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Pasture-Based versus Conventional Milk Production: Where Is the Profit?

Jeffrey Gillespie and Richard Nehring

Costs and returns of pasture-based dairy production are compared with those of conventional production using matching samples. Both whole-farm and dairy enterprise-level estimates are made using the U.S. Department of Agriculture's Agricultural Resource Management Survey data. Conventional farms are matched to pasture-based farms on the basis of operation scale, scope, region, and farmer demographics and adoption of technology. Results show for pasture-based production lower net farm income on per-cow, per-hundredweight milk produced, and total bases. On an enterprise basis, results show for pasture-based production, higher net return over operating cost and lower net return over total cost per hundredweight milk produced.

Key Words: farm management, matching samples, pasture-based dairy

JEL Classifications: Q10, Q12

Before the regular confinement of livestock and the transport of feed from land to animal, the standard milk production system was pasture-based. Advanced feed formulations, breeding, and animal confinement have been associated with rapid increases in milk cow productivity. Pasture-based systems, however, have never been wholly replaced by what has become known as "conventional" confinement production with pasture-based systems continuing to operate, particularly in parts of the U.S. Northeast, Upper Midwest, Missouri, the southern Mississippi Delta region, and areas of the West Coast. Based on their survival, it appears that some of these farms remain competitive despite oft-heard claims that pasture-based production cannot compete with conventional production. At least three recent developments have increased U.S. interest in pasture-based dairying and perhaps influenced its competitiveness: 1) increased certified organic milk production, where rules since 2010 have required that organic operations be essentially pasture-based (Neuman, 2010); 2) consumer willingness to pay premiums for milk from alternative production systems such as pasture-based operations; and 3) recent increased feedgrain prices resulting from higher feedgrain demand, which have increased feed costs for conventional relative to pasture-based dairies.

These observations raise a number of questions that have not been fully addressed in previous studies: 1) How do costs and returns of pasture-based and conventional operations of similar size and scope compare in this new economy? 2) What specific components of costs and returns differ between pasture-based and conventional operations, and by how much? The objective of the present study is to determine

Jeffrey Gillespie is the Martin D. Woodin Endowed Professor, Department of Agricultural Economics and Agribusiness, Louisiana State University Agricultural Center, Baton Rouge, Louisiana. Richard Nehring is an Agricultural Economist, Economic Research Service, U.S. Department of Agriculture, Washington, DC.

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differences in the costs, returns, and profitability of U.S. pasture-based dairy operations relative to conventional operations accounting for similar operation scale, scope, propensity to adopt technology, location, and self-selection of producers into a production system.

Defining Pasture-Based Milk Production

A number of definitions of pasture-based dairy systems can be found. Hanson et al. (1998) designated Pennsylvania grazers as those requiring animals to obtain ≥40% of forage needs from pasture during the summer. Dartt et al. (1999) defined a Michigan management intensive grazing operation as one where animals received ≥25% of their forage from pasture and grazed at least four months during the year. Taylor and Foltz (2006) separated Wisconsin milk systems using pasture into "mixed feed" operations, which grazed animals but relied primarily on stored feed, and "management intensive grazing" operations, which relied primarily on pasture for their forage source during the grazing season. Using Agricultural Resource Management Survey (ARMS) data, Nehring et al. (2009) divided U.S. dairy farms into two groups, those where ≥25% of the forage requirement was met by pasture during the grazing season (pasture-based) and those where <25% was met by pasture during the grazing season (conventional). Gillespie et al. (2009) further divided these farms into three groups: those where ≥50% of the forage requirement was met through pasture during the grazing season (pasture-based), >0% but <50% of the forage requirement was met through pasture during the grazing season (semipasture-based), and no pasture was used to meet the forage requirement. New (2010) organic dairy production rules require ≥30% of dry matter during the grazing season to be from pasture (Neuman, 2010), which is closest to the ≥50% forage requirement from pasture designation. For the present study, we define a pasture-based dairy operation similar to that of Gillespie et al. (2009), where ≥50% of the forage requirement is met by pasture during the grazing season.

Previous Studies Examining the Economics of Pasture-Based Dairy Systems

A number of studies have examined the economics of pasture-based dairy systems. Studies using linked spreadsheet, simulation, or partial budgeting models to examine pasture-based dairy economics have included Elbehri and Ford (1995), Parker, Muller, and Buckmaster (1992), Soder and Rotz (2001), and Tozer, Bargo, and Muller (2003), all in the context of Pennsylvania and with relatively small dairy farms (<125 cows). In all cases except for Tozer, Bargo, and Muller (2003), pasture-based operations were competitive with conventional farms. Studies comparing pasture-based versus conventional dairy production economics using experiment station field trials have also shown pasture-based production to be competitive or at least potentially competitive with conventional production: Rust et al. (1995), Minnesota; Tucker, Rude, and Wittayakun (2001), Mississippi; and White et al. (2002), North Carolina. Studies examining pasture-based versus conventional dairy production economics using commercial farm survey data include Hanson et al. (1998), Pennsylvania; Dartt et al. (1999), Michigan; and Foltz and Lang (2005), Connecticut. Each found pasture-based operations to be competitive with conventional operations.

Each of these studies, with the possible exception of Foltz and Lang (2005), assumed relatively small-scale operations, justifiable given the practical size limits associated with pasture-based production. Costs associated with gathering animals twice daily over the expansive land required for a large-scale pasture-based operation would be significant. Benson (2008) reviewed studies comparing pasture-based and conventional systems, noting that most had found pasture-based systems to be competitive with conventional systems.

