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Pasture-Based Dairy Systems: Who Are the Producers and Are Their Operations More Profitable than Conventional Dairies?

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U.S. dairy operations are sorted via a multinomial logit model into three production systems: pasture-based, semi-pasture-based, and conventional. Region, farm size, financial situation, and production intensity measures impact system choice. Analysis follows to determine the impact of production system on enterprise profitability. Region, farm size, and demographic variables impact profitability, as does system choice: semi-pasture-based operations were less profitable than conventional operations on an enterprise, per hundredweight of milk produced basis. Significant differences were not found in the profitability of pasture-based operations versus those using other systems.

Key words: dairy farm size, grazing, pasture-based dairying

Introduction

Pasture-based dairying in the United States has received renewed attention in recent years. Though the trend for a number of decades was a movement away from pasture-based to conventional dairy operations using total mixed rations (TMRs), at least two factors have revived the interest in pasture-based dairying: a boost in demand for organic milk that has coincided with an increase in the number of organic dairy farms, many of which are pasture-based, and a willingness of consumers and dairy product manufacturers in some U.S. markets to pay premium prices for milk from pasture-based (yet non-organic) systems. Significant interest in pasture-based dairying resulted in the recent opening of a research, extension, and outreach center at Michigan State University that will concentrate on the development of markets and supply chains for dairy products derived from pasture-based systems (Todd, 2007).

Concurrent with increased attention to pasture-based dairying has been rapid, dramatic structural change occurring within the U.S. dairy sector. As chronicled by MacDonald et al. (2007), this change is characterized by concentration of production onto fewer, but larger farms and geographic consolidation of production. The most notable changes in farm size have been outside the traditional dairy areas of the Northeast and Upper Midwest, largely in the West.

Increased interest in pasture-based systems while, conversely, a growing share of dairy farms are becoming larger and more intensive in new technology usage, raises the following

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question: Can pasture-based systems be competitive in today's dairy sector? Casual observation of the trends does not lead to a conclusion, as pasture-based dairy operations have been increasing in number in some parts of the United States and on the decline in others. In the 2000 and 2005 dairy versions of the Agricultural Resource Management Survey (ARMS), farmers were asked, "Did this operation use pasture or cropland to graze dairy cattle during the prior year?" In 2000 and 2005, 68.5% and 64.5%, respectively, of farmers indicated use, though the difference was not significant at the 10% level. Defining regions in table 1, those with > 50% of farmers indicating use included the Northeast, Appalachia, Southern Plains, and Corn Belt. Use in the Corn Belt declined from 2000 to 2005, while use in the West increased. Caution is suggested in placing great emphasis on these data to indicate the prevalence of pasture-based systems since they do not identify the extent of pasture use by farm—i.e., the ARMS queried respondents on the extent of pasture usage as a percentage of the forage ration only in 2005, the data set which is used in the current study.

The objectives of this study are to compare the characteristics of pasture-based dairy operations with those of conventional dairy operations and to determine whether there are differences in dairy enterprise and whole-farm profitability associated with conventional (non-pasture-based) and pasture-based systems. Dairy enterprise data from the U.S. Department of Agriculture's (USDA's) 2005 ARMS are used to conduct the analysis.

Defining Pasture-Based Dairying

Pasture-based dairying has been defined in a variety of ways, with the authors finding no clear consensus on a specific definition but general agreement on the overall concept. Taylor and Foltz (2006) categorize pasture-based dairies as either "management intensive grazing" or "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. In selecting a sample of Pennsylvania dairy farms for a survey of grazers, Hanson et al. (1998) required that the animals obtain 40% of their forage needs during the summer months from pasture. Dartt et al. (1999) defined a "management intensive grazing operation" as one where at least 25% of the annual forage requirement was obtained via pasture and the animals were to have been grazed for at least four months.

The varying criteria for dairies to be termed "pasture-based" is partially due to pasture-based production varying by region, as forage availability from pasture depends upon climate and soil. The U.S. grazing season ranges from 4–5 months in Wisconsin to year-round in the Southeast.

Previous Research on the Economics of Pasture-Based Dairying

Previous studies comparing the economics of pasture-based systems with conventional production systems have used a variety of modeling procedures and assumptions. Simulation, linked spreadsheet, and partial budgeting models have been employed to examine the issue in Pennsylvania. Parker, Muller, and Buckmaster (1992) used linked spreadsheet analysis to compare Pennsylvania pasture-based dairy production with a conventional dry-lot system. A 200-acre pasture-based farm with 53 cows generated a higher gross margin than conventional production. Soder and Rotz (2001) simulated a representative 250-acre Pennsylvania dairy farm, varying the grazing rate and amount of concentrate fed. The farm utilizing pasture with a high concentrate supplement level yielded higher net return to management than did the farm using a conventional system. Elbehri and Ford (1995) simulated production systems for a 60-cow Pennsylvania dairy farm. An intensive grazing pasture-based system stochastically dominated a conventional system; however, if milk yields for the pasture system dropped by only 4% to 6%, the intensive grazing system would no longer be preferred.

