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Labor-use efficiency and New York dairy farm financial performance

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Abstract

Purpose – Dairy farms, along with livestock and specialty crop farms, face a tight labor supply and increasing labor costs. To overcome the challenging labor market, farm managers can increase labor-use efficiency through both human resource and capital investments. However, little is known about the relationship between such investments and farm profitability. The purpose of this paper is to examine the relationship between dairy farm financial performance and labor-use efficiency, as measured by labor productivity (milk sold per worker equivalent); labor costs (hired labor cost per unit of milk sold and hired labor cost per worker); and investment in labor-saving equipment.

Design/methodology/approach – Cluster analysis is applied to partition dairy farms into three performance categories (high/middle/low), based on farms' rate of return on equity, asset turnover ratios and net dairy income per hundredweight of milk. Next, the annual financial rank is fitted into both random- and farm-level fixed-effects ordered logit and linear models to estimate the relationship between dairy farms' financial performance and labor-use efficiency. This study also investigates the implications of using a single financial indicator as a measure of financial performance, which is the dominant approach in literature.

Findings – The study finds that greater labor productivity and cost efficiency (as measured by hired labor cost per unit of milk sold) are associated with better farm financial performance. No statistically significant relationship is found between farm financial performance and both hired labor cost per worker and advance milking systems (a proxy of capital investment in labor-saving technology). Future studies would benefit from better measurements of labor-saving technology. This study also demonstrates inconsistency in regression results when individual financial variables are used as a measure of financial performance. The greater labor-use efficiency on high-performing farms may be a combination of hiring more-skilled workers and managerial strategies of reducing unnecessary labor activities. The results emphasize the importance of managerial strategies that improve overall labor-use efficiency, instead of simply minimizing total labor expenses or labor cost per worker.

Originality/value – This study examines the importance of labor productivity and labor cost efficiency for dairy farm management. It also develops a novel approach which brings a more comprehensive financial performance evaluation into regression models. Furthermore, this study explicitly demonstrates the potential for inconsistent results when using individual financial variable as a measure of financial performance, which is the dominant measurement of financial performance in farm management studies.

Keywords Labour productivity, Farm financial performance, Labour performance

Paper type Research paper

Introduction

Along with other agricultural sectors, US dairy farms are facing challenges to maintain a sufficient and qualified labor force (Hertz and Zahniser, 2013; Ifft and Grout, 2017; Karszes, 2017; Maloney and Eiholzer, 2017; Richards, 2018; Zahniser *et al.*, 2018). The substantial structural changes to the US dairy industry including farm consolidation and expansion

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further increase dairy farms' dependent on hired labor. Maloney and Eiholzer (2017) showed that 11 out of 12 participating dairy farm managers are either concerned or very concerned with finding qualified workers in the future. Dairy farm managers have to raise wages or provide better benefits to keep qualified labor workers (Maloney and Eiholzer, 2017), and hired labor has become the second largest production expense after feed (Karszes, 2017). With the tightening farm labor market, increasing labor costs and potential changes in immigration policy, labor is becoming a crucial management challenge for dairy farms.

In this situation, labor management strategies and technological innovations that improve labor productivity and efficiency may play an important role in adaptation to tightening labor markets and rising labor costs. Dairy farm managers can choose to hire expensive skilled workers to improve labor productivity, or invest capital in equipment and technology to substitute labor inputs, as has been widely adopted in crop production (Karszes, 2017). However, very few, if any, studies have investigated the impact of these strategies on dairy farms' financial performance. To fill in the gap, this study employs farm-level unbalanced panel data to provide novel evidence on the relationship between dairy farms' financial performance and labor cost and productivity, as well as financial performance and capital investment in labor-saving equipment.

Although many studies have used farm financial performance as a dependent variable in regression models to evaluate the relationship between financial performance and managerial factors, a single financial variable is typically employed as a measure of financial performance. A single measure only provides incomplete information for regression models. Thus, conclusions from those regression models could be biased. Multiple financial variables can provide a more comprehensive financial assessment, but it is difficult for a regression model to incorporate multiple variables as a dependent variable. Although various financial variables could be treated as dependent variables in seemingly unrelated regression (SUR) equations and the estimates would be more efficient estimation of standard errors than OLS, regression results would not change. Furthermore, results may not provide a clear interpretation of the relationship between a specific managerial factor and farm overall financial performance, as the estimated coefficient of a specific farm characteristic could be positive in one equation, but negative in other equations. To address the above problems, cluster analysis is applied on multiple financial variables in the first stage to partition NY dairy farms into three financial performance ranks (low/middle/high). Thus, farms in the same rank are more similar to each other than to those in other ranks, and the ranks provide a more robust financial performance evaluation as they are generated based on more comprehensive financial information, in contrast to using an individual financial variable in the majority of farm financial studies. Next, the ordered financial performance rank is the dependent variable in regression models to estimate the relationship between dairy farm financial performance and labor-use efficiency. Information from this analysis with micro-level unbalanced panel data, together with a novel approach to measuring financial performance, provides dairy farm managers with important insights into labor management and capital investments in labor-saving equipment.

The following section describes the data characteristics. We then present the conceptual framework of this analysis, with a brief literature review to illustrate the contributions of this study. Next, financial performance ranks and regression results are presented. Regression results based on the financial performance rank are also compared with results from the traditional approach which applies a single financial variable to measure farms' financial performance. Conclusions are summarized in the end.

Data

This study employs a longitudinal data set from the New York Dairy Farm Business Summary program maintained by Cornell University. Since 1993, the survey is carried out every year among participating dairy farms to collect data regarding farm production and financial characteristics. To better control the farm-level heterogeneity, dairy farms with at least five years participation construct a panel data set for this study. The longitudinal data set contains more than 300 dairy farms and 3,000 observations from 1993 through 2016.

Table I shows a list of independent variables used in this analysis. One worker equivalent is defined as 2,760 h a year. Labor productivity is measured by 1,000 cwt[1] of milk sold per worker equivalent. Labor cost efficiency is quantified as hired labor costs per unit of milk sold. Milking systems are used as proxies of capital investment in labor-saving equipment considering that advanced milking systems may reduce labor cost as they can work with more cows (Short, 2000)[2]. Variables such as herd size, feed costs and dairy housing type are also incorporated into regression models as control variables. Following Gloy *et al.* (2002) and Mishra *et al.* (2009), milk prices are not incorporated in the regression models, under the assumption that NY dairy farms are facing similar annual milk prices in a competitive market.

Three financial variables are used in the cluster analysis to evaluate farms' financial performance from different aspect: net dairy income (NDI) per cwt of milk sold, rate of return on equity (ROE) and asset turnover ratios (ATR). More details of each variable are discussed in the following section. In order to compare with previous studies, we follow the convention in the literature and use net farm income (NFI), ROE and ATR to measure farm financial performance and take each of them as a dependent variable.