Studies using ARMS data to examine competitiveness of pasture-based dairy production have included Gillespie et al. (2009) and Nehring et al. (2009). Nehring et al. (2009) estimated an input distance function for dairy farms included in the 2003–2007 ARMS data, finding that farm size rather than production system was the major profitability driver. Some small farms, however, were competitive from both pasture-based and conventional groups. Gillespie et al. (2009) used 2005 ARMS data, dairy version, to determine types of producers operating both pasture-based and semipasture-based operations and corrected for self-selection in determining the impact on farm profitability. Profitability differences were not found between pasture-based and conventional groups. The present study differs from these studies in two primary ways. First, we use 2010 ARMS data, dairy version, to examine profitability in a period of relatively high feedgrain prices. Second, we use the method of matching samples to ensure that pasture-based operations are compared with conventional operations of the same size and general structure except for system choice.

Materials and Methods

In determining relative profitability of alternative production systems, production economists have traditionally used methods such as linear programming models (Peterson, 1955), compared costs and returns of systems using experimental data (Gillespie et al., 2008), used regression analysis to determine impacts of production systems on profitability (McBride and Greene, 2009), or compared efficiency measures derived from production frontiers (Mayen, Balagtas, and Alexander, 2010). An increasingly used method for comparing economic performance of farms that are similar in all respects other than chosen system is to match samples of treated farms (those using the system of interest) with samples of untreated farms (those not using the system of interest) (Mayen, Balagtas, and Alexander, 2010; Tauer, 2009; Uematsu and Mishra, 2012. Once the samples are matched to one another, their economic performance can be compared with the assumption that structural concerns such as size and region and selectivity concerns such as managerial ability are held constant. Thus, for firm i using system $W = 1$, a firm that is similar to firm i but using system, $W = 0$ is identified for comparison. If $Y_i(W_i)$ is an economic performance measure such as profit, then for firm i, $Y_i(1)$ is compared with $Y_i(0)$. Extensive use of matching samples has been made in the field of medicine with Billewicz (1964) and Cochran (1953) representing early applications.

For effective use of the method of matching samples, two assumptions are required (Imbens, 2004): the treatment groups must have overlapping characteristics and firm characteristics must be unconfounded so that they can be used to reduce selection bias. If either assumption does not hold, then outcome differences will be biased. Using matching samples, six treatment effect measures can be estimated. In deciding which of these treatment effect measures to use, the researcher must first decide whether inference is to be made for the population the sample represents or for the sample alone. The choice will depend on whether it can be assumed that the sample data are representative of the population. If another sample drawn from the population can be assumed to yield the same results, then inference can be made for the population. The researcher must then decide whether to match treated observations with control observations, control observations with treated observations, or both. The population average treatment of the treated (PATT) and sample average treatment of the treated (SATT) match control (untreated) observations to each of the treated observations, with the "P" and "S" in the acronyms referring to whether the inference is made for the population or the sample, respectively. The population average treatment of the control (PATC) and sample average treatment of the control (SATC) match treated observations to each of the untreated (control) observations. Population average treatment effects (PATE) and sample average treatment effects (SATE) include all observations with all treated and control observations being matched to control and treated observations, respectively.

We chose the PATT because a relatively small percentage of farms in our sample (the ARMS data) were pasture-based as compared with conventional. Perhaps more important, the size range of conventional operations is generally wider (range from very small to very large) than that of pasture-based operations (range from very small to medium-sized). Use of either average treatment for the control (ATC) or average treatment effects (ATE)measures would have required that very large conventional operations (>1000 cows) be matched with pasture-based operations, for which there are few very large operations. Thus, using either of these measures would have violated the overlapping characteristics requirement. Furthermore, the ARMS was designed to represent the U.S. farm population, so population inferences are appropriate. The PATT is estimated as from Abadie et al. (2004):

$$(1) \qquad \tau^{pop,t} = E\{Y(1) - Y(0)|W = 1\}$$

In matching treatment with control observations, multiple criteria may be used. With k variables used to match farms, a $k \times k$ diagonal matrix of the inverse sample standard errors of the matching variables is used as the weighting index. This weighting matrix allows for normalization of variables by their standard deviations. Suppose treated firm i has covariate values x and a potential matching control firm has covariate values s. Then $\|s - x\|_V$ represents the distance between vectors s and x with positive definite matrix V. If M matches are to be selected for each treated observation, then all matches must be at least as close to the treatment observation as the M^{th} match. Abadie et al. (2004) and Tauer (2009) provide more extensive discussion of these methods.

In identifying closest matches, nearest matches of treatment and control groups may still look somewhat different. For ATE measures, bias may be reduced by estimating the dependent variable using regression functions for both the treated and control groups, where covariates used in matching the samples serve as the independent variables:

$$(2) \qquad \mu_\omega(x) = E\{Y(\omega)|X = x\} \text{ for } \omega = \text{zero or one.}$$

For average treatment for the treated (ATT) measures, the dependent variable for the control is regressed against all matching variables, so only the control observations that are matched to the treated observations (rather than all control observations) are included in the regressions. Effectively, the values of the covariates for each treatment observation are used in the regression to determine predicted values for the matched control observations, reducing bias that might result from differences in the matches. Following Abadie et al. (2004), Rubin (1979), and Tauer (2009), we used this method to reduce selection bias. The reader is referred to those papers for greater detail on this procedure.

Similar to the Gillespie and Nehring (2013) analysis of organic versus conventional beef operations, we matched one conventional operation with each pasture-based operation. Robust standard errors were estimated using the Huber-White estimator (Huber, 1967; White, 1980). Organic operations were excluded from the study; only nonorganic pasture-based and nonorganic conventional operations were included in our analysis.