Tozer, Bargo, and Muller (2003) examined three production systems in Pennsylvania: TMR non-grazing, TMR combined with pasture during daytime hours, and pasture-based. Using partial budgeting, the TMR conventional system yielded the highest profit. The authors acknowledge their results run counter to other studies, explaining that they used "high-yielding Holstein cows grazing high-quality pastures in the northeast United States for a limited grazing season" (p. 814). Milk yields were 25% and 16% lower for the pasture-based and TMR with daytime grazing treatments, respectively.

Experiment station field trials have been used to compare the economics of pasture-based with conventional dairy production in three states. Based on a two-year trial in northern Minnesota, Rust et al. (1995) compared an intensive rotational grazing pasture-based system with a conventional confinement system. Due to reduced feed requirements and lower facilities, labor, and equipment costs, net returns per cow were higher for the pasture-based than the conventional system, despite lower milk production. Tucker, Rude, and Wittayakun (2001) evaluated dairy cow performance on a total mixed ration (TMR) diet versus rotational grazing of annual ryegrass during the March to May period in Mississippi. Daily milk production declined on the ryegrass diet, but return over feed costs was higher. White et al. (2002) conducted a four-year experiment with conventional and pasture-based systems in North Carolina. The authors concluded that a pasture-based system had the potential to be economically competitive since significant differences in return over feed costs between the systems were not found.

Survey results have been used for economic comparisons of pasture-based and conventional production. Hanson et al. (1998) surveyed 53 Pennsylvania dairy farms, finding those using intensive grazing pasture-based systems to be profitable, but increased pasture use to be associated with negative cash flows. Dartt et al. (1999) surveyed 35 management-intensive grazing and 18 conventional dairy farms in Michigan with average sample herd sizes of 70 and 80 cows, respectively. Pasture-based farms yielded higher economic profit than conventional dairies. Foltz and Lang (2005) examined the adoption of management-intensive rotational grazing on Connecticut dairy farms and its effect on productivity, cost, and profit. Adopters used pasture as the primary feed source for milking cows during the grazing season. Adoption did not significantly influence production per cow, cost of production, or profit, though results suggested that full adoption resulted in greater profit than partial adoption.

Several observations are made with respect to previous studies. First, they have often relied on experimental situations, simulation techniques, or surveys of limited numbers of small farms in specific regions. With the possible exception of Foltz and Lang (2005), earlier investigations have compared relatively small conventional farms with relatively small pasture-based operations, none fully addressing the increasingly common large (i.e., > 250 cows) operation. As the number and proportion of larger-scale operations increase, the majority of which are likely to be conventional, it is useful to compare profitability covering the full range of operation sizes.

A Model to Estimate the Impact of Pasture-Based Systems on Dairy Profitability

A model for estimating the impact of pasture-based systems on dairy enterprise and whole-farm profitability for firm i, π_i, assumes profit is a function of discrete variables indicating the extent of pasture use, g_i , and other explanatory variables, x_i. The equation can be written as:

$$\pi_i = \beta' x_i + \sum_{j=1}^{n} \delta_j g_{ij} + \varepsilon_i , \tag{1}$$

where ε_i is a random error term and j refers to the specific pasture system, with $j = 1$ denoting an intensive pasture-based system and $j = 2$ referring to a less intensive pasture-based system, both with a third "conventional" system serving as the base. Other explanatory variables x_i include farmer and farm characteristics hypothesized to influence farm profitability, such as region, farm size, and demographic variables.

Pasture use decisions are likely to be dependent upon farm and farmer characteristics, so the outcomes are not expected to be random, but based on the farmer's self-selection. As such, in the spirit of Heckman (1990), variables indexing g_{ij} are treated as endogeneous. Thus, instrumental variables are appropriate for estimating their impact on profit. The equation for estimation of instrumental variables for pasture use is expressed as:

$$g_{ij} = \gamma' z_i + u_{ij} . \tag{2}$$

In cases where the producer chooses $j = 1$, it is assumed he or she realizes the greatest *profit* from system g_{i1}. Variables z_{ij} are farmer and farm characteristics hypothesized to influence system choice. With three possible pasture systems, (2) can be estimated using the multinomial logit model, which follows Greene (2000, p. 858).

In sum, this model can be estimated using two stages: (*a*) in the first stage, a multinomial logit model to estimate which of three production systems is chosen, from intensive pasture use to conventional production; and (*b*) in the second stage, ordinary least squares (OLS) to estimate the impact of production system and other factors on profitability.[1] Specific variables used in each of the equations, as well as the data, are discussed in the following section.

