by using weighted observations.

The Translog Input Distance Function Approach

Recently-developed regression techniques used in this analysis allow us to relate several outputs to several inputs in a single equation to develop measures of technical (best practice production techniques) and scale efficiency scores by farm, as described in Paul and Nehring and Paul et al. We use SPF measurement to econometrically estimate the input distance function $DI(\mathbf{X}, \mathbf{Y}, \mathbf{R})$. Approximating this function using a translog functional form to limit a priori restrictions on the relationships among its arguments results in:

- (1) $\ln D_{it}^l / X_{1,it} = \alpha_0 + \sum_m \alpha_m \ln X_{mit}^* + .5 \sum_m \sum_n \alpha_{mn} \ln X_{mit}^* \ln X_{nit}^* + \sum_k \beta_k \ln Y_{kit} + .5 \sum_k \sum_l \beta_{kl} \ln Y_{kit} \ln Y_{lit} + \sum_q \phi_q R_{qit} + .5 \sum_q \sum_r \phi_{qr} R_{qit} R_{rit} + \sum_k \sum_m \gamma_{km} \ln Y_{kit} \ln X_{mit}^* + \sum_q \sum_m \gamma_{qm} \ln R_{qit} \ln X_{mit}^* + \sum_k \sum_q \gamma_{kq} \ln Y_{kit} \ln R_{qit} = TL(X^*, Y, R)$, or
- (2) $-\ln X_{1,it} = TL(X^*, Y, R) - \ln D_{it}^l$,

where i denotes farm, t time period, k, l outputs, and m, n, q, r inputs. We specify X_l as land, so the function is essentially specified on a per-acre basis, consistent with much of the literature on farm production and productivity in terms of yields.

This functional relationship, which embodies a full set of interactions among the \mathbf{X} and \mathbf{Y} arguments of the distance function, can be more compactly written as $-\ln X_{l,it} = TL(\mathbf{X}/X_l, \mathbf{Y}, t) = TL(\mathbf{X}^*, \mathbf{Y}, t)$. A symmetric error term, \mathbf{v} , is appended to equation (1) to account for noise, and also to change the notation “ $-\ln D_{it}$ ” to “ u ”. The resulting $-\ln X_l = TL(\mathbf{X}^*, \mathbf{Y}) + \mathbf{v} - u$ function (with the subscripts suppressed for notational simplicity) may be estimated by maximum likelihood (ML) methods, to impute the technical efficiency measures as the distance from the frontier. For the SPF model, $-u$ thus represents inefficiency; the efficiency scores generated by FRONTIER essentially measure $\exp(-U) = DI(\mathbf{X}^*, \mathbf{Y})$. This is, therefore, our measure of technical efficiency. In addition to land, the X_{it} represent expenditures on six other inputs: labor, fuel, fertilizer, all other operating expenses—primarily feed, and capital services. Our outputs are corn, other crops (primarily soybeans and alfalfa hay), and livestock revenue, primarily dairy revenues.

To account for the effect of differences in land characteristics across dairy farms, we included three environmental variables, population accessibility, soil texture, and soil water holding capacity, crossed with the outputs, as variables in the input distance function and as characteristics in the inefficiency effects.

The productivity impacts (marginal productive contributions, MPC) of outputs or inputs can be estimated from this model by the first order elasticities $MPC_m = -\varepsilon_{Dl, Y_m} = -\partial \ln D^l(\mathbf{X}, \mathbf{Y}, \mathbf{R}) / \partial \ln Y_m = \varepsilon_{X_l, Y_m}$ and $MPC_k = -\varepsilon_{Dl, X^*_k} = -\partial \ln D^l(\mathbf{X}, \mathbf{Y}, \mathbf{R}) / \partial \ln X^*_k = \varepsilon_{X_l, X^*_k}$. MPC_m indicates the increase in overall input use when output expands (and so should be positive, like a marginal cost or output

elasticity measure), and MPC_k indicates the shadow value (Färe and Primont) of the k^{th} input relative to X_1 (and so should be negative, like the slope of an isoquant). Similarly, the marginal productive contributions of structural factors (water holding capacity, soil texture, population accessibility, and the time shifters) can be measured through the elasticities $MPC_{Rq} = -\epsilon_{D1,Rq} = -\partial \ln D^1(\mathbf{X}, \mathbf{Y}, \mathbf{R}) / \partial R_q = \epsilon_{X1,Rq}$ (if $\epsilon_{X1,Rq} < 0$, increased R_q implies that less input is required to produce a given output, which implies enhanced productivity, and vice versa).