Data

The 2010 ARMS data, dairy version, were used for this study. These data include 1915 observations from 26 states representing 90% of the U.S. dairy farm population. States included in the survey were Arizona, California, Colorado, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Michigan, Minnesota, Montana, New Mexico, New York, Ohio, Oregon, Pennsylvania, Tennessee, Texas, Vermont, Virginia, Washington, and Wisconsin. Farms for the survey were selected from a list maintained by the U.S. Department of Agriculture (USDA) National Agricultural Statistics Service. To ensure that only commercial operations were included in the survey, the farm must have had ≥10 cows to be surveyed. The ARMS includes "weights" that allow results to be expanded to 90% of the U.S. commercial dairy farm population. The "weight" for each observation is an estimate of the number of "like" farms that it represents. There were 207 nonorganic pasture-based operations in the sample, so with one match for each, a total of 414 observations was used. These data include whole farm costs and returns, enterprise estimates of dairy costs and returns, and dairy production practice information.

Comparing Performance Measures

Performance measures compared by production system include both whole-farm and dairy enterprise measures. Whole-farm measures include *Total Farm Income, Total Farm Expenses,* and *Net Farm Income*. These measures are compared on total, per hundredweight of milk (per cwt milk) produced, and per-cow bases. *Total Farm Income* includes gross cash income adjusted for changes in inventory, value of products consumed in the home, and farm dwelling rentals. *Total Farm Expenses* include operating expenses plus interest payments and depreciation on capital. Three of the most important ways that whole-farm measures differ from enterprise measures are: 1) whole-farm measures do not include opportunity costs for land and labor, whereas enterprise measures do; 2) whole-farm measures value homegrown feeds as the costs incurred in producing them, whereas enterprise measures value them at their opportunity cost, the price at which they could be purchased; and 3) whole-farm measures value capital consumption based on federal tax depreciation, whereas enterprise measures estimate its value using the capital recovery approach as shown in Boehlje and Eidman (1984, pp. 142–44). Whole-farm measures are found on the income statement; they do not include opportunity costs. Enterprise measures are found in the enterprise budget.

Dairy enterprise measures used in this study were those developed as part of the USDA commodity cost and return estimation project (www.ers.usda.gov/data-products/commodity-costs-and-returns.aspx). The revenue measure is *Gross Value of Milk Production*. Operating cost measures include *Cost of Purchased Feed*; *Cost of Grazed Feed*, which is the opportunity cost of land rental for pasture; *Cost of Harvested Feed*, which is the opportunity cost of homegrown feeds based on state average market prices; *Total Cost of Feed*, which is the sum of the previous three listed measures; *Cost of Veterinarian and Medicine*; *Cost of Bedding and Litter*; *Cost of Marketing*; *Cost of Custom Hire*; *Cost of Fuel and Lubricants*; *Cost of Repairs*; and *Cost of Operating Capital*. These operating cost measures sum to the *Total Operating Cost,* which must be covered for the farm to meet short-term financial obligations.

Allocated cost measures include *Cost of Paid Labor,* which does not include the labor included in the previous *Cost of Custom Hire* category where the labor and machine are hired together; *Cost of Unpaid Labor*, which is an opportunity cost of hours of unpaid labor multiplied by a wage estimated using the econometric model by El-Osta and Ahearn (1996); *Cost of Capital Recovery* for machinery and equipment, which includes economic depreciation and opportunity costs for cattle housing, milking facilities, feed and manure handling equipment and storage structures, trucks, tractors, and dairy replacements; *Cost of Land*, which is the opportunity cost of land used for animal holding areas and dairy buildings; *Cost of Taxes and Insurance*, which is allocated to the dairy enterprise as the percentage of the whole-farm gross margin from the dairy enterprise; and *Cost of Overhead*, which includes electricity, utilities, maintenance and repair of buildings, farm supplies, fees paid for services, vehicle registration and licensing, and general business expenses, which are allocated as the percentage of the whole-farm gross margin from the dairy enterprise. These expenses sum to *Allocated Costs*. *Total Expenses* is the sum of *Total Operating Cost* and *Allocated Cost*. These expenses must be covered to meet financial obligations, replace capital assets as required, and cover opportunity costs. *Net Return over Operating Cost* equals *Gross Value of Milk Production* less *Total Operating Cost*. *Net Return over Total Cost* equals *Gross Value of Milk Production* less *Total Expenses.*

Dairy enterprise measures are compared on total, per-cwt milk, and per-cow bases. Because most dairy farms are relatively highly specialized in dairy, whole-farm measures are generally also reasonable measures of dairy productivity. Two additional measures were compared: *Milk Produced per Cow per Year*, measured in hundredweight, and *Milk Price per Hundredweight*. These measures allowed for further comparisons of cow productivity and value of milk produced by production system.

Variables Used for Matching Pasture-Based and Conventional Dairy Farms

Variables used to match pasture-based and conventional dairy farms include: 1) farmer demographic variables to reduce selection bias; 2) farm size variables to control for scale effects; 3) a technology variable to isolate the impact of production system on economic impacts; and 4) locational variables to ensure that farms were operating under similar environmental conditions. In addition to the variables used in estimating the weighting index, exact matches were requested for several variables using Stata's nnmatch command. Within the weighting matrix, exact-match variables are weighted heavier (weights multiplied by 1000) than the others, receiving priority in matching (Abadie et al., 2004).

Farmer demographics used for matching the samples included operator age and whether the operator held a four-year college degree. Selection bias is of concern when there are unobservables such as the decision-maker's managerial ability, time horizon, or goals that may impact decisions, impacting farm performance. The age and education variables were included to reduce selection bias that might result from farmer differences in managerial ability, time horizon, and goal structure by system. McBride and Greene (2009) showed that dairy cost of production differed by farmer age and education, and Gillespie et al. (2009) showed differences in dairy profitability by age. More highly educated producers are expected to earn higher profit as a result of greater managerial ability. Likewise, profitability of older farmers might differ from that of younger farmers as a result of experience, age of facilities, or differences in incentives explained by the family firm life cycle (Boehlje, 1973). Age and education have been used in previous economic studies that have used matching samples to reduce selection bias among agricultural production systems (Gillespie and Nehring, 2013; Mayen, Balagtas, and Alexander, 2010; Uematsu and Mishra, 2012). It is important to note, however, that although we use these variables to reduce selection bias, we cannot assume that matching estimators completely eliminate selection bias. There may remain unobservable factors that explain a farmer's decision to select a particular production system. As discussed by Uematsu and Mishra (2012), selection bias is not a testable assumption in the context of matching analysis.