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[1] Alternative estimation procedures were considered. A reviewer suggested a strategy that is more consistent with the Heckman selection bias correction utilized by Gyourko and Tracy (1988): (1) was reformulated as

$$\pi_i = \beta' x_i + \lambda_c g_{ic} h_{ic} + \sum_{j=spb,pb}^{n} \left(\alpha_j g_{ij} + \lambda_j g_{ij} h_{ij} \right) + \varepsilon_i ,$$

where α_j and λ_j are estimable parameters; g_{ij} indicates use of systems j = conventional (c), pasture-based (pb), and semi-pasture-based (spb);

$$h_{ij} = \phi\left(\Phi^{-1}\left(e^{\beta' x_{ij}} / \sum_{j=1}^{3} e^{\beta' x_{ij}} \right) \right) \sum_{j=1}^{3} e^{\beta' x_{ij}} / e^{\beta' x_{ij}}$$

for standard normal density $\phi(\cdot)$ and cumulative distribution $\Phi(\cdot)$ functions; and j are generalized Heckman selection bias corrections. This is analogous to the inverse Mill's ratio with application to the multinomial logit. The λ_j were never significant, providing no evidence of selection bias. Coupled with multicollinearity problems arising with this specification, this led to selection of the chosen specification. It is also common to estimate separate equations for each system, as done by Gyourko and Tracy, though the single-equation approach allows testing for differences across systems. To determine whether control variables had the same effects for all three systems, interaction terms were included: system × control variables. None of the interaction terms were significant, leading us to the current specification.

Determining Which of Three Production Systems Is Used

To determine the dependent variable of equation (2), the following question was asked of producers: "Did this operation use pasture or cropland to graze dairy cattle during 2005?" Respondents answering "yes" were then asked, "About what percent of their total forage ration do milk cows obtain from pasture during the grazing months?" Answers were allocated among the following four categories: 1–24%, 25–49%, 50–74%, and 75–100%. For purposes of this study, three types of production systems were identified: (*a*) conventional—producers who answered "no" to the first question, (*b*) semi-pasture-based—producers who answered "yes" to the first question and either "1–24%" or "25–49%" to the second, and (*c*) pasture-based—producers who answered "yes" to the first question and either "50–74%" or "75–100%" to the second. Pasture-based producers can be characterized as heavily pasture-dependent, while the semi-pasture-based group ranges from very limited to significant pasture use.

Independent variables included in equation (2), estimated via multinomial logit, are categorized by: resource characteristics, farm financial and size characteristics, and farm operator characteristics. Resource characteristics include regional and land price variables. Seven regions of the United States are included in the model as dummy variables: *Appalachia, Corn Belt, Lake, Pacific, Southeast, Southern Plains,* and *Mountain West*, with the eighth region, *Northeast*, serving as the base. These regions are defined in table 1. States included in each region are limited to the 24 included in the ARMS dairy survey. Regional variables adjust for differences in input prices, forage species, and grazing season length. *Land Price* is the farmland value per acre. Producers farming relatively higher priced farmland are expected to more likely choose conventional production rather than to pasture land having high opportunity cost.

Farm financial and size characteristics include measures of farm size, debt, and specialization. The farm size variable included is *Acres*, which measures total acres operated and is included to determine whether farm size influences system choice. Larger farms are expected to choose conventional production, as the increased management associated with grazing on a large-scale farm is likely to be constraining.

Holding dairy enterprise size constant, it is expected that dairy producers planning a more diversified operation would select a conventional over a pasture-based system. Engaging in non-dairy-related enterprises constrains management resources, and extensive pasture use is generally rather management-intensive. The reverse of diversification, specialization, is measured as the percentage of farm income derived from milk, *%Income Milk*.

The debt-asset ratio (*Debt/Asset*) is included as a measure of the farmer's financial management.[2] Operator age (*Age*) and whether the producer holds a four-year college degree (*College*) are also included.

An additional variable serves as a proxy for land that is unsuitable for cropping. *Non-Crop Acres* is determined as the subtraction of harvested acres of all crops and hay from total operated acres. Thus, it measures any land use other than for harvested crops, including woodland, fallow cropland, pasture, government land retirement, and other uses. It is expected that those

[2] Ascribing debt-asset ratio a priori to be the *result of production system choice for a given dairy size* would be less clear, as any of the three systems could result in substantial debt relative to assets, whether for investment in buildings and equipment (conventional production) or generally rapidly increasing and highly variable land values across the United States (pasture-based operations). Hanson et al. (1998) found higher debt among pasture-based farms than conventional farms, while Taylor and Foltz (2006) found pasture-based Wisconsin operations to hold less debt than conventional farms, not holding size constant.

Table 1. Definitions and Means of Variables Used in the Analysis

Variable	Definition	Weighted Mean
Resource Characteristics:		
Lake	Dummy for Lake states: MI, MN, WI	0.39
Corn Belt	Dummy for Corn Belt states: IL, IN, IA, MO, OH	0.15
Appalachia	Dummy for Appalachian states: KY, TN, VA	0.05
Southeast	Dummy for Southeastern states: FL, GA	0.01
Southern Plains	Dummy for Southern Plains states: TX	0.01
Mountain West	Dummy for Mountain states: AZ, ID, NM	0.07
Northeast	Dummy for Northeastern states: ME. NY, PA, VT	0.26
Pacific	Dummy for Pacific states: CA, OR, WA	0.05
Organic	Dummy for organic status	0.02
Land Price	Value of farmland, per acre	5,298.23
Milk Price	Average price received for milk, per cwt	15.20
Farm Financial and Size Characteristics:		
Cows	Number of cows in the dairy operation	154
Acres	Acres operated on the farm	408
%Income Milk	Percentage of farm income derived from milk	87
Debt/Asset	Debt/asset ratio	0.14
Non-Crop Acres	Total operated farm acres less harvested acres	126
Farm Operator Characteristics:		
Age	Operator age (years)	51
College	Dummy for holding a 4-year college degree	0.16

with greater *Non-Crop Acres* would more likely engage in pasture-based or semi-pasture-based production, due primarily to land suitability.