Scale economies (SE) are calculated as the combined contribution of the m outputs Y_m , or the scale elasticity $SE = -\epsilon_{D1,Y} = -\sum_m \partial \ln D^1(\mathbf{X}, \mathbf{Y}, \mathbf{R}) / \partial \ln Y_m = \epsilon_{X1,Y}$. That is, the sum of the input elasticities, $\sum_m \partial \ln X_1 / \partial \ln Y_m$, indicates the overall input-output relationship and thus returns to scale. The extent of scale economies is, thus, implied by the shortfall of SE from 1; if $SE < 1$, inputs do not increase proportionately with output levels, implying increasing returns to scale.

Results

Parameter estimates for the preliminary input distance function are reported in Appendix Table A. Close to half of the estimated coefficients are significant at the 20 percent level or better and most of the measures of outputs and inputs reported in Appendix Table B have the expected signs —positive for outputs and negative for inputs--suggesting a reasonable specification. Only fuel and fertilizer have the wrong signs, but our estimates of these input contributions are insignificant. Hence, the results are suitable for making population inferences. More parsimonious specifications with one less input (aggregating fertilizer and fuel, for example) would undoubtedly increase the proportion of significant coefficients.

As shown in Table 1, forage-reliant pasture-based farms are characterized by significantly higher levels of dairy pasture acres relative to potential beef acres, total hay acres relative to harvested acres, and dairy pasture acres per cow, and significantly lower levels of

annual milk production per cow than semi-forage reliant dairy farms and conventional dairy farms. Consistent with Tozer, Bargo, and Muller, we generally find that forage-reliant pasture-based operations are characterized by lower rates of return on assets than conventional farms of all sizes but they are more technically efficient than some medium sized conventional farms. Additionally, we find that forage-reliant pasture-based farms (if we accept that such farms can be considered as operating on the same production possibilities frontier as conventional farms) could reduce costs by increasing the sizes of their operations. Interestingly, the data in Table 1 indicate that small conventional farms exhibit the lowest levels of manure nitrogen and phosphorous production per harvested acre.

In Table 2, we see that forage reliance in the Corn Belt, Lake States, and Northeast mirrors the national average. In contrast, forage reliance on dairy operations is much lower in the West and much higher in the South. Western dairy operations are much larger than in the other three regions, much more scale efficient, and exhibit much higher returns on assets.

We track changes in forage reliance over time in the Northeast (Table 3), and in the Corn Belt and Lake States (Table 4). Both regions show dramatic reductions in pasture forage reliance over time. Still close to 40 percent of farms in the Northeast and close to 30 percent in the Corn Belt and Lake States are characterized as pasture forage or semi-forage reliant.

Summary and Conclusions

The rapid structural change occurring in the dairy sector in recent years is reflected in increased size (fewer and larger dairy farms), geographic concentration, and to some extent, shifts in the location of dairy production out of the traditional dairy areas. Urban expansion into both traditional and non-traditional dairy production areas can result in increased production costs (higher input and materials, land, and labor costs), reduced production efficiency, and

increased complaints from neighbors about odor and other issues associated with dairy production. One way some of these problems can be addressed is by utilizing pasture-based dairy systems. Fewer, but larger farms can result in excess nutrients from more animal units being concentrated on the available acres and impose additional costs on larger units to meet new manure regulations.

Dairy producers also face increased competitive pressures from the imposition of new animal feeding operation regulations. The use of pasture-based dairy operations, where animals are allowed to graze for varying periods, reducing the quantity of manure accumulated in confined areas and potentially reducing odor problems is suggested as a means of addressing these pressures. Though pasture-based operations often have lower milk production per cow, they are considered, in many circles, to be “low-input” and more “sustainable” than are conventional systems. Our findings tend to support Tozer, Bargo, and Muller who found that conventional farms were more competitive than forage reliant farms. Clearly some forage reliant farms have lower costs and higher technical efficiency than some conventional, but on average appear to be at a competitive disadvantage relative to conventional farms when all costs — not just grazing season costs — and scale are considered.