Farm size variables used for matching the samples included number of cows milked and number of acres operated as well as an exact-match variable to ensure that matched conventional farms were in the same farm size categories as the pasture-based operations. Categories designated for exact matches were: ≤100 cows, 101–250 cows, 251–500 cows, 501–1000 cows, and >1000 cows. The exact match ensured a first priority that pasture-based and matched conventional farms were within the same categories on the basis of cow numbers. From there, matching could be further refined based on actual cow numbers. Cow numbers are generally considered to be the primary farm size measure for dairy farms, thus the priority of both primary and secondary selection criteria to ensure similar farm sizes on that basis. Farm size is not, however, limited to measuring cow numbers; acreage is also important. Because many farmers begin with a given land base and land acquisition is very costly, particularly in many of the major dairy production regions such as the Northeast and California, we also match on farm acreage. This helps to prevent matching a large-acreage pasture-based farm with a small-acreage conventional farm. Matching on the basis of farm size is of importance because significant economies of size exist in the dairy industry (Nehring et al., 2009; Tauer and Mishra, 2006). Thus, similar-sized farms should be compared, isolating the impact of production system on farm profitability. Gillespie et al. (2009) showed significant differences in both numbers of cows and acres operated between the two systems with conventional operations being larger on average in both respects.

The total number of the following technologies, management practices, and production systems was used to further isolate the impacts of pasture versus confinement in determining costs, returns, and profitability: use of artificial insemination, use of embryo transfer and/or sexed semen, use of regularly scheduled veterinary services, use of a nutritionist to design feed mixes or purchase feed, use of a computerized feed delivery system, keeping of individual cow production records, use of an on-farm computer to manage dairy records, accessing the Internet for dairy information, forward purchasing of inputs, negotiation of price discounts for inputs with dealers or suppliers, milking cows three or more times daily, use of automatic takeoffs, use of a holding pen with an udder washer, use of a computerized milking system, use of recombinant bovine somatotropin, and use of a parlor. This allows us to separate the effects of the pasture-based production system from the use of technologies and management practices that may be generally complementary with system but not necessarily used by only one system. Gillespie et al. (2009) found that conventional producers were more likely than pasture-based producers to adopt recombinant bovine somatotropin, a parlor, a computerized milking system, a computerized feeding system, three or more times daily milking, the Internet for dairy information, and a computer for managing dairy records. It is acknowledged that some of these technologies could be applied differently in conventional versus pasture-based systems; however, our intention was to control for the general technological advancement of these farms using technologies that could potentially be used in either system.

Exact matches were requested for state and USDA–Economic Research Service-designated farm resource region (Heartland, Fruitful Rim, Southern Seaboard, etc.). These variables helped to ensure that the dairies were producing under similar environmental conditions such as heat, humidity, and forage type; similar economic conditions such as milk and input prices; and similar farm typology, i.e., crop and livestock mixes. Although a state-only designation would likely have been sufficient for many cases, many states include multiple resource regions where climate and forage conditions differ. There are 82 state $\times$ farm resource region combinations in the 48 contiguous United States. These combinations have generally similar climates, soil types, and farm crop/livestock mixes.

Results

Table 1 provides population estimates of dairy farms included in the 2010 ARMS data, dairy version, by production system. These weighted estimates include all 1915 observations in the data, not just the subsample that was pulled for the matching analysis, enabling us to analyze differences in farm characteristics by production system. For comparison purposes, in addition to conventional and pasture-based systems, we also show estimates for semipasture-based operations, where >0% and <50% of a cow's forage needs are received from pasture during the grazing season and organic operations. Estimates show that, in 2010, 38%, 37%, 16%, and 9% of U.S. dairy farms were nonorganic conventional, nonorganic semipasture-based, nonorganic pasture-based, and organic, respectively. However, because conventional farms were larger scale and produced more milk per cow, the percentages of the value of U.S. milk production represented by each system were 73%, 17%, 6%, and 5%, respectively. Although 561 dairy farms in the sample were pasture-based, only 207 of those were nonorganic and were thus used in our matching analysis. Operator age and education differed by production system with nonorganic conventional farmers more likely to hold college degrees and to be older than nonorganic semipasture-based farmers. Farm size and number of technologies adopted differed, with nonorganic conventional operations being larger scale and more technology/advanced management practice-intensive than the others. These differences underscore the importance of matching farms that are of similar size and technology use if the objective is to isolate the impact of production system.

There were no significant differences among the systems in terms of farm income diversification, measured as the percentage of farm income from the dairy enterprise. Milk prices were lowest for nonorganic conventional operations. As expected, milk production per cow was highest for nonorganic conventional followed by nonorganic semipasture-based, and finally nonorganic pasture-based and organic. This is consistent with other studies such as Gillespie et al. (2009).