Organic producers are expected to more likely choose semi-pasture-based or pasture-based production systems. Current USDA rules for organic ruminant production call for pasture access, but are not specific as to the extent of access. Some organic farms may resemble conventional production more than pasture-based production, as organic feed is furnished to the animals in a TMR. For purposes of the present study, those categorized as organic produced organic milk or were transitioning into organic milk production.

The Influence of Production System on Net Return to the Dairy Enterprise and the Whole Farm

To determine the impact of production system choice on net return to the dairy enterprise and whole farm [equation (1)], four models were estimated using OLS regression. Dependent variables include two dairy enterprise profit measures and two whole-farm profit measures. Each of the profit measures represents commonly used methods for examining dairy enterprise and whole-farm profitability. For the enterprise and whole-farm measures, both the value of production less total costs per cow and value of production less total costs listed per hundredweight (cwt) of milk produced are estimated. To determine enterprise net returns, revenue includes: value of milk sold, cattle, and other income from the dairy enterprise. Operating costs include: feed, veterinary and medical, bedding, marketing, custom services, fuel, lube, electricity, repairs, other operating costs, and interest on operating costs. Allocated overhead costs include: hired labor, opportunity cost of unpaid labor, capital recovery of machinery and equipment, opportunity cost of land (rental rate), taxes and insurance, and general farm overhead. This profitability measure is closest to the typical "enterprise budget," which generally includes all variable and fixed costs, including non-cash items such as opportunity costs (Doye, 2004).

Whole-farm net farm income measures the profit or loss associated with the farm. Revenue includes gross cash income adjusted to reflect changes in inventory, estimated value of home-consumed products, and rental of dwellings on the farm. Total operating expenses include both interest payments and depreciation taken on capital stock. Two important differences are noted between enterprise and whole-farm profitability measures: (*a*) for the enterprise net return, homegrown feeds are valued at their opportunity cost—the price at which they would be purchased, while for the whole farm, costs of producing homegrown feeds are included; and (*b*) opportunity costs for labor and land are included in the enterprise, but not the whole-farm measures. The whole-farm measure of profitability is that found on the income statement, which does not include opportunity costs.

Use of enterprise measures of profit is of interest, as they are designed specifically to focus solely on the entity of interest, the dairy. Gillespie et al. (2009) show significant differences in percentage of value of production from dairy during 2003–2007, depending upon farm size and extent of pasture use; hence, analyzing the dairy enterprise separately from the rest of the farm is of interest. However, from table 1, it is noted that on average, 87% of a dairy farm's income is from dairy, so it can be argued that, for most dairy farms, a whole-farm measure is also a reasonable measure of dairy farm profitability.

The enterprise measure cannot provide a precise measure of actual cost. In the context of the enterprise, the costs of home-growing feed and forage cannot be fully allocated to the dairy due to the indivisibility of inputs such as tractors and fertilizers and the fact that some dairy farms also sell feed and forage. This is why homegrown feeds are valued at their opportunity cost in the enterprise measures. Because the dairy is part of a whole-farm planning process, other enterprises may also be included that are complementary to the dairy enterprise. Examining only the enterprise measures neglects to recognize these important factors.

We point out that any number of estimates for farm profitability could have been chosen, such as return over operating costs, inclusion of opportunity costs for land, and operator labor in the whole-farm measures, etc. We analyzed each of these alternatives, but selected the measures included here for two major reasons: (*a*) they are among the most commonly used measures of enterprise and farm profitability used by agricultural production economists, making their results relatively straightforward for interpretation by users; and (*b*) they differ in their approaches, opening the possibility that one commonly used measure of profitability could suggest greater profitability of one system while the other either does not show a difference or could even lead to conflicting results. Given that both whole-farm and enterprise measures are useful in farm decision making, analysis using both approaches is particularly warranted.

Independent variables in the profit equations include regional variables as described in the multinomial logit models, the number of dairy cows in the operation (*Cows*), the number of dairy cows squared (*Cows Squared*, divided by 1,000 for scaling purposes)*, College, Age, Acres, Land Price,* and the average price received for milk (*Milk Price*), and *Debt/Asset*.

Scale economy suggests *Cows* would positively influence net return. Tauer and Mishra (2006) found economies of scale among U.S. dairies, with further evidence discussed in MacDonald et al. (2007). *Cows Squared* is included to test for nonlinearities associated with size and profitability; with diminishing returns, it would have a negative sign. *Acres* is also included as an alternative measure of overall farm size, with the expectation that farms with more acreage would be more profitable, particularly on a whole-farm basis. *College* is expected to have a positive sign, as education should positively influence managerial ability, and thus net returns. A positive sign for *College* would be consistent with results reported by Mishra and Morehart (2001), who examined factors affecting returns to operator labor and management. The expected impact of *Age* is less clear, as older farmers would be more experienced, but likely using older technology.

