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ESTIMATING ECONOMIC EFFICIENCY UNDER RISK FOR AGRICULTURAL COOPERATIVES

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Abstract

This study examined the impact of downside risk on cost efficiency (CE) and revenue efficiency (RE) for a sample of agricultural cooperatives. Downside risk is an appropriate measure of risk as it accounts for loss below the target return level regardless of individuals' risk preference. The semi-variance of return on equity was used a measure of downside risk. CE and RE were estimated using data envelopment analysis (DEA) without adjusting for downside risk and then re-estimated adjusting for downside risk. The average CE and RE scores were higher with the inclusion of downside risk than the scores without downside risk. The DEA method without accounting for risk overestimates inefficiency and may misguide managers on adjustments needed to improve performance.

Key words: agribusiness, cost efficiency, data envelopment analysis, downside risk, revenue efficiency
JEL Codes: C14, Q13

1. Introduction

Agricultural cooperatives are an integral part of production agriculture and agribusiness in supporting farmers in the United States. The agricultural cooperative sector has been undergoing a transition period with tight profit margins, high commodity price volatility, and consolidations (USDA, 2017). Recent trends in agricultural grain marketing and farm supply cooperatives include large investment in infrastructure, changes in profit distributions strategies, and consolidation that result in a lower number of agricultural cooperatives (Briggeman, Jacobs, Kenkel, & McKee, 2016). The number of cooperatives decreased by 25% from 2005 to 2015 while gross sales more than doubled over the same period. Gross sales and total assets concentrated to a few large cooperatives. The top 10 largest cooperatives accounted for more than 39% of assets and 41% of gross businesses during the period (USDA, 2017).

In addition, the financial landscape of agricultural cooperatives has changed in recent years compared to the 1990s and 2000s due to an increased proportion of debt in capital structure (Pokharel, Regmi, Featherstone, & Archer, 2019). These changes illustrate the importance of efficiency (performance) analysis. Moreover, high commodity price volatility and uncertain markets introduce risk in the operation of agricultural cooperatives. Risk faced by cooperatives can be divided into internal and external risks. Internal risks are associated within the cooperatives such as financing, level of specialization, innovation activities while external risks are associated with macroeconomic environments such as an increase in interest rates, government policies. An overview of internal and external risks and how the risk factors affect cooperatives' businesses can be found in Georgieva and Kirechev (2017). Since risk is an inherent factor of any business, it is important to include risk in estimating and comparing efficiency among agricultural cooperatives. Failure to consider a risk factor may underestimate economic efficiency (Yeager & Langemeier, 2013). Efficiency estimation for cooperatives accounting for risk has not been adequately examined in the literature.

A commonly used method for measuring risk in economics and finance is the mean-variance or expected value (E) - variance (V) approach. The EV efficient frontier shows different combinations of minimum variance for an alternative level of expected returns (Markowitz, 1952; Robinson & Barry, 1987). However, the limitations of the EV model are that it penalizes upside potential in the same way as downside loss and assumes that returns follow a multivariate normal distribution or the investor's utility function is quadratic, conditions that rarely hold in practice (Hoe, Hafizah, & Zaidi, 2010). An alternative to the E-V approach for measuring risk is an asymmetric measure of risk (downside risk) or lower partial moments. Downside risk is an appropriate measure of risk for businesses or investors because businesses are more concerned about losses below the target return or benchmark return level (Markowitz, 1959; Tauer, 1983).

The objective of this study is to examine the impact of downside risk on cost efficiency (CE) and revenue efficiency (RE) under variable returns to scale (VRS) for agricultural cooperatives. Downside risk was measured as the semi-variance of return on equity. CE and RE were estimated using data envelopment analysis (DEA) with traditional inputs and outputs and then re-estimated including downside risk under VRS. The VRS is an appropriate technology because firms may operate at sub-optimal scale due government regulations, financial constraints, and imperfect markets (Coelli, Rao, O'Donnell, & Battese, 2005). Pokharel and Featherstone (2019) used a multiproduct approach to estimate scale economies for agricultural cooperatives in the United States and found that the vast majority of agricultural cooperatives experience multiproduct scale economies different than one indicating variable returns to scale is an appropriate technology for modeling cooperatives. This article complements previous studies by identifying an appropriate measure of risk that is of concerns to agribusiness and investors and comparing economic efficiency without and with risk. The study tests for the robustness of previous studies that estimate economic efficiency without risk. In addition, the study estimates the economic efficiency of agricultural cooperatives during a period of volatile returns in production agriculture.