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Table 1. Cost and Production Means and Statistics by Forage Intensity and Herd Size, 1993, 2000, and 2005^a

Item	Forage ^b Reliant	Semi-forage ^c Reliant	Conventional ^d 0 to 250 cows	Conventional ^e 251 to 500 cows	Conventional ^f GT 500 cow
Number of Observations	795	378	1,516	295	342
Number of farms	40,273	20,383	89,022	3,906	4,394
Percent of farms	25.5	12.9	56.4	2.5	2.8
Percent of value of production	11.2	7.1	40.3	11.0	30.5
Number of Cows per Farm	55.99 ^{CDE}	53.57 ^{CDE}	68.22 ^{ABDE}	355.48 ^{ABCE}	1,028.18 ^{ABCD}
Milk per Cow lbs annually	16,005 ^{BCDE}	19,533 ^{ADE}	19,637 ^{ADE}	23,129 ^{AB}	22,397 ^{AB}
Efficiency Score	0.67 ^{BD}	0.70 ^{ACDE}	0.67 ^{BDE}	0.64 ^{ABC}	0.64 ^{BC}
Returns to Scale	0.62 ^E	0.64 ^E	0.69 ^E	0.80 ^C	0.83 ^C
Pasture acres	109.84 ^{BCDE}	71.12 ^{ACDE}	17.50 ^{ABDE}	25.75 ^{AB}	35.91 ^{ABC}
Variable costs per cow (\$)	1,177.71 ^{BC}	1,297.77 ^{ACE}	1,340.50 ^{ADE}	1,219.03 ^C	1,091.81 ^{BC}
Labor costs per cow (\$)	634.70 ^{CDE}	651.70 ^{CDE}	523.40 ^{AD E}	241.30 ^{ABCE}	178.30 ^{ABCD}
Fuel costs per cow (\$)	32.90 ^{BCDE}	38.40 ^{ADE}	42.70 ^{ADE}	26.80 ^{ABCE}	18.70 ^{ABCE}
Fertilizer costs per cow (\$)	51.00 ^{BCDE}	73.40 ^{ACDE}	91.30 ^{ABDE}	38.80 ^{ABCE}	18.60 ^{ABDC}
Miscellaneous costs per cow (\$)	560.90 ^{BCDE}	554.30 ^{ACDE}	574.30 ^{ABDE}	600.30 ^{ABCE}	512.10 ^{ABCE}
Machinery costs per cow (\$)	148.50 ^{BCDE}	166.00 ^{ACDE}	225.20 ^{ABDE}	194.40 ^{ABCE}	144.50 ^{ABCE}
Land price per acre (\$)	1,287.71 ^{CDE}	1,337.86 ^{CDE}	1,944.50 ^{ABDE}	3,609.19 ^{ABC}	4,303.60 ^{ABC}
Corn yield, bu. per acre	122.57	123.04	131.09	145.56 ^{ABC}	144.51
Hay yield, tons per acre	2.41 ^{CDE}	2.88 ^{CDE}	3.61 ^{AB}	3.49 ^{AB}	6.03 ^{ABCE}
Acres harvested per farm	165.40 ^{BCDE}	208.15 ^{ADE}	292.51 ^{ADE}	452.10 ^{ABCE}	639.57 ^{ABCD}
Operator age	51.10	50.20	48.09 ^{AB}	51.27	50.42
Gov't payments per acre (\$)	15.92 ^{CD}	17.27 ^{CD}	36.11 ^{ABD}	46.39 ^{ABC}	40.97 ^{AB}
Off-farm income per acre (\$)	48.49	43.80	43.78	33.57 ^A	46.91
Debt to asset ratio	11.60 ^{CDE}	10.75 ^{CDE}	15.86 ^{ABDE}	18.39 ^{ABCE}	26.51 ^{ABCE}
Acres Operated	309.20 ^{BCDE}	418.72 ^{ADE}	377.50 ^{ADE}	556.50 ^{ABCE}	801.88 ^{ABCD}
Return on Assets (%)	4.51 ^{CDE}	4.29 ^{DE}	5.14 ^{AE}	7.17 ^{AB}	7.52 ^{ABC}
Dairyoutput/total livestock	85.72 ^{DE}	84.94 ^{DE}	85.85 ^{DE}	94.54 ^{ABC}	93.97 ^{ABC}
Forage Intensity Variables					
Total animal units per crop acre	0.90 ^C	0.85 ^{CDE}	0.75 ^{ADE}	2.27 ^{ABCE}	5.04 ^{ABCD}
Dairy pasture/cow	1.96 ^{BCDE}	1.32 ^{ACDE}	0.26 ^{ABDE}	0.07 ^{ABCE}	0.03 ^{ABCD}
Cornsil acres/acres harvested	0.12 ^{CDE}	0.14 ^{DE}	0.15 ^{ADE}	0.31 ^{ABCE}	0.37 ^{ABCD}
Total hay acres/acres harvested	0.55 ^{BCDE}	0.44 ^{ACDE}	0.25 ^{ABDE}	0.21 ^{ABC}	0.22 ^{ABC}
Dairy pasture /beef pasture	0.77 ^{BCDE}	0.33 ^{ACDE}	0.19 ^{AB}	0.19 ^{AB}	0.17 ^{AB}
Manure n per crop acre (lbs)	50.86 ^{CDE}	48.62 ^C	40.33 ^{ABDE}	132.10 ^{ABCE}	293.41 ^{ABCD}
Manure p per crop acre (lbs)	19.73 ^{CDE}	19.11 ^{CDE}	15.90 ^{ABDE}	51.22 ^{ABCE}	113.98 ^{ABCD}
Fertilizer cost per crop acre (\$)	28.81 ^{BCDE}	36.80 ^{ADE}	45.00 ^{AB}	56.65 ^{ABC}	60.14 ^{ABC}