Conceptual model

Following previous studies, the objective of a dairy farm manager is profit maximization with production constraints (e.g. El-Osta and Johnson, 1998; Mishra and Morehart, 2001; Gloy *et al.*, 2002; Mishra *et al.*, 2009). Specifically:

$$\max \pi = \sum P_i Q_i(\cdot) - \sum C_j(\cdot), \tag{1}$$

where π is the overall profit of farm management. P_i is the price of output i and $Q_i(\cdot)$ is the corresponding production function, and $C_j(\cdot)$is the cost function.

Based on Equation (1), financial performance is hypothesized to be a function of farm- and market-specific characteristics:

$$\text{FP} = \beta \text{X} + \varepsilon, \tag{2}$$

Table I.
List of independent variables used in regressions

Categories	Variables	Description
Labor productivity	Milk sold per worker equivalent (1,000 cwt)	One worker equivalent is defined as 2,760 h a year
Labor cost efficiency	Hired labor cost per unit of milk sold (cwt)	
Labor wage	Hired labor cost per worker equivalent	
Capital investment in labor-saving	Milking systems (labor-saving)	Advanced vs basic milking systems
Herd size	Average number of cows	
Cost control	Forage acres per cow	
	Purchased feed and crop expense per cwt	
Other control variables	Farm ownership	Owned vs rented
	Dairy housing	Stanchion/tie-stall, freestall, and combination
	Tillable acreage	

where FP denotes farms' financial performance, X is a vector of farm characteristics, and ε is the error term. Equation (2) has been estimated in a large number of studies in farm management with various measures of financial performance. These studies can be grouped into three categories. Analyses of farm management in the first group of studies relied on one measure of financial performance. For example, NFI was used in Lins *et al.* (1987) and Ford and Shonkwiler (1994); return on assets (ROA) was used in Haden and Johnson (1989), Gloy *et al.* (2002), Mishra *et al.* (2009, 2012); returns to operators' labor and management was used in Mishra and Morehart (2001); modified NFI per dollar of assets was used in Mishra *et al.* (1999) to measure farms' financial performance.

In the second group, alternative measures of financial performance were regressed with a series of covariates to estimate the relationship between managerial factors and farm financial performance. For instance, Haden and Johnson (1989) tried cash income, net income and returns to operator labor and management as measures of dairy farms' financial performance, and each of the three variables was treated as a dependent variable in an ordinary least square model. Both NFI and net returns per unit (NRU) of milk sold were used as measures of financial performance in El-Osta and Johnson (1998), and performed as dependent variables in regression models. Similarly, Detre *et al.* (2011) used NFI and ROA as measures of financial performance and fitted them independently in regression. A derivative work is Mishra *et al.* (2012) which applied the idea of DuPont expansion and used net profit margins, ATR and total assets to net worth ratios in SUR models to identify factors influencing agricultural profitability.

Studies in the third group generated performance categories based on multiple financial performance measures prior to treating financial performance as a dependent variable in regression. Kauffman and Tauer (1986) applied four measures to categorize dairy farms as successful and less successful groups using stochastic dominance analysis. Next, this dichotomous variable was fitted into a logit regression model to identify the associated managerial performance using a panel of dairy farms.

The first two groups account for the vast majority of the studies in farm financial management, but very few of them discussed the appropriateness of the approach despite the important role of financial performance in research. The problem with one measure of financial performance is that the dependent variable may only carry incomplete information into the regression system. For example, NFI indicates a farm's profitability but it does not consider the farm's financial efficiency of using its assets in generating revenue. Dairy farms with large capital investment may receive high NFI and also carry high opportunity costs. Thus, farms' financial performance evaluated only through one variable does not provide comprehensive information into regression. Kirby (2005) stated "figuring out who stands tallest is far from straight forward: it depends upon which yardstick you use." If a biased "yardstick" is used as a dependent variable, analysis from regression results are doubtable. Even more concerning is that, not only in farm management, this is a general issue in management studies. Richard *et al.* (2009) pointed out that "In contrast to the dominant role that organizational performance plays in management fields is the limited attention paid by researchers to what performance is and how it is measured."

In traditional financial evaluation, multiple financial ratios are jointly employed to provide a comprehensive evaluation of firms' financial performance. However, a regression model can only take one variable as a dependent variable for quantitative analysis. Although several variables can be applied as dependent variables in the SUR system and the generalized least squares can improve the estimation efficiency, the SUR method may not provide a consistent interpretation between financial performance and farm managerial objectives, as different dependent variables are used in the model to measure financial performance from different aspects. For example, Mishra *et al.* (2012) found that comparing with small farms, medium-sized farms are negatively associated with net profit margin, positively associated with asset-to-equity ratio, and no significant impact on ATR. True financial performance is unobserved, but reflected in several financial performance metrics. Unless a composite measure is used, researchers and managers may be unable to conclude general, robust relationships between critical farm management objectives and financial performance.

To address this problem, we use cluster analysis to create three groupings based on three financial variables, and rank the three groupings as low-, middle- and high-financial performance. The ordered financial performance rank is then used as the dependent variable in ordered logit models. The financial rank provides a more comprehensive assessment compared with previous studies which use one financial variable.

Farm financial performance rank

To generate the financial ranks described above, we can take advantage of the K-means algorithm in cluster analysis. K-means cluster is an algorithm of unsupervised learning, and it iteratively assigns each firm to three groups based on the selected financial attributes to minimize the within-cluster sum of squares of distances. Thus, the objective of the K-means algorithm is:

$$\arg\min_{f_i} \sum_{j=1}^{3} \sum_{i=1} (c_i - f_i)^2, \tag{3}$$

where c_i indicates the centroid of cluster k, and f_i is the location of dairy firm i in the coordinate system. The term $\sum_{i=1}(c_i - f_i)^2$ calculates the sum of squared differences between the centroid and each firm i in cluster j. Therefore, the results of the K-means algorithms partition dairy farms into three clusters, and farms in the same cluster are more similar to each other than to those in other clusters.

Similar to DuPont expansion (Mishra *et al.*, 2012), three financial variables are used to rank dairy farms' financial performance: NDI per cwt of milk sold, rate of ROE and ATR. The three variables measure farms' performance from different aspects. NDI is calculated based on milk receipts and total costs of producing milk per cwt, which directly shows the net profit of producing each unit of milk:

$$\text{NDI} = \text{Milk receipts per cwt} - \text{Total cost of producing milk per cwt.} \tag{4}$$

The ROE is the ratio of net return to farm equity capital, and is constructed as:

$$\text{ROE}_{it} = \frac{\text{NFI}_{it} - \text{Labor}_{it} - \text{Management}_{it}}{\text{Equity}_{it}}, \tag{5}$$

where NFI_{it} indicates net farm income of firm i in year t, Labor_{it} is unpaid family labor, Management_{it} is the value of the operator's labor and management. The numerator calculates the NFI after labor and management costs. The denominator Equity_{it} is the farm i's average equity in year t. Thus, ROE reveals a dairy farm's overall profitability by evaluating the profit generated by the farm' equity. ATR is an indicator of dairy farms' capital efficiency by examining dairy farms' ability to use total assets to generate revenues. ATR is constructed as the ratio of total farm income to total farm assets:

$$\text{ATR}_{it} = \frac{\text{Rev}_{it}}{\text{Assets}_{it}}, \tag{6}$$

where Rev_{it} is dairy farm i's revenue in year t, Assets_{it} is farm i's total assets, which is the sum of farm equity and liability. Generally, a higher ATR indicates that the dairy farm uses its assets more efficiently.