Table 1. Measures for Pasture-Based, Semipasture-Based, and Conventional Dairy Farms, Agricultural Resource Management Survey Data, Dairy Survey, 2010

Measure	Nonorganic Conventional Farm Means A	Nonorganic Semipasture-based Farms Means, B	Nonorganic Pasture-based Farms Means, C	Organic Farm Means D
Sample characteristics				
Number of observations	545	432	207	580
Percent of farms represented	37.8	36.5	16.3	9.4
Percent of value of production represented	72.6	17.0	5.9	4.5
Means of variables used for sample selection				
Operator age (years)	52.1^{B}	49.7^{A}	50.4	49.3
Portion of operators holding college degrees	0.14^{B}	0.09^{A}	0.13	0.14
Number of milk cows	317.6^{BCD}	87.1^{A}	74.8^{A}	98.6^{A}
Total farm acres	545.3^{BC}	333.9^{A}	317.1^{A}	381.6
No. of technologies adopted	7.5^{BCD}	5.3^{AC}	4.5^{AB}	4.4^{A}
Means of additional variables of interest				
Percent of farm income from the dairy enterprise	89.3	88.6	89.6	90.0
Milk price, per cwt	17.34^{BCD}	19.22^{AD}	19.72^{AD}	28.17^{ABC}
Milk produced per cow (lbs)	$22{,}123.7^{BCD}$	$17{,}503.7^{ACD}$	$15{,}721.9^{AB}$	$13{,}598.2^{AB}$
Means of cost and return estimates				
Gross value of milk production	$1{,}218{,}328^{BCD}$	$292{,}974^{A}$	$231{,}727^{A}$	$377{,}852^{A}$
Total feed cost	$672{,}991^{BCD}$	$173{,}047^{AC}$	$129{,}202^{AB}$	$194{,}592^{A}$
Total operating expenses	$861{,}610^{BCD}$	$227{,}195^{AC}$	$171{,}887^{AB}$	$250{,}816^{A}$
Allocated expenses	$414{,}489^{BCD}$	$190{,}366^{AC}$	$161{,}816^{AB}$	$224{,}360^{A}$
Total expenses	$1{,}276{,}099^{BCD}$	$417{,}561^{AC}$	$333{,}703^{AB}$	$475{,}176^{A}$
Total farm income	$1{,}376{,}677^{BCD}$	$333{,}263^{AC}$	$256{,}022^{AB}$	$408{,}714^{A}$
Total farm expenses	$1{,}112{,}935^{BCD}$	$275{,}253^{AC}$	$215{,}136^{AB}$	$336{,}779^{A}$

Note: Conventional, semipasture-based, and pasture-based farms refer to farms where cows receive 0%, 1–49%, and ≥50%, respectively, of forage requirements from pasture during the grazing season. Superscripts denote significant differences at the 0.10 level. Within rows, superscripts indicate column entries that differ from the reference entry at the $P \leq 0.10$ level. For example, the mean operator age for nonorganic conventional farms differs from the mean operator age for nonorganic semipasture-based farms, represented by Column B, at the $P \leq 0.10$ level.

Table 2. Means of Measures for Pasture-Based and Matched Conventional Farms, Unweighted

Measure	Pasture-Based Mean	Conventional Mean
Means of matching variables		
Operator age	51.92	52.87
Operator holds college degree (dummy)	0.15	0.13
Number of milk cows	131.39	148.51
Total farm acres	426.79	380.43
Number of technologies adopted	4.55	5.36
Distribution of samples among exact match variables: percentages by category		
Basin and Range and Prairie Gateway	6	8
Eastern Uplands	20	19
Fruitful Rim	17	15
Heartland	16	16
Northern Crescent	35	35
Southern Seaboard	7	8
Size: ≤100 cows	70	70
Size: 101–250 cows	21	21
Size: 251–500 cows	5	5
Size: >500 cows	4	4
Observations	207	207

Note: These data represent subsets of the Agricultural Resource Management Survey data, not the full population. The pasture-based sample includes all nonorganic pasture-based observations shown in Table 1. The conventional sample includes all observations that were matched to the nonorganic pasture-based group and is thus a subsample of the conventional observations shown in Table 1.

Unweighted[1] means of matching variables for nonorganic pasture-based farms and their matched conventional farms are provided in Table 2. Means suggest that matched conventional producers were slightly older, slightly less likely to hold a college degree, milked approximately 13% more cows but operated approximately 11% fewer acres, and were more prone to adopt technology. Of the variables where exact matches were requested (state, region, and size category), 95.7% of the matches were exact with percentages in the region and size categories for both samples shown in Table 2. For the nine matches that were not exact, state or region were the variables for which an exact match could not be found. These unweighted sample comparisons illustrate the challenges associated with identifying "perfect" matching samples. In cases in which we tightened the cow number intervals for exact matches, the percentage of exact matches decreased as not only did some of the matches differ in farm size category, but farms were increasingly chosen from outside their states and regions, which in our view would be of concern as a result of differences in input (climate, land, forage, etc.) quality. Furthermore, increasing (i.e., tightening) the cow number intervals resulted in larger differences in acreage among matches. Examination of the means, however, suggests that the two samples were not greatly different, and the bias correction procedure outlined in Abadie et al. (2004) was used to adjust for selection bias that might have resulted. In other words, with the two groups having overlapping characteristics and being unconfounded, discrepancies for matching variables were corrected for using the

[1] We report unweighted means here because our objective in Table 2 is to show the results of one-to-one, equally weighted comparisons of the treatment and control samples. This allows us to truly see how the characteristics of the samples differ. Had we reported weighted means, the comparisons would have been distorted with the conventional farm sample appearing much larger scale than the pasture-based sample as a result of the larger weights associated with the larger scale conventional farms. The weighted means for the control (conventional) group would have been essentially useless because they represent merely a weighted subsample (the matched control farms) of the population of conventional farmers.

bias correction regression analysis, where match differences were handled by adjusting covariate values and estimating economic differences between the systems accordingly (Abadie et al., 2004).