Note: Column letters indicate significance of means of items in row from other items at the 10% level .

Source: Authors' analysis of USDA Agricultural Resource Management Survey USDA (1999).

a. The t-statistics are based on 3,327 observations using weighting techniques described in Dubman.

b. Haytot/harvested acres greater than .22, dairy pasture per cow greater than .6, dairy pasture acres/ beef pasture acres greater than .3, and dairy pasture acres/operated acres greater than .01.

c. Haytot/harvested acres less than .22 and greater than .18, dairy pasture per cow greater than .6, dairy pasture acres/ beef pasture acres less than .3, and dairy pasture acres/acres less than .01.

d. Haytot/harvested acres less than .18 and dairy pasture per cow less than .6.

e. Dairy pasture per cow less than .6.

f. Dairy pasture per cow less than .6.

Table 2. Cost and Production Means and Statistics by Region, 1993, 2000, and 2005

Item	Northeast	Corn Belt and Lake States	South	West
Number of Observations	776	1,231	681	629
Number of farms	44,035	94,473	9,583	9,887
Percent of farms	27.9	59.8	6.1	6.3
Percent of value of production	19.5	38.6	8.7	33.2
Percent of farms forage reliant	27.0	24.5	40.6	13.7
Percent of prod forage reliant	13.2	11.9	31.6	3.8
Percent of farms semi-forage rel	18.7	10.9	14.5	4.5
Percent of prod semi-forage rel	13.0	7.9	9.8	2.0
Number of Cows per Farm	70.35 ^{CDE}	63.52 ^{CDE}	149.04 ^{ABDE}	473.63 ^{ABCE}
Milk per Cow lbs annually	19,973 ^{CD}	19,502 ^{CD}	18,103 ^{ABE}	21,931 ^{ABC}
Efficiency Score	0.58 ^B	0.61 ^{AC}	0.58 ^B	0.59 ^B
Returns to Scale	0.65 ^{BCD}	0.69 ^{ACD}	0.71 ^{ABD}	0.76 ^{ABC}
Pasture acres	45.27 ^{BCD}	35.58 ^{ACD}	137.55 ^{ABD}	98.31 ^{ABC}
Variable costs per cow (\$)	1,370.62 ^{BCD}	1,256.73 ^{AD}	1,246.10 ^{AD}	1,108.85 ^{ABC}
Labor costs per cow (\$)	599.90 ^{BCD}	541.60 ^{ACD}	326.80 ^{ABD}	179.70 ^{ABC}
Fuel costs per cow (\$)	72.00 ^{BC}	29.80 ^{AC}	43.70 ^{AB}	17.30 ^{ABC}
Fertilizer costs per cow (\$)	84.70 ^{BC}	71.80 ^{AC}	59.40 ^{AB}	17.30 ^{ABC}
Miscellaneous costs per cow (\$)	1,180.10 ^{BC}	734.00 ^{AC}	296.10 ^{AB}	528.50 ^{ABC}
Machinery costs per cow (\$)	49.30 ^{BC}	261.90 ^{AC}	237.30 ^{AB}	132.30 ^{ABC}
Land price per acre (\$)	696.32 ^{BC}	1,428.53 ^{AC}	2,888.61 ^{AB}	4,798.64 ^{ABC}
Corn yield, bu. per acre	121.53 ^{BD}	130.58 ^{BD}	127.24 ^{BD}	191.17 ^{ABC}
Hay yield, tons per acre	2.63 ^{BCD}	3.59 ^{ACD}	2.99 ^{ABC}	4.62 ^{ABC}
Acres harvested per farm	250.92 ^{BC}	273.26 ^{AD}	221.35 ^{AB}	256.42
Operator age	49.20 ^C	48.95 ^{CD}	51.10 ^{AB}	50.88 ^{AB}
Gov't payments per acre (\$)	22.46 ^{BD}	34.21 ^{CA}	21.69 ^{BD}	32.65 ^{AC}
Off-farm income per acre (\$)	42.27 ^D	41.03 ^D	48.46 ^D	77.05 ^{ABC}
Debt to asset ratio	15.07 ^D	16.65 ^{CD}	12.95 ^{BD}	20.23 ^{ABC}
Acres Operated	372.49 ^{CD}	373.10 ^{CD}	480.18 ^{ABD}	405.76 ^C
Return on Assets (%)	4.73 ^D	5.34 ^D	4.89 ^D	7.15 ^{ABC}
Dairy output/total livestock	89.08 ^{BD}	84.66 ^{ACD}	89.90 ^{BD}	93.71 ^{ABC}
Forage Intensity Variables				
Total animal units per crop acre	0.80 ^{CD}	0.76 ^{CD}	1.82 ^{AB}	5.75 ^{AB}
Dairy pasture/cow	0.64 ^{CDE}	0.56 ^{CDE}	0.92 ^{ABD}	0.21 ^{ABC}
Cornsil acres/acres harvested	0.21 ^{CDE}	0.13 ^{ACD}	0.21 ^{BD}	0.28 ^{ABC}
Total hay acres/acres harvested	0.41 ^{BD}	0.27 ^{AC}	0.42 ^{BD}	0.32 ^{BC}
Dairy pasture /beef pasture	0.35 ^{CD}	0.33 ^{CD}	0.53 ^{AB}	0.54 ^{AB}
Manure n per crop acre (lbs)	44.19 ^{CD}	41.45 ^C	104.37 ^{AB}	334.95 ^{AB}
Manure p per crop acre (lbs)	17.09 ^{CD}	16.41 ^{CD}	40.59 ^{AB}	129.94 ^{AB}
Fertilizer cost per crop acre (\$)	33.64 ^{BCD}	37.96 ^{ACD}	67.22 ^{AB}	64.48 ^{AB}

Note: Column letters indicate significance of items in row from other items at the 10% level .

Source: Authors' analysis of USDA Agricultural Resource Management Survey USDA (1999).

a. The t-statistics are based on 3,327 observations using weighting techniques described in Dubman.

Table 3. Cost and Production Means and Statistics In the Northeast, 1993, 2000, and 2005