Thus, the three financial variables evaluate dairy farms from three different dimensions: NDI captures dairy farms direct net income per unit of milk sold, ROE evaluates the farm's overall profitability of using owners' equity and ATR examines the farm's ability of converting assets to revenue. Compared to previous studies which used a sole financial variable as a measure of farms' financial performance, the three-dimensional strategy will provide a more comprehensive assessment.

The K-means algorithm clusters individual farms based on disparities among farms, and disparities are measured by distances in the three-dimensional coordinate system in this study. Thus, outliers and scales can have a large influence on clustering results (Ketchen and Shook, 1996). To remove outliers, we loop through each year and dairy farm i is treated as an outlier if the distance between farm i's feature j and the mean of feature j is greater than four standard deviation of feature j:

$$\text{outlier}_i \text{ if } \left\| f_{i,j} - \overline{f_j} \right\| > 4 \cdot \sigma\left(f_{i,j}\right), \tag{7}$$

where $f_{i,j}$ denotes farm i's feature j. $\overline{f_j}$ represents the mean of feature j in the corresponding year. $\|\cdot\|$ is the operator of absolute value. $\sigma(f_{i,j})$ indicates the standard deviation of feature j across all dairy farms in that year. Subscript t is omitted in Equation (7) for the sake of simplicity since this process is conducted in each year. According to the Chebyshev's inequality, the four standard deviation approach keeps observations in 94% confidence interval of each feature even if the underlying does not follow a normal distribution.

Next, to have a consistent scale, each of the three financial variables (Ratio_{jt}) is normalized to have a mean of zero and a standard deviation of one by:

$$\text{NormRatio}_{jt} = \frac{\text{Ratio}_{jt} - \mu_{j,t}}{\text{std}_{j,t}}, \quad j = 1, 2, 3, \tag{8}$$

where NormRatio_{jt} is the normalized financial ratio j in year t. $\mu_{j,t}$ represents the mean and standard deviation of the financial variable j in year t. After removing outliers and normalizing the financial variables, we loop through each year's data to cluster dairy farms into three groups using the K-means clustering algorithm.

Estimation method

Once dairy farms are grouped into three clusters in each year, the three clusters are further converted to low-, middle- and high-financial performance ranks based on the financial attributes of each cluster. Next, the single-metric financial performance rank is fitted into regression models to analyze the relationship between dairy farms' financial performance and labor-use efficiency.

The probability of a dairy farm belonging to the low-, middle- and high-performance group can be expressed as:

$$y_{it} = j \quad \text{if } \phi_{j-1} \leqslant y_{it}^* < \phi_j \quad \text{where } j = 0, 1, 2, \tag{9}$$

where y_{it} is the discrete financial performance rank generated from the cluster analysis, y_{it}^* is the latent variable of y_{it}, ϕ_j is cut points for the thresholds for each performance rank. The latent variable y_{it}^* can be estimated in econometric models as follows:

$$y_{it}^* = \beta' \text{x}_{it} + \alpha_i + \varepsilon_{it}, \tag{10}$$

where x_{it} is a vector of observed explanatory variables, and α_i is unobserved farm-specific effects and assumed to be constant across time, which is referred to as unobserved heterogeneity in the literature (e.g. Wooldridge, 2005). ε_{it} is the error term which is assumed following the logistic distribution, and $E[\varepsilon_{it}|x_{it}, \alpha_i] = 0$.

The probability of observing farm f_i belonging to rank j can be reconstructed as:

$$\Pr(y_{it} = k|x_{it}, \alpha_{it}) = \Lambda(\phi_j - \alpha_i - \beta' x_{it}) - \Lambda(\phi_{j-1} - \alpha_i - \beta' x_{it}), \tag{11}$$

where $\Lambda(\cdot)$ is the logistic cumulative distribution function. For example:

$$\Lambda(\varepsilon) = \frac{1}{1 + \exp(-\varepsilon_{it})}. \tag{12}$$

Random-effects method can be used to estimate Equation (10) to evaluate the relationship between financial performance and labor-use efficiency, under the assumption that unobserved farm-specific effects are a random shock and are uncorrelated with explanatory variables:

$$E[\alpha_i|x_{it}] = E[\alpha_i] = 0. \tag{13}$$

In this study, the random-effects ordered logit model is fitted using maximum likelihood (ML).

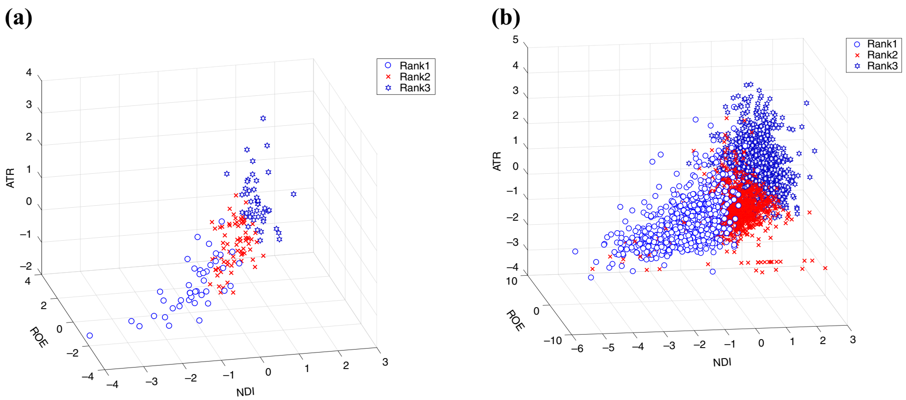
Considering that unobserved factors such as managerial strategies could have impact on dairy farms' labor productivity and cost efficiency, which is a violation of the strict exogeneity assumption of Equation (13), fixed-effects models would be more appropriate. Baetschmann *et al.* (2015) proposed a consistent estimation of fixed-effects ordered logit models by "blowing-up" the sample, and dichotomizing individuals at different cut-off points. Thus, in this study, the conditional ML estimator is applied on the "blown-up" sample, and standard errors are clustered at the individual level to fit the farm-level fixed-effects ordered logit models. Furthermore, with the assumption that ε_{it} follows the normal distribution, linear random- and fixed-effects models are also utilized in this study for robust checks, in addition to the random- and fixed-effects ordered logit models.