Also included is *Debt/Asset*. Haden and Johnson (1989) found mixed results on the impact of debt-asset ratio with Tennessee farmers, depending upon how profitability was measured. *Pr−Pasture-Based* and *Pr−Semi-Pasture-Based* indicate the specific production systems used, with the conventional system serving as the base. The expected impact is unclear, given mixed results of the previously cited studies. Our more extensive model and representative data set are expected to provide significant insights on this issue.

Data

The USDA's Agricultural Resource Management Survey (ARMS) is administered by the National Agricultural Statistics Service (NASS) and the Economic Research Service (ERS). The 2005 ARMS Phase III dairy version provides 1,815 usable responses from 24 states. Via personal interview, this survey collected information on farm size, type, and structure; income and expenses; production practices; and farm and household characteristics. Because this design-based survey uses stratified sampling, the data set contains weights for each observation that can be used to extend the results to the U.S. commercial dairy farm population. Weighted regression procedures were used to estimate all models reported in this paper. 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 (National Research Council, 2008).[3]

Results

Differences in means tests provide insight as to system characteristics (table 2). Farmers who did not utilize grazing were the greater adopters of technology in general, with higher adoption rates of recombinant bovine somatotropin, a dairy parlor, computerized milking systems, computerized feeding systems, use of the internet for accessing dairy information, use of the computer for managing dairy records, membership in the Dairy Herd Improvement

[3] The regression results reported in the results section are derived using farm-level 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, we use a jackknifing procedure with 15 replicates to estimate sample variances (to obtain *t*-statistics on our coefficients from our base-run regressions) to make inferences to the population. For a further explanation as to why "nonclassical" econometrics must be employed to achieve sensible inferences to the population of the sample, see National Research Council (2008, chapters 4 and 7).

Table 2. Means of Selected Variables Depending upon Grazing Intensity

Measure	Conventional	Semi-Pasture-Based	Pasture-Based
Technology, System, and Record Keeping Use (portion adopted):			
Recombinant bovine somatotropin	$0.255^{SPB,PB}$	$0.133^{Conv,PB}$	$0.039^{Conv,SPB}$
Artificial insemination	0.833	0.835	0.755
Parlor	$0.637^{SPB,PB}$	0.401^{Conv}	0.340^{Conv}
Computerized Milking System	$0.092^{SPB,PB}$	0.033^{Conv}	0.023^{Conv}
Computerized Feeding System	$0.131^{SPB,PB}$	$0.049^{Conv,PB}$	$0.013^{Conv,SPB}$
Use internet for dairy information	$0.502^{SPB,PB}$	0.313^{Conv}	0.275^{Conv}
Use computer to manage dairy records	$0.422^{SPB,PB}$	0.168^{Conv}	0.140^{Conv}
Member, Dairy Herd Improvement Assn.	$0.581^{SPB,PB}$	0.383^{Conv}	0.368^{Conv}
Organic or transitioning to organic	0.001	0.015	0.090
Milks three times per day	$0.117^{SPB,PB}$	$0.054^{Conv,PB}$	$0.004^{Conv,SPB}$
Farm Characteristics (means):			
Number of acres	$502.781^{SPB,PB}$	352.460^{Conv}	298.380^{Conv}
Number of cows	$259.269^{SPB,PB}$	$91.058^{Conv,PB}$	$70.343^{Conv,SPB}$
Hundredweight milk per cow per year	$183.521^{SPB,PB}$	164.756^{Conv}	151.344^{Conv}
Pasture acres / cow	$0.000^{SPB,PB}$	$0.777^{Conv,PB}$	$1.583^{Conv,SPB}$
Percent of acres in silage	$18.125^{SPB,PB}$	$11.871^{Conv,PB}$	$7.002^{Conv,SPB}$
Percent of acres in hay	$5.714^{SPB,PB}$	$10.456^{Conv,PB}$	$17.012^{Conv,SPB}$
Debt-asset ratio	$0.190^{SPB,PB}$	0.121^{Conv}	0.114^{Conv}
Farm Numbers:			
Number of farms in sample	653	644	399
Number of farms represented	18,473	21,893	9,542

Note: Superscripts indicate significant column difference tests based on pairwise two-tailed delete-a-group jackknife *t*-statistics at a 90% confidence level or higher with 15 replicates and 28 degrees of freedom. Presence of superscripts coded as pasture-based (PB), semi-pasture-based (SPB), and conventional (Conv), respectively, indicate the measure differs from the super-scripted measure at the 10% level.

Association, and milking cows three times per day. Furthermore, semi-pasture-based farms were greater adopters of recombinant bovine somatotropin and computerized milking systems, and were more likely to milk cows three times per day than were pasture-based farms. Less intensive grazing was clearly associated with greater technology adoption. Further evidence of differences in farms using the three systems is that conventional farms were larger in terms of acreage and number of cows, produced more milk per cow per year, had higher percentages of land devoted to silage production and lower percentages devoted to hay production, and held higher debt relative to assets. Of the farms that utilized grazing, the more intensive grazers had fewer cows, and lower percentages of farm acres were devoted to silage while higher percentages were devoted to hay. These results show clear evidence that farms utilizing the three systems differ significantly in size, structure, and the propensity to adopt technology.