Item	Northeast 1993	Northeast 2000	Northeast 2005
Number of Observations	186	145	445
Number of farms	13,677	17,824	12,533
Percent of farms	31.1	40.5	28.5
Percent of value of production	20.6	37.2	42.2
Percent of farms forage reliant	39.2	23.7	18.3
Percent of prod forage reliant	29.5	10.8	7.4
Percent of farms semi-forage rel	23.3	14.4	19.8
Percent of prod semi-forage rel	18.6	13.2	10.0
Number of Cows per Farm	56.34 ^{BC}	68.74 ^{AC}	87.93 ^{AB}
Milk per Cow lbs annually	17,898 ^{BC}	19,876 ^{AC}	21,532 ^{AB}
Efficiency Score	0.63 ^{BC}	0.54 ^A	0.58 ^B
Returns to Scale	0.64 ^C	0.65	0.68 ^A
Pasture acres	61.29 ^{BC}	37.64 ^A	38.63 ^{AB}
Variable costs per cow (\$)	1,794.30 ^{BC}	950.50 ^{AC}	975.10 ^A
Labor costs per cow (\$)	1,093.50 ^{BC}	619.50 ^{AC}	412.20 ^{AB}
Fuel costs per cow (\$)	72.00 ^{BC}	29.80 ^{AC}	43.70 ^{AB}
Fertilizer costs per cow (\$)	84.70 ^{BC}	71.80 ^{AC}	59.40 ^{AB}
Miscellaneous costs per cow (\$)	1,102.60 ^{BC}	570.60 ^{AC}	303.60 ^{AB}
Machinery costs per cow (\$)	49.30 ^{BC}	261.90 ^{AC}	237.30 ^{AB}
Land price per acre (\$)	696.32 ^{BC}	1,428.53 ^{AC}	2,888.61 ^{AB}
Corn yield, bu. per acre	100.65 ^{BC}	115.72 ^{AC}	145.21 ^{AB}
Hay yield, tons per acre	1.24 ^{BC}	3.66 ^{AC}	2.87 ^{ABC}
Acres harvested per farm	220.84 ^C	246.04	290.64 ^A
Operator age	49.41 ^C	47.70	51.10 ^A
Gov't payments per acre (\$)	15.90 ^{BC}	41.67 ^A	39.37 ^A
Off-farm income per acre (\$)	39.62	43.08	43.97 ^A
Debt to asset ratio	12.62	19.27 ^A	13.45 ^B
Acres Operated	376.30 ^C	345.70	406.36 ^A
Return on Assets (%)	4.58	4.65	4.86
Dairy output/total livestock	88.64	88.82 ^A	89.50
Forage Intensity Variables			
Total animal units per crop acre	0.51 ^{CD}	0.76 ^{CD}	1.09 ^{AB}
Dairy pasture/cow	1.09 ^{BC}	0.55 ^{AC}	0.44 ^{AB}
Corn sil acres/acres harvested	0.18 ^C	0.21	0.22 ^A
Total hay acres/acres harvested	0.48 ^{BC}	0.37 ^{AC}	0.41 ^{AB}
Dairy pasture /beef pasture	0.39	0.34	0.32
Manure n per crop acre (lbs)	22.82 ^{BC}	48.80 ^{AC}	56.36 ^{AB}
Manure p per crop acre (lbs)	8.87 ^{BC}	18.75 ^{AC}	21.91 ^{AB}
Fertilizer cost per crop acre (\$)	21.62 ^{BC}	39.38 ^{AC}	36.69 ^{AB}

Note: Column letters indicate significance of items in row from other items at the 10% level.

Source: Authors' analysis of USDA Agricultural Resource Management Survey USDA (1999).

a. The t-statistics are based on 776 observations using weighting techniques described in Dubman.

Table 4. Cost and Production Means and Statistics In the Corn Belt and Lake States , 1993, 2000, and 2005