Results and discussion

Results of this study are comprised by three sections. The first part provides the financial performance rank generated from cluster analysis using three financial variables. The second part discusses the regression results of financial performance using the rank generated in the first stage. The third part compares the regression results estimated from the performance rank and the dominant performance measures from the literature.

Stage 1 – financial performance measurement

Dairy farm financial performance is constrained by temporal factors, such as market milk price, domestic and international demand as well as supply, weather and input prices. Thus, we loop through the data set and apply the K-means clustering algorithm on each year's normalized financial ratios to partition dairy farms to three ranks (low/middle/high). In each year, to avoid the impact of outliers on cluster analysis, a four standard deviation approach in Equation (7) is applied on NDI, ROE, rate of ROA and ATR to automatically remove observations that lie outside of the 94% confidence interval, and 2 percent of observations are removed from the data set. Once the outliers are removed from the data set, Equation (8) is applied to NDI, ROE and ATR, so that each coordinate has a mean of zero and a standard deviation of one. Next, the K-means cluster analysis is applied based on the three consistent coordinates to segment dairy farms into three groups[3]. Figure 1 shows the dairy farm's financial performance ranks in year 2016 (the top panel) and the pooled farms



Notes: (a) 2016 NY Dairy Farm Financial Performance; (b) pooled NY Dairy Farm Financial Performance (1993–2016). In both figures, the *x*-coordinate indicates normalized net milk income per cwt (NDI); the *y*-coordinate is normalized rate of return on equity (ROE); and the *z*-coordinate is normalized asset turnover ratios (ATR). The top and bottom panel shows the financial performance ranks of year 2016 and pooled farms during 1993–2016, respectively. Dairy farms in circle have the relatively low financial performance. Crosses represent farms in middle-financial performance group, and farms in star fall into the high-performance group

Figure 1. Financial performance ranks of 2016 and pooled NY dairy farms

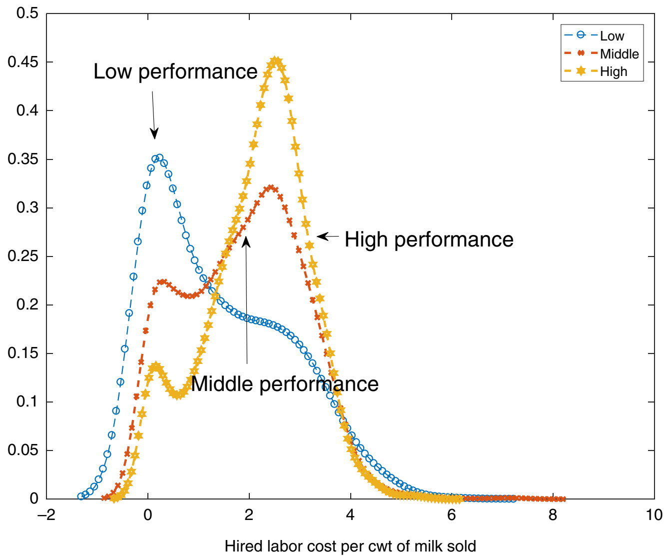
(the bottom panel) generated by the cluster analysis. Rank 1, 2 and 3 indicates the low-, middle- and high-financial performance group, respectively.

Dairy farms in star (Figure 1) have the relative best financial performance based on ROE, ATR and NDI. Farms in the same group are more similar to each other than to those in other clusters. Next, by farm financial performance, we plot out the kernel density of hired labor costs per cwt of milk sold (Figure 2) and hired labor costs (in $1,000) per worker equivalent (Figure 3) by using the panel data from 1993 through 2016[4]. The coefficient of variation of hired labor cost per cwt of milk sold is 0.95, 0.64 and 0.45 in the low-, middle- and high-performance farms, respectively. The high-performance group has the lowest variation of hired labor cost per cwt of milk sold, while the low-performance group has the highest variation.

Figure 3 shows that high-performance dairy farms spend more on hired labor per worker on average. The higher wage could be associated with high-skilled workers. The coefficient of variation of hired labor cost per worker equivalent ($1,000) is 0.76, 0.51 and 0.40 in the low-, middle- and high-performance farms, respectively. Although less successful dairy farms also hire expensive workers, Figure 3 implies that there is a wide wage range on less successful farms, while more profitable farms typically hire high-skilled workers.

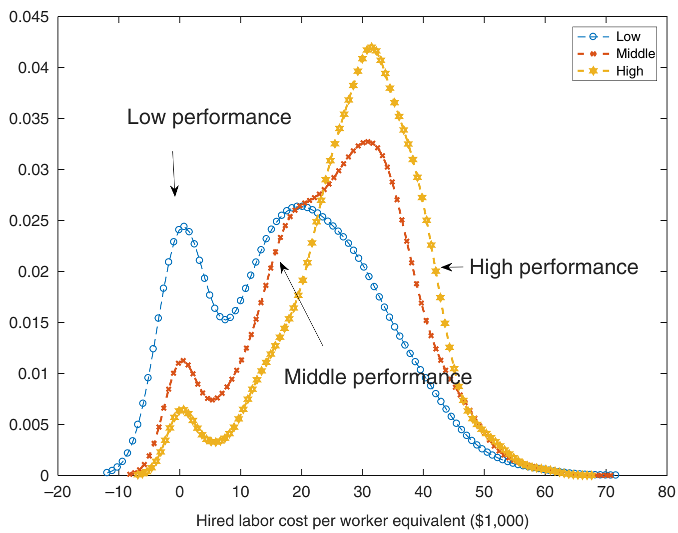
Based on Figures 2 and 3, it seems that more successful dairy farms spend more on hired labor costs per worker and per unit of milk production on average. To further investigate labor costs, we plot out hired labor costs per worker equivalent and labor costs per cwt by low- and high-performance farms with fitted lines in each year. Individual graphs of each year are presented in Figures A1 and A2, and Figure 4 uses the year 2008 (top panel) and 1993 (bottom panel) as an example to illustrate the relationship. Figure 4 implies that even with similar hired labor costs per worker equivalent, high-performance dairy farms tend to have lower hired labor costs per cwt of milk sold. This relationship holds almost for each year in the data set, except the year 2011 (see Figures A1 and A2).