Table 3 presents paired *t*-test results on which system is most profitable using both enterprise and whole-farm measures. Both enterprise-level net return measures indicate conventional

Table 3. Net Returns Measures by Dairy System ($)

Net Returns Measure	Conventional	Semi-Pasture-Based	Pasture-Based
Enterprise net return per cow	$26.29^{PB,SPB}$	-825.93^{Conv}	$-1,045.10^{Conv}$
Enterprise net return per cwt milk	$0.13^{PB,SPB}$	-4.68^{Conv}	-6.72^{Conv}
Whole-farm net return per cow	725.24	731.55	733.58
Whole-farm net return per cwt milk	3.65^{PB}	4.15	4.72^{Conv}

Note: Superscripts indicate significant column difference tests based on pairwise two-tailed delete-a-group jackknife *t*-statistics at a 90% confidence level or higher with 15 replicates and 28 degrees of freedom. Presence of superscripts coded as pasture-based (PB), semi-pasture-based (SPB), and conventional (Conv), respectively, indicate the measure differs from the superscripted measure at the 10% level.

farms are more profitable than pasture-based and semi-pasture-based farms. On the other hand, when whole-farm measures are used, significant differences are not found on a per cow basis, but the pasture-based operations yield higher net return on a cwt milk produced basis. The discrepancy between measures by system can be attributed to the fact that enterprise net returns (but not whole-farm net returns) include opportunity costs for unpaid labor and land, both of which would be relatively higher for pasture-based systems. Though these results provide information as to the profitability of the farms under each of the systems, yielding some initial insight as to the average profitability of these systems across the United States, they are not estimated in a multivariate framework that includes region, farm size, and other factors, all of which provide a more thorough analysis of the drivers of net returns and whether significant differences still hold among systems when the other factors are also taken into account. Thus, the more complete multivariate analysis follows.

Multinomial Logit Production System Choice Estimates

The multinomial logit model for determining how producers choose among the alternative dairy production systems is shown in table 4. Results suggest a number of drivers influence system choice. The percentage correctly predicted for this model is 62.7%, with 710, 756, and 342 farms being predicted to fall into the conventional, semi-pasture-based, and pasture-based systems, respectively. If the model had no predictive value (i.e., the placing of farms into the three categories was completely random), the percentage correctly predicted would be 33.3%.

Region significantly influenced production system choice, with the Lake States, Corn Belt, Mountain West, and Pacific regions more likely than the Northeast to utilize conventional production relative to the other two systems. In addition, the Southern Plains region was more likely than the Northeast to utilize a conventional relative to a pasture-based system. The odds ratios are particularly striking, ranging from a low of 2.465 to a high of 13.864 for conventional versus pasture based, and 0.057 to 0.349 for semi-pasture-based versus conventional, suggesting the odds of a producer in these regions opting for a system other than conventional production are much lower than in the Northeast.

Results underscore the relationship between farm size and system choice. Larger farms in terms of acreage were less likely than smaller farms to utilize either pasture-based or semi-pasture-based systems relative to conventional production. Adding another acre to the farm decreased the odds of choosing semi-pasture-based relative to conventional production by 0.2% and increased the odds of choosing conventional relative to pasture-based by 0.6%. As observed in the industry, these results underscore smaller farms as the greater users of pasture.

Table 4. Multinomial Logit Results, Choice of Forage System

	Conv vs. PB		SPB vs. PB		SPB vs. Conv	
Variable	Beta (|*t*-Statistic|)	Odds Ratio	Beta (|*t*-Statistic|)	Odds Ratio	Beta (|*t*-Statistic|)	Odds Ratio
Constant	−1.802 (1.486)	N/A	−0.738 (0.703)	N/A	1.064** (2.080)	N/A
Lake	1.522** (2.115)	4.580	0.461 (0.822)	1.586	−1.061*** (2.754)	0.346
Corn Belt	1.172*** (2.607)	3.227	0.120 (0.259)	1.127	−1.052*** (3.022)	0.349
Appalachia	0.106 (0.146)	1.112	0.543 (1.048)	1.722	0.437 (1.172)	1.549
Southeast	2.705 (0.265)	14.948	3.425 (0.329)	30.727	0.721 (0.624)	2.056
Southern Plains	0.902* (1.695)	2.465	0.119 (0.191)	1.127	−0.783 (1.378)	0.457
Mountain West	2.629*** (3.901)	13.864	−0.229 (0.289)	0.796	−2.858*** (8.264)	0.057
Pacific	1.940*** (2.794)	6.960	−0.466 (0.664)	0.628	−2.406*** (9.171)	0.090
Land Price	7.3E-5* (1.735)	1.000	6.5E-5 (1.375)	1.000	−8.5E-6 (0.834)	1.000
Acres	6.0E-3*** (4.001)	1.006	4.3E-3** (2.438)	1.004	−2.1E-3*** (4.761)	0.998
%Income Milk	−1.7E-3 (1.057)	0.998	−2.5E-3 (0.840)	0.997	−8.0E-4 (0.254)	0.999
Debt/Asset	2.855*** (3.041)	17.368	0.654 (0.583)	1.923	−2.201*** (2.679)	0.111
Age	−7.2E-3 (0.425)	0.993	0.012 (0.785)	1.012	0.019* (1.892)	1.019
College	0.189 (0.553)	1.208	0.372 (0.741)	1.451	0.183 (0.524)	1.201
Non-Crop Acres	−6.6E-3** (2.575)	0.993	−4.3E-3** (2.034)	0.996	2.3E-3** (2.151)	1.002
Organic	−5.263*** (2.795)	0.005	−1.562*** (2.643)	0.210	3.702* (1.793)	40.513
% Correctly Predicted = 62.7% Number of Observations = 1,747						