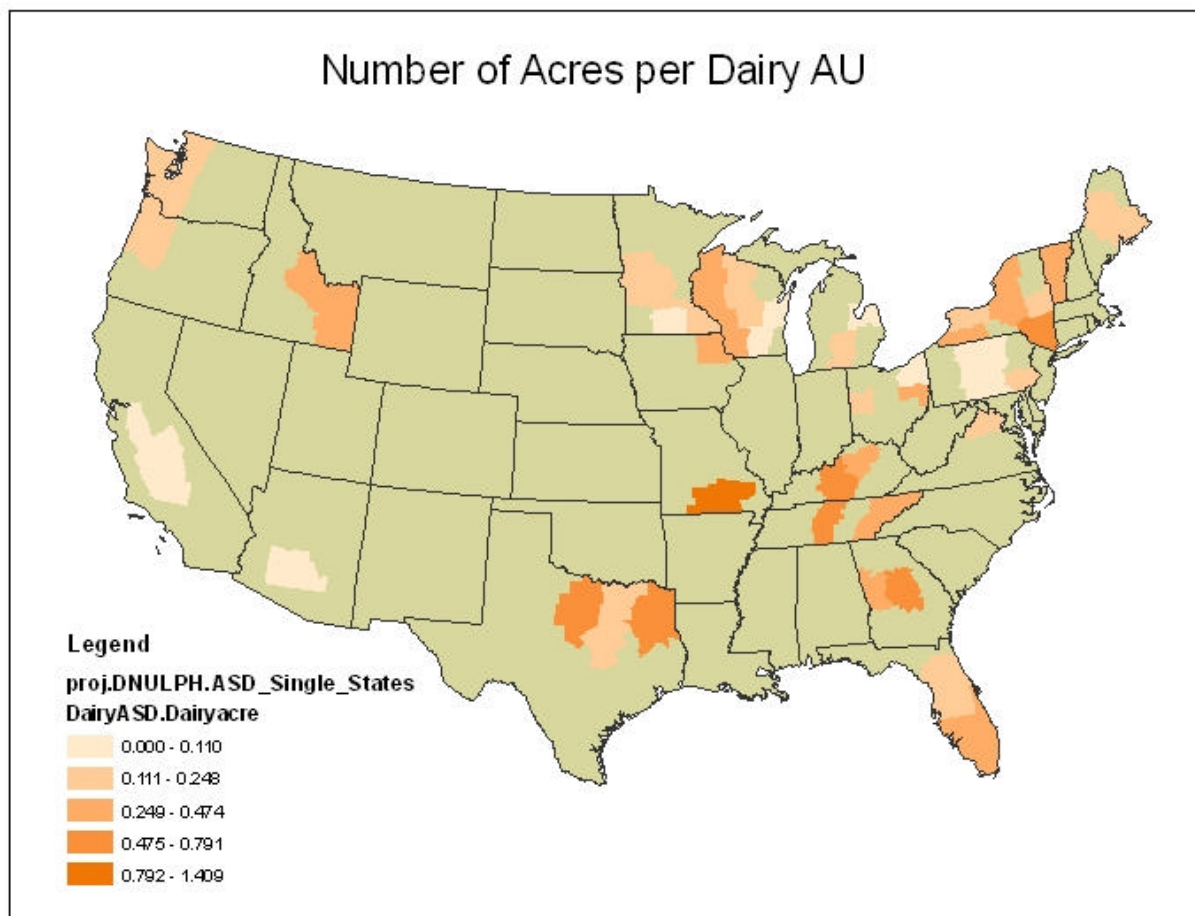
Item	Corn Belt and Lake States 1993	Corn Belt and Lake States 2000	Corn Belt and Lake States 2005
Number of Observations	263	321	647
Number of farms	27,845	40,352	26,275
Percent of farms	29.5	42.7	27.8
Percent of value of production	17.9	37.1	45.0
Percent of farms forage reliant	28.0	24.2	21.2
Percent of prod forage reliant	20.3	11.3	9.0
Percent of farms semi-forage rel	13.0	9.7	10.5
Percent of prod semi-forage rel	14.3	8.0	5.3
Number of Cows per Farm	46.18 ^{BC}	60.74 ^{AC}	86.50 ^{AB}
Milk per Cow lbs annually	17,245 ^{BC}	18,831 ^{AC}	21,532 ^{AB}
Efficiency Score	0.61	0.61	0.61
Returns to Scale	0.63 ^C	0.71	0.75 ^A
Pasture acres	61.29 ^{BC}	37.64 ^A	38.63 ^{AB}
Variable costs per cow (\$)	1,746.10 ^{BC}	769.20 ^{AC}	946.60 ^A
Labor costs per cow (\$)	1,165.50 ^{BC}	539.40 ^{AC}	377.10 ^{AB}
Fuel costs per cow (\$)	86.60 ^{BC}	28.50 ^{AC}	43.90 ^{AB}
Fertilizer costs per cow (\$)	109.40 ^{BC}	87.40 ^{AC}	76.30 ^{AB}
Miscellaneous costs per cow (\$)	1,102.60 ^{BC}	570.60 ^{AC}	303.60 ^{AB}
Machinery costs per cow (\$)	49.30 ^{BC}	261.90 ^{AC}	237.30 ^{AB}