Figure 5 shows the kernel density plot of labor productivity, which is measured through milk sold per worker equivalent (1,000 cwt) using the panel data from 1993 through 2016. The high-performance farms are on the right-hand side in Figure 5, which implies that they



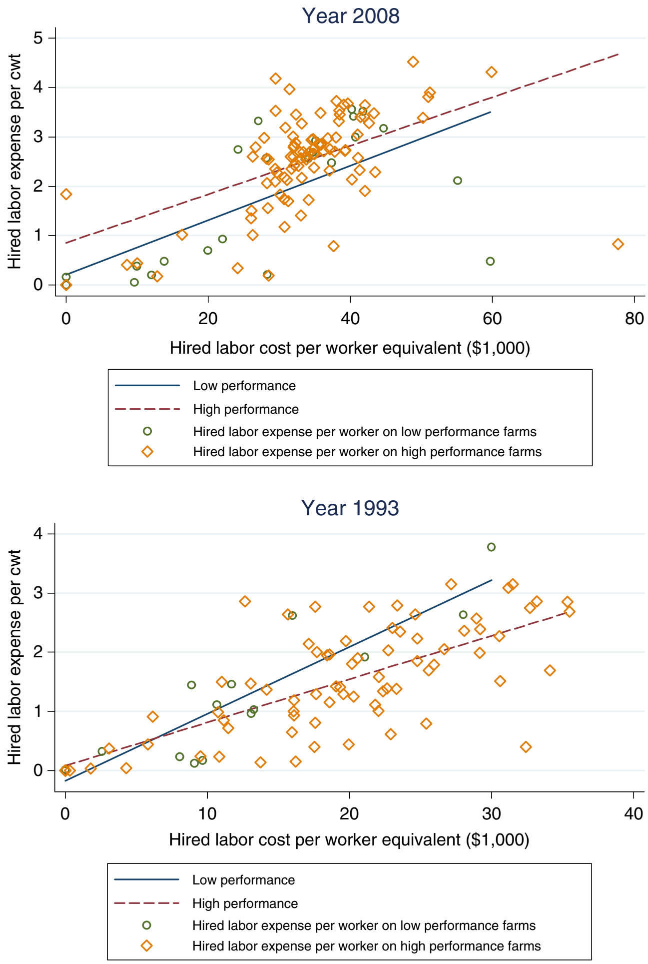
Note: The line with circles, crosses and diamond indicates the kernel density plot of hired labor costs per cwt of milk sold of the low-, middle - and high-performance group, respectively

Figure 2. Kernel density plot of hired labor costs per cwt of milk sold (1993–2016)



Notes: The line with circles, crosses and diamond indicates the kernel density plot of hired labor costs per worker equivalent of the low-, middle - and high-performance group, respectively. One worker equivalent is 2,760 h a year

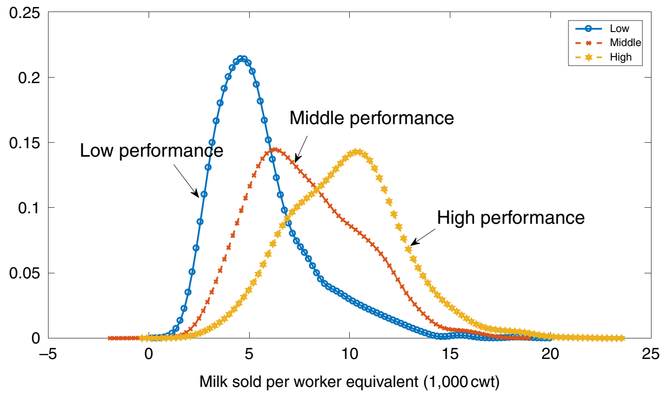
Figure 3. Kernel density plot of hired labor costs per worker equivalent (1993–2016)



Notes: Hired labor costs in year 2008 (top) and 1993 (bottom) are plotted out to illustrate the different labor costs by farm financial performance. Individual graphs of each year is shown in Appendix. The *x*-axis is hired labor costs per worker equivalent, and the *y*-axis is hired labor cost per cwt. The circle and diamond indicates low- and high-performance dairy farms in the corresponding year, respectively. The solid and dashed line is the fitted line for the low- and high-performance dairy farms, respectively

Figure 4.
Labor costs by financial performance

have the highest average labor productivity. Table II lists the summary statistics of labor productivity by financial performance. The labor productivity of each worker equivalent of high-performance farm is almost twice that of the low-performance group over time. Figure 6 plots labor cost efficiency on the *x*-axis (hired labor costs per cwt of milk sold) and labor productivity on the *y*-axis (milk sold per worker equivalent) with fitted lines by dairy farms' financial performance using data in the year 2016. The fitted lines in Figure 6 imply that labors with similar wages have a greater productivity on high-performance farms.



Notes: Figure shows the kernel density plot of labor productivity measured by milk sold (1,000 cwt) per worker equivalent. The line with circles, crosses and diamond indicates the kernel density plot of total labor costs per cwt of milk sold of the low-, middle- and high-performance group, respectively. One worker equivalent is 2,760 h a year

Figure 5. Kernel density plot of labor productivity by performance (1993–2016)

Table II. Labor productivity by financial performance

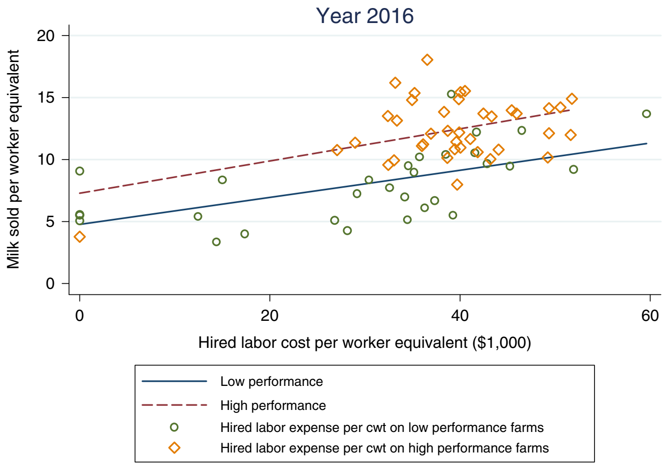
Rank	Mean	CV	(95% conf. interval)	
Low	5.383	0.013	5.241	5.525
Middle	7.729	0.008	7.650	7.810
High	9.806	0.008	9.700	9.910

Note: Labor productivity is measured by milk sold (1,000 cwt) per worker equivalent

Stage 2 – regression results

The ordered financial performance rank created in the first stage is applied as a dependent variable in regression analysis, to further evaluate the relationship between dairy farms' financial performance and labor productivity, labor cost efficiency and capital investment in labor-saving equipment. Parameters are estimated by linear and ordered logit farm-level fixed-effects models, and results are reported in the first two columns in Table III. The last two columns in Table III present the coefficients from linear and ordered logit random-effects models. The random-effects models assume that omitted variables are not correlated with the explanatory variables, while the fixed-effects models relax this assumption by allowing the correlation between unobserved farm-level characteristics and the covariates. As the dependent variables are performance ranks, from the regression results, we focus on whether or not overall financial performance rank is statistically significantly correlated with labor-use efficiency as well as capital investments in labor-saving equipment, and the direction of the relationship, rather than the marginal effects of the covariates.