Table 3 provides estimates of per cow, per cwt milk, and total economic differences between nonorganic pasture-based and matched nonorganic conventional dairy farms. In Table 3, the base system is conventional, so negative (positive) signs indicate that the measure was lower (higher) for pasture-based relative to conventional farms. Appendix Table 1 provides weighted cost and returns estimates for the pasture-based and matching conventional sample for purposes of examining the magnitude of income and costs for each of the reporting bases (per cow, per cwt milk, and total). The reader is cautioned that simply subtracting the pasture-based estimate from the conventional estimate will not result in the exact estimates provided in Table 3 because such calculations would not be bias-adjusted. The reader is also cautioned to not assume that the conventional numbers represent the conventional population; they are estimates of the matched sample, which should not be interpreted as being representative of the conventional system population. Estimates suggest that nonorganic pasture-based operations produced 2288 fewer pounds of milk per cow than did the matched conventional operations (Table 3). Lower production per cow was expected and similar in magnitude to differences found by White et al. (2002). Using 2005 ARMS data, Gillespie et al. (2009) showed an absolute difference between the systems of 3218 pounds, not controlling for farm size, use of other technologies, region, or selection criteria. The absolute difference calculated for 2010 using 2010 ARMS data is 6402 pounds (Table 1), not controlling for farm size, use of other technologies, region, or selection criteria. The price received by nonorganic pasture-based operations was \$0.60/cwt higher than that for matched conventional operations, suggesting that although the cows on conventional operations produced more milk, the value of the milk they produced was lower. Horner, Milhollin, and Prewitt (2012) explain that price premiums received for pasture-based milk may result from higher butterfat and protein components and lower somatic cell counts. This is compared with estimates calculated in Table 1 for all nonorganic conventional and pasture-based farms, \$2.38.

Total whole-farm income (including milk and all other products produced on the farm) was \$26,299 higher in total and \$503.91 higher per cow on matched conventional than pasture-based operations, whereas total whole-farm income per cwt milk was \$0.82 higher on pasture-based farms. The discrepancy is explained largely by more milk being produced on the conventional farms, but the milk produced on pasture-based operations was of higher value. Total farm expense was \$2.67/cwt higher on pasture-based than conventional farms. Net farm income was \$23,868 higher in total, \$365.83/cow higher, and \$1.85/cwt higher on matched conventional than pasture-based operations. Gillespie et al. (2009) found no differences in net farm income between systems using per-cow and per-cwt milk comparisons.

From a dairy enterprise perspective, the gross value of milk production was \$1.23/cwt milk higher but \$279.55/cow lower on pasture-based operations than on matched conventional operations. Like with the whole-farm total farm income measures, this is explained by the lower level of milk production but higher price of milk produced on pasture-based operations.

Enterprise feed costs differed depending on feed type. Cost of purchased feed per cwt milk was higher for pasture-based operations, whereas harvested feed costs were lower for pasture-based operations using all three measures. These results suggest that, relative to matched conventional farms, pasture-based farms rely more heavily on purchased than harvested feed. The cost of grazed feed was higher for pasture-based operations using all three measures. Overall, matched conventional operations harvested more feed and delivered it to the cows, whereas pasture-based farmers allowed cows to graze for feed. Total feed cost was lower on pasture-based operations on both per-cow and total expense bases.

Several other operating costs differed by treatment. Veterinary and medical costs and bedding and litter costs were lower on per-cow

Table 3. Estimates of Economic Differences in Pasture-based and Conventional Milk Production Using Matching Samples, Weighted

Measure	Estimate per Cow	Standard Error per Cow	Estimate per cwt	Standard Error per cwt	Estimate Total	Standard Error Total
Whole farm income and expenses						
Total farm income	–503.91***	121.81	0.82*	0.44	–26,299**	11,564
Total farm expense	–138.08	99.32	2.67***	0.49	–2,431	9,684
Net farm income	–365.83***	86.41	–1.85***	0.46	–23,868***	6,802
Dairy enterprise income and expenses						
Gross value of milk production	–279.55***	63.88	1.23***	0.19	–4,449	8,865
Cost of purchased feed	19.26	36.65	0.94***	0.22	6,039	4,099
Cost of grazed feed	101.24***	2.07	0.85***	0.02	5,189***	139
Cost of harvested feed	–567.54***	79.91	–2.11***	0.47	–36,294***	5,280
Cost of total feed	–447.05***	89.20	–0.31	0.53	–25,066***	7,087
Cost of veterinarian and medicine	–13.96**	7.01	0.04	0.04	65	603
Cost of bedding and litter	–13.31*	8.08	–0.02	0.04	–674	661
Cost of marketing	–2.85*	1.62	0.03**	0.01	–381	272
Cost of custom hire	0.90	6.49	0.12**	0.05	687	586
Cost of fuel and lubricants	–14.65	9.15	0.09*	0.05	–620	549
Cost of repairs	–37.02**	16.90	–0.07	0.10	–4152***	1,177
Cost of operating capital	–0.53***	0.10	–0.00	0.00	–30***	8
Total operating expenses	–528.48***	101.96	–0.12	0.60	–30,171***	8,294
Cost of paid labor	–12.41	16.82	0.02	0.09	3,976**	1,636
Cost of unpaid labor	369.42***	80.33	5.02***	0.49	–8,222**	3,705
Cost of capital recovery	24.20	47.61	1.72***	0.29	–3,642	4,230
Cost of land	1.86	1.37	0.04***	0.01	–318***	82
Cost of taxes and insurance	7.05**	3.23	0.12***	0.02	–26	244
Cost of overhead	–24.83***	8.94	0.06	0.05	–2,173**	858
Total allocated expenses	365.30***	105.06	6.97***	0.65	–10,406	7,495
Total expenses	–163.17	150.51	6.85***	0.99	–40,577***	12,873
Net return over operating cost	248.93*	126.13	1.36**	0.64	25,722***	8,705
Net return over total cost	–116.37	161.97	–5.62***	1.01	36,128***	10,217
Productivity and milk price measures						
Milk produced per cow per year (lbs)					–2,288***	298
Milk price per hundredweight					0.60***	0.16

Note: Estimates represent differences in the measure of interest for the pasture-based system relative to the conventional system. ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels, respectively.

bases on pasture-based operations. Marketing costs for milk were $0.03/cwt milk higher but $2.85/cow lower on pasture-based operations, the discrepancy the result of the lower amount of milk produced per cow on pasture-based operations. On per-cwt milk bases, costs of custom operations and of fuel and lubricants were higher for pasture-based operations. Total repair costs were lower in total and per cow on pasture-based operations, primarily because of lower milk production per cow and lower capacity machinery being required. Likewise, the cost of operating capital was lower in total and per cow on pasture-based operations. Overall, total operating expense was $30,171 in total and $528.48/cow lower on pasture-based operations.