Land price per acre (\$)	696.32 ^{BC}	1,428.53 ^{AC}	2,888.61 ^{AB}
Corn yield, bu. per acre	85.73 ^B	136.85 ^B	153.24 ^{AB}
Hay yield, tons per acre	2.63 ^{BC}	3.59 ^{AC}	2.99 ^{ABC}
Acres harvested per farm	250.92 ^{BC}	273.26 ^A	221.35 ^{AB}
Operator age	47.67 ^C	49.18 ^C	49.99 ^A
Gov't payments per acre (\$)	15.90 ^{BC}	41.67 ^A	39.37 ^A
Off-farm income per acre (\$)	36.70	38.56	48.27 ^A
Debt to asset ratio	17.77	17.15	15.80
Acres Operated	330.68 ^C	377.39	412.07 ^A
Return on Assets (%)	4.32	5.36	5.72 ^A
Dairy output/total livestock	80.15 ^C	84.22 ^A	86.77 ^A
Forage Intensity Variables			
Total animal units per crop acre	0.57 ^C	0.67 ^C	1.04 ^{AB}
Dairy pasture/cow	0.73 ^C	0.64 ^C	0.37 ^{AB}
Cornsil acres/acres harvested	0.14 ^{BC}	0.12 ^{AC}	0.16 ^{AB}
Total hay acres/acres harvested	0.31 ^{BC}	0.26 ^A	0.25 ^A
Dairy pasture /beef pasture	0.33	0.38	0.32
Manure n per crop acre (lbs)	22.34 ^{BC}	43.48 ^{AC}	53.65 ^{AB}
Manure p per crop acre (lbs)	9.38 ^{BC}	16.89 ^{AC}	21.26 ^{AB}
Fertilizer cost per crop acre (\$)	21.92 ^{BC}	42.40 ^{AC}	44.50 ^{AB}