Based on the results of the farm-level fixed-effects models, labor productivity is statistically positively associated with dairy farm financial performance. As labor cost efficiency and wages are controlled in the regression, the positive coefficient of labor productivity confirms the information presented in Figure 6 that a worker is more productive on more profitable dairy farms. In Table III, there is a statistically significant negative relationship between dairy farms' financial performance and farms' hired labor



Notes: The *x*-axis is hired labor cost per unit of milk sold, and the *y*-axis is milk sold per worker equivalent. The hollow circles and squares indicate low- and high-performance dairy farms in 2016, respectively. The dashed and solid line is the fitted line for the low- and high-performance group, respectively

Figure 6.
Labor productivity vs wage by financial performance (2016)

Variables	(1) Fixed-linear	(2) Fixed-logit	(3) Random-linear	(4) Random-logit
Milk sold per worker equivalent (1,000 cwt)	0.033*** (0.010)	0.152*** (0.044)	0.068*** (0.008)	0.281*** (0.036)
Hired labor expense per cwt	−0.067** (0.028)	−0.260** (0.123)	0.020 (0.019)	0.084 (0.079)
Hired labor cost per worker equivalent ($1,000)	−0.001 (0.002)	−0.008 (0.007)	−0.003* (0.001)	−0.011* (0.006)
Advanced milking system	−0.046 (0.110)	−0.215 (0.451)	0.026 (0.078)	0.055 (0.312)
Owned dairy farm	−0.180* (0.103)	−0.635* (0.370)	−0.307*** (0.068)	−1.282*** (0.306)
Dairy housing = freestall	0.137 (0.116)	0.568 (0.453)	0.213*** (0.082)	0.833** (0.327)
Dairy housing = combination	0.086 (0.081)	0.358 (0.333)	0.249*** (0.066)	0.972*** (0.251)
Average number of cows	0.0001 (0.000)	0.0001 (0.000)	0.0001*** (0.000)	0.001** (0.000)
Forage acres per cow	0.009 (0.029)	0.083 (0.134)	0.024 (0.022)	0.093 (0.095)
Purchased feed and crop expense per cwt	−0.052*** (0.008)	−0.218*** (0.033)	−0.066*** (0.007)	−0.270*** (0.028)
Tillable acres per 1,000 cwt of milk	−0.008* (0.005)	−0.039* (0.023)	−0.013*** (0.003)	−0.054*** (0.013)
Prob > χ^2		0	0	0
Prob > F	0			
Observations	3,428			
Number of Farm_number	387			

Notes: Standard errors are clustered at the individual farm level. Coefficients in Column (1) are estimated by fixed-effects linear model; coefficients in Column (2) are estimated by fixed-effects logistic model; coefficients in Column (3) are estimated by random-effects linear model; coefficients in Column (4) are estimated by random-effects logistic model. *,**,***Significant at the 10, 5, and 1 percent level, respectively

Table III.
Regression results of financial performance rank

cost per unit of milk sold in fixed-effects models. This result is consistent with Kauffman and Tauer (1986) and El-Osta and Johnson (1998), which found that dairy farms' success is significantly associated with hired labor costs per cow. As wage (labor cost per worker equivalent) and labor productivity (milk sold per worker equivalent) are controlled in the models, the significant relationship between farm performance and labor cost efficiency is consistent with our early interpretation of Figure 4 that more financially successful farms can generate a greater labor cost efficiency even when the same wages are paid as other farms. These farms may be more capable of finding good labor workers, so they acquire better-skilled workers with same wages, or these farms may be better at labor management, so they can achieve a greater labor cost efficiency (Figure 4) and productivity (Figure 6) by avoiding unnecessary activities.

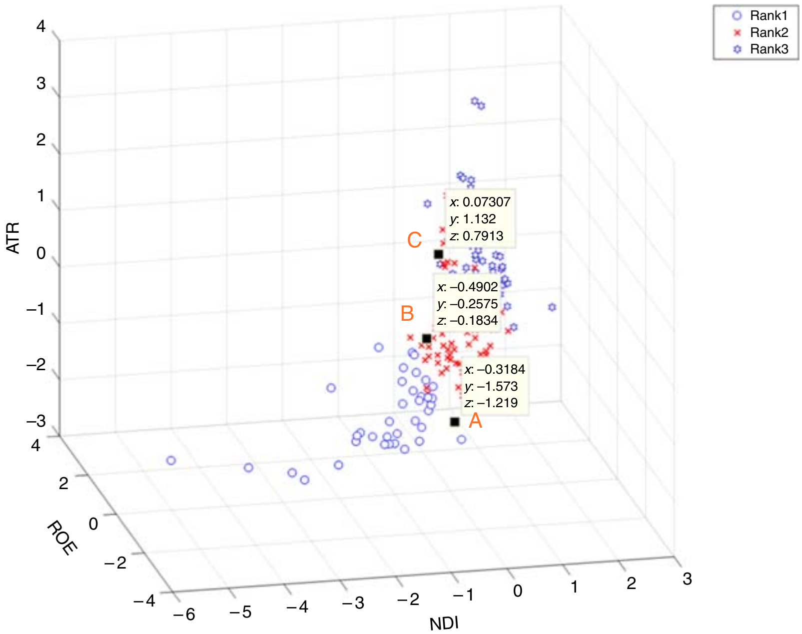
The results in Table III also illustrate the importance of controlling farm-level fixed effects in labor-use efficiency analysis. Contrary to fixed-effects models, estimations of random-effects models show a significant relationship between wage and farm success, while no significant relationship between labor cost efficiency and farm success. Considering that omitted variables such as dairy farms' managerial strategies likely affect farms' labor productivity and cost efficiency, we prefer to the results fitted by fixed-effects models.

Due to data limitations, we do not have detailed information regarding dairy farms' capital investment. Advanced milking systems are used as a proxy of capital investment in labor-saving equipment. We do not find a statistically significant correlation between the advanced milking systems and dairy farms' financial performance. The statistically significant relationship between purchased feed and crop costs and financial performance is consistent with Kauffman and Tauer (1986). Holding other factors constant, dairy farms with more feed costs are expected to have lower financial performance. Besides, the regression results (Table III) from fixed-effects models do not show statistically significant differences in farm performance of using different dairy housing types.

When farm-level unobserved time-invariant characteristics are controlled, there is no statistically significant relationship between the number of cows and dairy farms' financial performance (Table III). The economies of scales of dairy farms are controversial in the literature. For example, Kauffman and Tauer (1986) and Haden and Johnson (1989) did not find a significant relationship between herd sizes and dairy farms' success. When both herd sizes and milk production per cow were incorporated into regression, the two items both showed significant association with dairy farms' ROA (Gloy *et al.*, 2002). In our study, instead of milk production per cow, we control labor productivity (milk sold per worker) and use a more comprehensive financial measurement, and there is no statistically significant relationship between herd size and farms' comprehensive financial performance. The expansion of herd size may improve dairy farms' sales, and further increases ROA, but when net profit and the efficiency of equity use are considered in this study, herd size is not associated with dairy farms' overall financial performance. Our finding, to some extent, confirms Tauer and Mishra's (2006a) earlier conclusion that "efficiency was more important than farm size in reducing net production costs" (Tauer and Mishra, 2006b).