Notes: Single, double, and triple asterisks (*,**,***) denote statistical significance at the 10%, 5%, and 1% levels or better, respectively, with jackknife standard errors and 14 degrees of freedom. Abbreviations are defined as follows: PB = pasture-based, Conv = conventional, and SPB = semi-pasture-based.

For the producer with a debt-asset ratio of 1 relative to the producer with a ratio of 0, the odds of operating a semi-pasture-based relative to a conventional system decrease by 88.9% and the odds of operating a conventional system are 17 times that of operating a pasture-based system. These results are consistent with findings reported by Taylor and Foltz (2006) and inconsistent with the findings of Hanson et al. (1998).

As expected, *Non-Crop Acres* was highly predictive of system choice. Producers having greater land devoted to non-crop uses were more likely to have chosen a pasture-based or semi-pasture-based system relative to conventional production, and more likely to have chosen pasture-based relative to a semi-pasture-based system.

Older producers were more likely to have chosen semi-pasture-based relative to conventional systems, with each year of age increasing the odds of choosing a semi-pasture-based system by 1.9%. Having an organic operation was highly predictive of system choice. An organic producer was most likely to have chosen a pasture-based system, followed by a semi-pasture-based system, and finally a conventional system. This finding is as expected, given U.S. Department of Agriculture rules for organic production that require organic dairy producers to provide cows with access to pasture.

Net Returns Equation Estimates

Net returns equations provide insight as to the type of operation yielding the highest net return per cow or per cwt milk (table 5). Results suggest that Lake States producers received higher whole-farm net returns than did Northeastern producers. On the other hand, Southeastern and Southern Plains dairy farms were less profitable than Northeastern producers on a whole-farm basis. As has been found in previous dairy studies where regional variables are included in net returns equations (McBride, Short, and El-Osta, 2004), not only is the significance of interest, but the magnitude is striking. In our case, Southern Plains and Southeastern producers are both estimated to have net returns per cow greater than $300 lower than Northeastern producers on a whole-farm basis. On the other hand, Lake States producers are estimated to have net returns per cow of over $300 more than Northeastern producers on a whole-farm basis. The magnitudes suggest major differences in profitability on a whole-farm basis by region. Significant regional estimates on a per cwt milk basis vary from the base Northeast region by at least $1.40, also suggesting major profitability differences by region.

Operations with greater cow numbers received higher net returns per cow and per cwt milk on an enterprise basis, consistent with significant economies of size in dairy production, as shown by Tauer and Mishra (2006) and discussed by MacDonald et al. (2007). Taking the first derivative with respect to the number of cows suggests net returns per cow and per cwt are maximized at 4,123 and 3,941 cows, respectively. Given, however, a relative paucity of data in the > 3,000 cow range and that use of the quadratic form to test for diminishing returns forces a maximum, these maxima should be viewed with caution.

Older producers were found to be less profitable on both enterprise and whole-farm bases, consistent with results from Tauer and Mishra (2006), who found older dairy farmers to be higher-cost producers. Production system (pasture-based, semi-pasture-based, or conventional) was found to influence net returns—in one case, semi-pasture-based producers were found to have $3.48 lower dairy enterprise net returns per cwt of milk produced than conventional producers. This result runs counter to some previously reported research conducted on experiment stations or via simulation techniques (Parker, Muller, and Buckmaster, 1992; Rust et al., 1995; Dartt et al., 1999; Soder and Rotz, 2001), but is consistent with Tozer, Bargo, and Muller (2003). In contrast, on an enterprise basis, the estimates are negative and their magnitudes are rather large ($523 / $318 per cow differences between pasture-based / semi-pasture-based and conventional), but the variability is wide such that we can have little confidence that they differ from zero. On a whole-farm basis, system choice is not found to have significantly greater net returns than conventional operations. The discrepancy of signs, though nonsignificant, can be attributed to greater specialization and greater reliance on purchased feeds by the conventional relative to the other farms. (The enterprise measure