Note: Column letters indicate significance of items in row from other items at the 10% level.

Source: Authors' analysis of USDA Agricultural Resource Management Survey USDA (1999).

a. The t-statistics are based on 1,231 observations using weighting techniques described in Dubman.

Figure 1.



Appendix Table A. Input Distance Function Parameter Estimates Dairy

Variable	Parameter t-test	Variable	Parameter t-test
α_0	8.395 (2.85)	$\alpha_{XF, XL}$	0.040 (1.06)
α_{XF}	-0.283 (-1.09)	$\alpha_{XF, XE}$	0.016 (0.48)
α_{XL}	0.576 (0.70)	$\alpha_{XF, XFEED}$	0.013 (0.70)
α_{XE}	0.506 (4.40)	$\alpha_{XF, XK}$	-0.029 (-5.83)
α_{XFEED}	-0.262 (-0.56)	$\alpha_{XL, XE}$	-0.066 (-0.84)
α_{XK}	0.080 (0.21)	$\alpha_{XL, XFEED}$	0.036 (0.46)
$\beta_{YNONDAIRY}$	-0.101 (-1.72)	$\alpha_{XL, XK}$	0.019 (0.35)
β_{YDAIRY}	-0.576 (-8.59)	$\alpha_{XE, XFEED}$	0.033 (1.60)
$\beta_{YNONDAIRY, YCNONDAIRY}$	0.023 (6.40)	$\alpha_{XE, XK}$	0.011 (0.40)
$\beta_{YDAIRY, YDAIRY}$	0.046 (18.71)	$\alpha_{XFEED, XK}$	-0.026 (-1.22)
$\beta_{YDAIRY, YNONDAIRY}$	-0.013 (-2.91)	ϕ_{2000}	0.193 (0.34)
$\gamma_{YNONDAIRY, TEXT}$	0.035 (1.71)	ϕ_{2005}	0.367 (0.55)
$\gamma_{YNONDAIRY, WATHCAP}$	-0.007 (-2.67)	$\phi_{DAIRYSIZE}$	0.308 (2.91)
$\gamma_{YDAIRY, URBAN}$	0.026 (9.74)	δ_0	12.077 (1.84)
$\alpha_{XL, XL}$	-0.055 (-0.89)	δ_{URBAN}	0.560 (0.76)
$\alpha_{XFEED, XFEED}$	-0.018 (-1.11)	$\delta_{PASTURE}$	-0.272 (-1.49)
$\alpha_{XK, XK}$	0.001 (0.03)	δ_{COWS}	-0.961 (-1.15)
$\alpha_{XE, XE}$	-0.021 (-0.27)	δ_{AGE}	-7.187 (-3.13)
		δ_{YEAR}	1.630 (5.01)
		δ^2	7.600 (4.34)
		γ	0.948 (72.31)
		Log-Likelihood	-1117.78

Notes: *** Significance at the 1% level (t=2.576). ** Significance at the 5% level (t=1.96). * Significance at the 10% level (t=1.645).

Source: USDA Agricultural Resource Management Study. USDA (1996-2004).

The t-statistics are based on 3,327 observations using weighting techniques described in Dubman's CV15 program.

Appendix Table B: MPC's for outputs, inputs, and time shifts, full sample (t-stats in parens)

MPC _{YNODAIRY}	0.207	(5.42)	MPC _{XF}	0.040	(0.34)	MPC ₂₀₀₀	0.193	(0.34)
MPC _{YDAIRY}	0.463	(5.28)	MPC _{XL}	-0.087	(-2.47)	MPC ₂₀₀₅	0.367	(0.55)
			MPC _{XE}	0.140	(1.31)			
			MPC _{XFEED}	-0.210	(-3.80)			
			MPC _{XK}	-0.063	(-0.75)			
			MPC _{XLND}	-0.810	(-5.96)			