Stage 3 – measures of financial performance

As we discussed above, the approach of using a single financial ratio as a measure of financial performance, and taking it as a dependent variable in regression would bring in incomplete information. Thus, the research conclusions could change given the selection of financial variables. Figure 7 plots the normalized NDI, ROE and ATR in year 2013 as the *x*-, *y*- and *z*-coordinate[5]. Three farms (A, B and C) in squares are selected to illustrate the potential problem of using one financial variable to evaluate firms' financial performance. If NDI is used as a ruler to assess dairy farms' financial performance, Farm B has the worst performance, while Farm C is the best one. If ROE is applied as the ruler, Farm C shows the



Notes: Dairy farms' normalized NDI, ROE and ATR are projected on the *x*-, *y*- and *z*-axis, respectively. Features are normalized to have a mean of zero and a standard deviation of one following Equation (8). The original three-dimensional coordinate system is rotated for readability

Figure 7. Normalized NFI, ROE and ATR of dairy farms in 2013

best performance, while Farm A has the lowest performance. Thus, which financial variable is used as the dependent variable would alter the regression results. To explicitly show the potential problem, linear fixed-effects models are regressed on three financial variables independently: NFI, ROE and ATR.

Table IV summarizes the regression results fitted on one financial variable using linear fixed-effects models. The regression results vary as the measure of financial performance changes. There is a statistically significant positive relationship between labor productivity and financial performance unless the performance is measured by ATR. Dairy farm net income and ATR are associated with labor cost efficiency, but not wages, while the relationship is different when ROE is independently used as a measure of dairy farm financial performance. The results are largely consistent with our analysis using performance rankings, but some conclusions would be changed if a single variable is used.

The varying results in Table IV may confirm our hypothesis that an individual financial variable only captures some aspects of farm financial performance, and it may also explain the different conclusions in previous dairy management studies. For example, El-Osta and Johnson (1998) found that the herd size is statistically significantly in association with farm financial performance when NFI is the measure of financial performance, while no significance is shown in regression results when performance is measured by NRU of milk sold. However, Mishra *et al.* (2012) found that compared with small-sized farms, medium-sized farms are positively related to ART, negatively related to net profit margin, no statistically significant association with asset-to-equity. The changing regression results are also observed in Table IV, even when the same data set and explanatory variables are

Table IV.
Regression results of one financial variable

Variables	(1) NFI ($1,000)	(2) ROE	(3) ATR
Milk sold per worker (1,000 cwt)	13.348* (6.947)	0.938*** (0.230)	0.005 (0.003)
Hired labor expense per cwt	−49.378*** (12.836)	−0.524 (0.494)	−0.010* (0.006)
Hired labor cost per worker equivalent ($1,000)	0.415 (0.571)	−0.059* (0.031)	−0.000 (0.000)
Advanced milking system	−97.668*** (25.796)	−3.385* (1.966)	−0.032 (0.054)
Owned dairy farm	12.680 (27.758)	3.643 (3.185)	−0.223*** (0.048)
Dairy housing = freestall	−22.355 (29.960)	3.288 (2.268)	−0.009 (0.046)
Dairy housing = combination	−76.876*** (29.117)	0.226 (1.754)	−0.002 (0.024)
Average number of cows	0.925*** (0.115)	−0.002* (0.001)	−0.0001** (0.000)
Forage acres per cow	3.278 (12.445)	0.880 (0.569)	0.007 (0.006)
Purchased feed and crop expense per cwt	44.892*** (7.221)	−0.140 (0.175)	0.006*** (0.002)
Tillable acres per 1,000 cwt of milk	0.236 (1.915)	−0.129 (0.102)	−0.006*** (0.001)
Constant	−276.924*** (65.871)	−0.355 (3.997)	0.808*** (0.059)
Prob > F	0	0	0
Observations	3,428		
Number of Farm_number	387		

Notes: NFI ($1,000) indicates net farm income with appreciation in $1,000; ROE is rate of return on equity; ATR is asset turnover ratio; robust standard errors in parentheses. Standard errors are clustered at the individual farm level. *,**,***Significant at the 10, 5, and 1 percent level, respectively

used (Table IV). In Table IV, herd size is estimated as positively associated with dairy farm NFI, while marginally negatively related to ROE and ATR. As each cow generates positive profit, increasing herd size may increase NFI, but not necessarily improve the farm's asset as well as equity use efficiency.

Conclusion

There is limited evidence of the relationship between labor management and dairy farm financial performance in the literature (Mugera and Bitsch, 2005; Bitsch *et al.*, 2006; Bitsch and Olynk, 2008), although labor costs are accounting for the second largest variable costs after feed costs on dairy farms, and dairy farm managers are facing increasing labor shortages and costs. As a response, a panel data set of NY dairy farms from 1993 through 2016 is utilized in this study to identify the relationship between dairy farms' financial performance and labor-use efficiency, with a novel approach of measuring farms' financial performance. To have a comprehensive financial performance evaluation, cluster analysis is applied to partition dairy farms into three performance groups based on three financial ratios: NDI, ROE and ATR, and the three clusters in each year are further converted into ordered financial performance ranks based on the financial features in each cluster. The performance rank is then regressed on a group of farm managerial factors to identify the relationship.

The cluster analysis and regression estimations indicate the significant positive relationship between dairy farm financial success and labor-use efficiency (labor productivity and cost efficiency). From the cluster analysis, we observe that average wages are higher on more profitable dairy farms (Figure 3), implying these farms tend to hire more-skilled workers. Regression results confirm that even with same wages and labor productivity, successful dairy farms are associated with a significantly greater labor cost efficiency. Moreover, when wage and labor cost efficiency are fixed, more profitable farms have statistically higher labor productivity. The high labor-use efficiency on more successful dairy farms might be caused by a combination of high-skilled workers and efficient managerial strategies of controlling "un-necessary expenses or disruptions to activities" (Karszes, 2017).

The regression results do not show a statistically significant relationship between capital investments in advanced milking systems and financial performance when farm asset use efficiency is considered in the financial performance evaluation. The dichotomous measurement of milking systems may not be an ideal proxy of capital investment in labor-saving equipment, and further study is required to better understand how labor-saving technology is associated with dairy farms' financial performance.

Other factors could affect dairy farm financial performance. For example, milk prices could have a heterogeneous effect on dairy farms' financial performance as some farms can quickly adjust farm management to hedge the changes in prices, while others are less capable due to managerial strategies or capital restrictions. The loss of market and closing of milk plants could also effect on dairy farms' financial performance. However, due to data limitations, we are unable to control for such local basis shifts in this study.