Table 5. Ordinary Least Squares Net Returns Equations

	Dairy Enterprise Net Return		Whole-Farm Net Return	
	per Cow	per cwt Milk	per Cow	per cwt Milk
Variable	Beta (|*t*-Statistic|)	Beta (|*t*-Statistic|)	Beta (|*t*-Statistic|)	Beta (|*t*-Statistic|)
Constant	−2,120.203** (2.243)	−9.851 (0.518)	872.540 (1.475)	3.643 (0.646)
Lake	41.100 (0.136)	−0.653 (0.213)	358.201*** (3.802)	2.469*** (2.796)
Corn Belt	27.550 (0.216)	−0.896 (0.264)	125.023 (1.076)	1.500 (1.532)
Appalachia	−16.452 (0.868)	−1.395 (2.768)	−209.164 (1.103)	−0.909 (0.557)
Southeast	144.414 (0.140)	0.721 (0.095)	−333.144*** (2.875)	−1.420* (1.832)
Southern Plains	354.224 (1.579)	1.911 (0.454)	−440.869*** (2.721)	−2.901* (1.737)
Mountain West	−172.742 (0.402)	−2.712 (0.628)	−151.859 (0.662)	−0.352 (0.207)
Pacific	135.308 (0.361)	0.257 (0.054)	−145.875 (0.665)	−0.218 (0.125)
Pr−Pasture-Based	−522.762 (0.596)	−8.421 (0.416)	223.759 (0.307)	2.117 (0.313)
Pr−Semi-Pasture-Based	−317.827 (0.814)	−3.477** (2.223)	107.131 (0.581)	0.825 (0.518)
College	27.754 (0.182)	1.208 (0.932)	−96.341 (0.972)	−0.794 (1.050)
Age	−17.659*** (2.915)	−0.182*** (2.696)	−7.551** (2.382)	−0.020 (0.715)
Cows	1.976*** (4.834)	0.013*** (4.281)	0.081 (0.483)	−9.4E-4 (0.677)
Cows Squared	−0.240** (2.065)	−0.002* (1.848)	−2.0E-4 (0.005)	1.7E-4 (0.491)
Acres	−2.7E-3 (0.028)	4.8E-4 (0.683)	−0.027 (0.523)	−1.4E-4 (0.491)
Land Price	1.1E-3 (1.199)	6.3E-6 (0.787)	−5.2E-4 (0.704)	−3.0E-6 (0.682)
Milk Price	111.895*** (2.751)	0.682 (1.098)	8.895 (0.267)	0.053 (0.155)
No. of Observations = 1,808				

Note: Single, double, and triple asterisks (*,**,***) denote statistical significance at the 10%, 5%, and 1% levels or better, respectively, with jackknife standard errors and 14 degrees of freedom.

prices homegrown feed as if it were purchased, implicitly including opportunity costs of operator labor and land, while the whole-farm measure does not.)

As expected, milk price significantly influenced net returns, with higher milk price leading to higher net return per cow; and farms under greater debt loads received lower whole-farm net returns per cow than those under lower debt loads.

Additional enterprise models were run separately by region, including (*a*) the Northeast, Lake States, and Corn Belt combined; (*b*) the Northeast only; (*c*) the Lake States only; (*d*) the Southeast and Appalachia combined; and (*e*) the Southern Plains, Mountain West, and Pacific combined. In none of these runs were *Pr−Pasture-Based* or *Pr−Semi-Pasture-Based* statistically different from zero. Thus, no differences in profitability were found among the systems when confined by region. These results are not included since they provide little additional specific information about the impact of production system on net return.

Conclusion

Pasture-based dairy systems remain a significant portion of the changing U.S. dairy production sector, and have gained increased attention recently. These results suggest that pasture-based dairy systems differ in prominence by region, but also by farm and operator demographics. Pasture-based producers are more likely to be smaller-scale and have lower debt, and can be thought of as "extensive," rather than "intensive" grazing operations, meaning that they utilize more land resource per cow and are relatively more likely to milk cows twice rather than three times per day and are less likely to adopt "intensive" technologies. Likewise, semi-pasture-based producers are more likely to be smaller-scale and have lower debt than conventional producers, but are larger than pasture-based producers. The semi-pasture-based category is fairly broad—it includes producers whose pasture utilization is very limited to quite significant, so it includes producers who are "close to conventional" as well as those who utilize significant pasture but do not depend upon it for the majority of the cow's nutritional requirement.

Paired *t*-tests reveal significant differences in profitability among systems, but the conclusion as to which system is more profitable depends upon whether an enterprise or a whole-farm measure of net returns is used. A multivariate framework, however, does not reveal major, or even significant in most cases, differences in net returns among systems. The coefficients are rather large and negative for both pasture-based and semi-pasture-based relative to conventional production on an enterprise basis, but they are significant only for semi-pasture-based in the per cwt milk produced case, suggesting there is great variation in net returns within each system. The most interesting results from the net returns analysis underscore the importance of farm size. Previous literature examining production systems, dairy farm size, and management would lead to this conclusion; however, compiling the results via a nationally representative sample of dairy farms provides evidence that the expectations based on generally smaller, regionally based studies holds in the context of the national dairy industry.

Further research will be required to discern conditions under which the competitiveness of pasture-based operations might be altered relative to large-scale conventional production. Such investigations could examine the influence of organic production, premiums paid for milk from pasture-based systems, economies of size associated with pasture-based systems, and regional characteristics.

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