Allocated costs included those for paid labor, unpaid labor, capital recovery, land, taxes and insurance, and overhead. Pasture-based operations incurred greater total hired labor costs. The cost of unpaid labor was $8222 lower in total on pasture-based operations but $5.02/cwt milk and $369.42/cow higher on these operations. The discrepancy is the result of less milk being produced on the pasture-based operations and the fact that unpaid labor was a major expense, averaging $79,857 across all operations in the sample. This suggests less labor being performed by family members on pasture-based operations but more on a per-unit basis, likely for pasture management and gathering animals for milking.

Capital recovery costs were $1.72/cwt milk higher for pasture-based operations, reflective of the lower amount of milk produced per cow on those operations. Land costs were lower on pasture-based operations but higher on a per-cwt milk basis given the lower milk production of these operations. The cost of taxes and insurance was $0.12/cwt milk and $7.05/cow higher on pasture-based operations, reflective of higher capital recovery costs. The cost of overhead, however, was $2174 in total and $24.83/cow lower on pasture-based operations. Overall, allocated costs for pasture-based operations were $6.97/cwt and $365.30/cow higher than for matched conventional operations.

Total expenses were $40,577 lower but $6.85/cwt milk higher on pasture-based operations than on matched conventional operations, the discrepancy because of the lower milk production per cow on pasture-based operations. Because of higher gross value of milk production and lower operating expenses on pasture-based operations, net return over operating cost was $25,722 in total, $1.36/cwt milk, and $248.93/cow higher on pasture-based operations. Net return over total cost was $36,127.93 higher on pasture-based than matched conventional operations. On a per-cwt milk basis, however, net return over total cost was $5.62/cwt milk lower, the discrepancy the result of the lower milk productivity per cow.

Discussion and Conclusions

Pasture-based dairy farms have continued to produce milk alongside conventional farms in the face of increased confinement, use of total mixed rations, and overall tighter control of dairy production systems. Despite lower milk productivity per cow, pasture-based farms have lower total production costs, so they have remained competitive with similar-sized conventional farms. Limited work, however, has examined the competitiveness of pasture-based operations on a national basis, and limited work has compared the specific cost components that allow pasture-based operations to remain competitive. Identifying the areas where pasture-based costs are higher than those of conventional systems can provide insights into how pasture-based farms can become more competitive.

On the revenue side, total farm income and total farm income per cow were lower for pasture-based operations, whereas per-cwt milk income measures were higher for pasture-based operations. These numbers were expected given the higher price received for milk produced from pasture-based operations and the lower amount of milk produced on pasture-based operations. Dairy enterprise gross value of milk production numbers were generally consistent with the whole farm numbers with pasture-based operations yielding lower returns per cow and higher returns per cwt milk. It is, however, worthwhile to note that although total farm income (whole-farm) is much lower ($26,299) for pasture-based operations, when examining from an enterprise basis, the nominal difference is much smaller and nonsignificant. We believe this is because of greater sales of other farm products on conventional farms. To test, we compared the value of other farm products (other than milk) sold using matching analysis. Although the nominal difference in the value of other farm products sold was quite large with the sign pointing toward greater sales of other products on conventional farms, it was not significant at the $P \leq 0.10$ level, providing insufficient evidence to conclude a difference. Note, however, that the nominal difference would nonetheless impact total farm income. Greater sales of other products on conventional farms would be consistent with our finding of no differences in the percentage of farm income from the dairy enterprise between the two systems coupled with conventional systems producing more milk per cow (but at a lower price), as shown in Table 1.

As expected, feed cost varies significantly between the two systems. The cost of grazed feed is higher for pasture-based operations, whereas the cost of harvested feed is lower. On a per-cwt milk basis, total feed costs did not differ, but on total cost and per-cow bases, feed costs were lower for pasture-based operations. From examining harvested and purchased feed costs, it is evident that the relative competitiveness of these systems on the basis of feed costs can change with feedgrain prices. In 2010, the year data for this study were collected, average monthly corn prices ranged from \$3.41 in April to \$4.82 in December but have increased since, from a low of \$4.94 in January 2011 to \$7.63 in August 2012 (USDA–National Agricultural Statistics Service, 2013). Likewise, other feedgrain prices have also increased since 2010, suggesting increased competitiveness for pasture-based production. Milk prices, on the other hand, must also be considered, because higher recent milk prices would favor conventional production. Although marketing, custom hire, and fuel and lubricant costs were higher per-cwt milk, total operating expenses were \$30,171 lower and total operating expenses per cow were \$528.48 lower for pasture-based operations.

Although operating costs were lower for pasture-based farms, allocated costs were higher on both per-cwt milk and per-cow bases. The largest contributor to higher allocated costs was unpaid labor, which is an opportunity cost, so from an accountant's perspective, it would not be considered. It is, however, of importance because it provides an estimate of what (mostly) family members could be earning if they were not working on the dairy farm. The increased costs of \$5.02/cwt milk and \$369.42/cow for labor on pasture-based relative to conventional operations suggest that the competitiveness of pasture-based systems is largely a function of increased labor being conducted by family members without charge. Other allocated costs such as those for capital recovery, land, taxes and insurance, and overhead were also higher for pasture-based farms on either or both of per-cwt milk and per-cow bases (although lower in total). In total, allocated costs were higher per cwt milk and per cow on pasture-based operations.