This analysis not only brings a better understanding of the relationship between dairy farms' financial performance and labor-use efficiency, but also proposes a novel approach to measuring farms' financial performance. To our knowledge, this is the first study that explicitly discusses the potential problems of using one single measure of financial performance in farm management. This study explicitly compares the regression results by using a single financial variable as the method used in previous studies, and presented the inconsistency in regression results as the measure of financial performance changes.

Three variables are used in the cluster analysis to create a performance rank in this study, but a different number of financial variables can be applied using the approached developed in this study to evaluate firm's performance according to the purpose of future studies. Although the same weights are used on the three financial variables in this study, different weights can be incorporated into the cluster analysis, based on industry characteristics or research objectives. For example, some studies may be more interested in equity holders' profit, others may focus more on asset use efficiency. Thus, the method developed in this study can be widely applied in future financial studies for a more comprehensive performance evaluation.

Although industry associations and university extension professionals have been emphasizing the importance of labor management for dairy farms[6], there is a lack of research-based evidence on the relationship between labor management and dairy farm financial performance. This study fills in the gap in the literature of dairy labor management as well as farm financial management by using a long-running micro-level survey data set, while creating a novel approach for comprehensive financial performance assessment. After controlling for unobserved farm-level characteristics, results show the importance of farm labor productivity and cost efficiency for dairy farm financial performance.

Notes

1. A hundredweight is abbreviated as cwt in this study.
2. Dumping station and pipeline milking types are grouped into the basic milking system in this study (account for 35 percent of observations), and herringbone, parallel, parabone and rotary milking types are defined as advanced milking system.
3. After the automatically outlier removal approach discussed in Equation (7), one observation in 1997 was manually removed as the observation's normalized ROE is greater than 6 and it is far away from other farms' normalized ROE. The "extremely" high normalized ROE significantly affects the in-cluster distance, and only four farms fall into the low-performance rank (267 observations in year 1997). Thus, this observation in 1997 is treated as an outlier. After removing

this observation, 114 farms fall into the low-performance rank. Similarly, one observation is manually removed from 2016 data set to have more evenly distributed performance groups.

4. After the cluster analysis, we removed observations that are not in the 95% confidence interval of hired labor cost per worker ($1,000). Otherwise, the unreasonably high labor costs influence the range of distribution diagrams and cause difficulties to read as well as analyze the figures.
5. We randomly select one year's data as an example.
6. E.g. Benchmarking labor efficiency and productivity available at: www.dairyherd.com/article/benchmarking-labor-efficiency-and-productivity; Labor Management on Dairy Farms available at: https://afs.ca.uky.edu/dairy/extension/labor-management-dairy-farms; Managing Dairy Labor available at: http://extensionpublications.unl.edu/assets/pdf/g1584.pdf

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Appendix

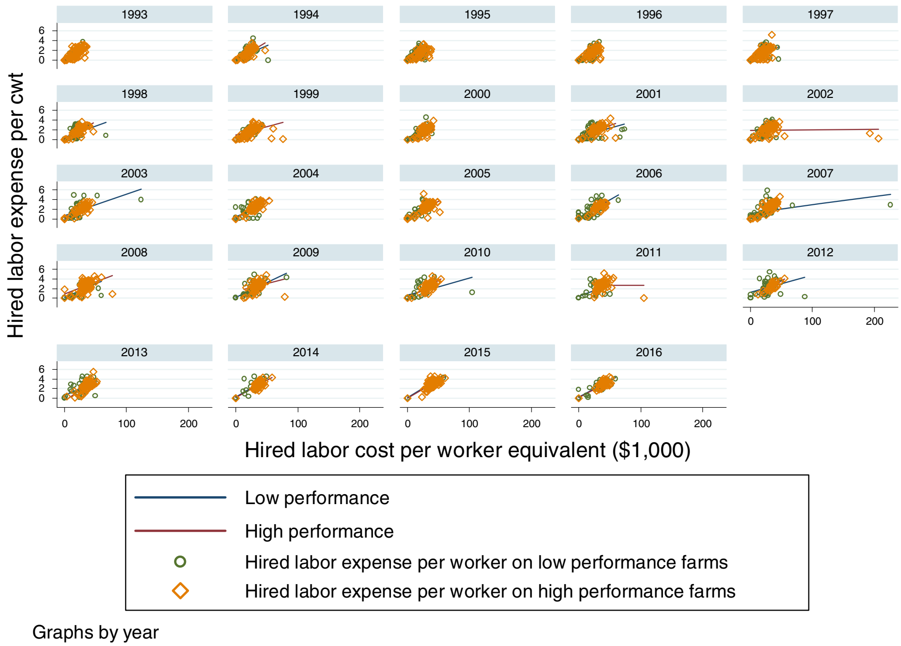

Figure A1.
Labor costs by financial performance and year

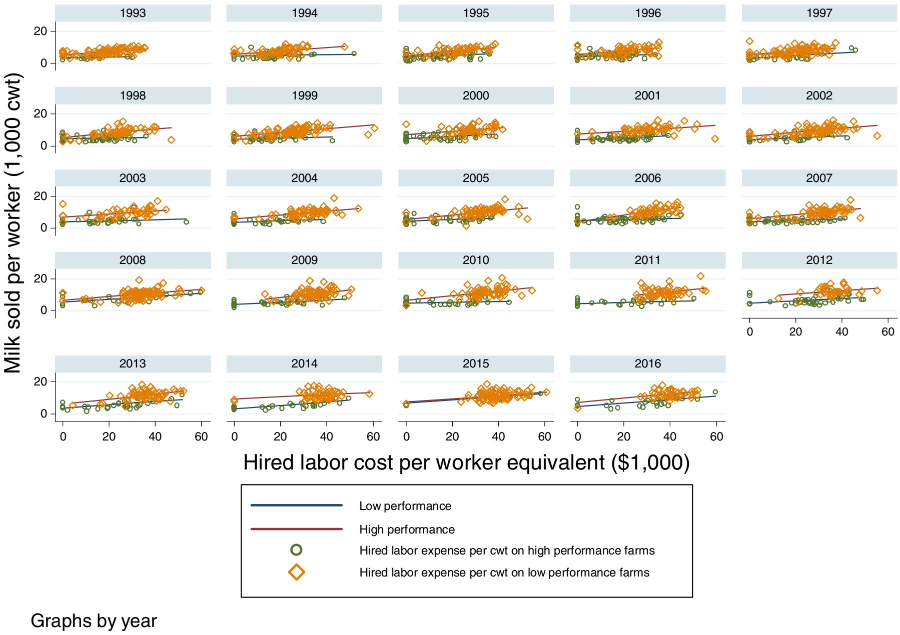

Figure A2.
Labor productivity vs wage by financial performance and year

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