Differences in whole-farm expenses generally lead to similar conclusions as those for the enterprise with higher expenses for pasture-based farms per cwt milk produced and nominally lower expenses per cow and in total. What is striking, however, is the magnitude of the difference in total expenses on an enterprise basis, \$40,577 lower for pasture-based systems, whereas the difference is quite small and nonsignificant on a whole-farm basis. We attribute this discrepancy primarily to differences in how several items are calculated using whole-farm and enterprise measures. We used matching analysis to test whether depreciation and interest differed between the two systems on a whole-farm basis and found higher measures for both for pasture-based production. This differs from the cost of capital recovery result for the enterprise basis, which provided an opposite (negative) sign but was nonsignificant. The whole-farm measure did not include unpaid labor, which was \$8222 lower on an enterprise basis for pasture-based operations. Finally, the cost of harvested feed was \$36,294 lower for pasture-based farms on an enterprise basis but was priced at its market value rather than its cost of production.

On an enterprise basis, net return over operating cost was \$25,722 in total, \$1.36/cwt milk, and $248.93/cow higher on pasture-based farms. Although net return over total cost was $36,128 higher on pasture-based farms, it was $5.62/cwt milk higher on conventional farms, attributable primarily to the greater unpaid labor cost on pasture-based farms. On a whole-farm basis, net farm income was lower on pasture-based farms than on conventional farms using all three measures. We attribute the differences in results for net farm income and enterprise net return over total cost primarily to four things as discussed earlier: 1) greater revenue from other farm enterprises on conventional operations, reflected in the whole-farm measure; 2) greater expense for unpaid labor on a total basis on conventional operations, reflected in the enterprise measure; 3) greater depreciation and interest on pasture-based operations in the whole-farm analysis; and 4) differences in the way harvested feed was valued.

Overall, whether pasture-based or conventional farms of similar size and structure are more profitable depends on how profit is measured: from a whole farm, enterprise, return over operating cost, per cwt milk produced, per cow, or total basis. In sum, our study confirms what previous studies have found, that pasture-based dairy operations are generally competitive with conventional operations of similar size and structure but with the additional caveats that region, general level of technological use, and demographic variables that might cause selection bias are held constant. Contrasting our study with that of Gillespie et al. (2009), our study finds differences in profitability with the most profitable system depending on whether whole-farm, enterprise, per-cow, per-cwt, or total measures were used. In their case using 2005 data, no significant differences were found for any of the measures.

Overall, results of this study suggest that the relative competitiveness of pasture-based versus conventional farms depends on which measure of profit is considered holding farm size constant. It should be noted, however, that the pasture-based dairy farm faces constraints in expanding, because these farms are land-intensive and the distance an animal can travel from the pasture to the parlor for milking is limited. This distinction is evident from results in Table 2, where conventional farms are much bigger and, thus, from a dairy population basis, lower cost and higher profit than pasture-based dairy farms.

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Appendix Table 1. Weighted Income and Expense Estimates for Pasture-based Farms (207 Observations) and Matched Conventional Farms (207 observations)

Measure	Estimate per Cow, Pasture-Based	Estimate per Cow, Conventional	Estimate per cwt, Pasture-Based	Estimate per cwt, Conventional	Estimate Total, Pasture-Based	Estimate Total, Conventional
Whole farm income and expenses						
Total farm income	3,395.74	3,992.88	23.99	22.79	255,573	400,643
Total farm expense	2,747.39	3,029.86	19.94	17.44	214,710	319,261
Net farm income	648.34	963.02	4.05	5.35	40,864	81,382
Dairy enterprise income and expenses						
Gross value of milk production	2,844.44	3,269.89	19.63	18.43	231,160	347,760
Cost of purchased feed	819.25	899.15	5.78	5.17	73,348	113,861
Cost of grazed feed	107.75	9.48	0.91	0.09	5,677	672
Cost of harvested feed	697.99	1,193.97	5.33	6.87	49,849	99,746
Cost of total feed	1,624.98	2,102.60	12.02	12.13	128,874	214,280
Cost of veterinarian and medicine	100.74	125.08	0.69	0.68	9,364	14,843
Cost of bedding and litter	52.15	73.90	0.34	0.39	3,958	7,526
Cost of marketing	28.46	35.01	0.21	0.20	2,471	4,660
Cost of custom hire	95.99	97.51	0.68	0.55	7,942	9,841
Cost of fuel and lubricants	147.10	164.08	1.10	0.97	10,550	14,152
Cost of repairs	120.61	166.42	0.85	0.95	8,150	16,090
Cost of operating capital	2.17	2.76	0.02	0.02	171	281
Total operating expenses	2,172.20	2,767.36	15.92	15.89	171,480	281,672
Cost of paid labor	93.03	121.28	0.64	0.68	14,271	17,297
Cost of unpaid labor	1,909.16	1,411.20	14.78	8.78	76,405	83,310
Cost of capital recovery	976.36	945.47	7.57	5.68	58,838	76,116
Cost of land	21.80	16.64	0.19	0.12	879	984
Cost of taxes and insurance	52.56	46.23	0.40	0.29	3,345	3,975
Cost of overhead	121.85	146.40	0.90	0.82	7,902	13,746
Total allocated expenses	3,174.76	2,687.23	24.47	16.36	161,641	195,428
Total expenses	5,346.96	5,454.59	40.39	32.25	333,121	477,100
Net return over operating cost	672.24	502.52	3.72	2.54	59,680	66,088
Net return over total cost	–2,502.51	–2,184.71	–20.76	–13.82	–101,961	–129,341

Note: Conventional estimates are means of the matched sample and should not be interpreted as conventional system population estimates.