Several studies have examined the efficiency of banking sectors using DEA accounting for risk (Chen, Chiu, Jan, Chen, & Liu, 2015; Matthews, 2013). Chen et al. (2015) used DEA to evaluate the impact of risk (non-performing loans) on the efficiency of the banking sector in Taiwan from 2006 to 2010 and concluded that risk is an important factor that should be accounted for estimating banking efficiency. For most of the inefficient banks, inefficiency was primarily caused by risk. Likewise, studies that estimate efficiency of cooperatives include Featherstone and Rahman (1996); Porter and Scully (1987); Sexton and Iskow (1993). Featherstone and Rahman (1996) used a non-parametric approach to examine the optimizing behavior of cooperatives and found that the objective of cooperatives is more consistent with cost minimization rather than profit maximization. Sexton and Iskow (1993) found that cooperatives are not less efficient than comparable investor-owned firms.

Literature has shown that "individuals generally avoid situations which offer the potential for substantial gains but which also leave them even slightly vulnerable to losses below some critical level" (Menezes, Geiss, & Tressler, 1980, p. 921). Moreover, downside risk can be used to represent downside risk aversion for both risk-averse and risk-loving individuals. Individuals can be characterized with downside risk aversion if their utility function has a positive third derivative (Menezes et al., 1980).

Tauer (1983) and Watts, Held, and Helmers (1984) developed models that account for downside risk. Tauer (1983) used the weighted sum of the deviations below a target return level for a five year period as a measure of downside risk. Yeager and Langemeier (2013) analyzed economic efficiency using a sample of Kansas farms accounting for downside risk. They used the equally weighted summation of net farm income below the amount needed to cover unpaid labor for 10 years as a measure of downside risk.

Markowitz (1959) proposed semi-variance as a measure of downside risk to overcome the limitation of the EV approach. Semi-variance is more appropriate than variance as it only accounts for negative deviations (the variability of return below the average) (Markowitz, 1959). Grootveld and Hallerbach (1999) argued that "from a decision-theoretic point of view, lower partial moment efficiency is more appealing since it implies third order stochastic dominance", p.317).

2. Research Methods

Literature uses two approaches to estimate efficiency of farms, agribusiness, and cooperatives. One applies parametric methods (non-frontier and stochastic frontier methods) to estimate cost and production functions. Parametric methods may violate the curvature conditions that are required for the existence of indirect cost functions (Featherstone and Moss, 1994). A second line of study uses a non-parametric data envelopment analysis (DEA) approach developed by Farrell (1957) to estimate cost and production frontiers. The DEA method uses a one-sided error term, which is consistent with the economic theory of the cost frontier. The DEA method does not impose any functional form on technology so the method is less prone to misspecification error (Färe, Grosskopf, & Lovell, 1985). However, the DEA method is not free from criticism. It does not account for measurement error assuming that any deviation from the frontier is due to inefficiency (Coelli et al., 2005).

Data envelopment analysis is a linear programing (LP) approach that uses inputs and outputs to construct a piece-wise linear surface using the optimal solution obtained for the LP model for each decision making unit (Coelli et al., 2005). This study uses the DEA method to estimate cost efficiency (CE) and revenue efficiency (RE) without and with risk. Estimating CE and RE with and without risk using DEA helps to identify inefficiencies for individual cooperatives. A cooperative's efficiency is compared with the efficiency of frontier cooperatives (the "best practice" cooperatives) from the sample.

2.1 Efficiency without Risk

This section discusses economic efficiency without risk. Cost efficiency is a ratio of minimum cost (C_i) to the total cost (TC_i) observed by individual cooperatives for producing a given output bundle. Mathematically,

$$CE_i = C_i/TC_i = w_i' x_i^* / w_i' x_i \tag{1}$$

where w_i is a vector of input prices for cooperative i, x_i and x_i^* are the vectors of observed input and optimal input levels, respectively (Coelli et al., 2005; Färe et al., 1985). The CE score ranges between zero and one and a CE score of one indicates that the cooperative is on the cost frontier, therefore, it is cost efficient. A CE score of less than one indicates that the cooperative has costs above the cost frontier. The minimum (optimal) cost under VRS is estimated using the following LP program.[i]

$$\text{Min } C_i = w_i' x_i^* \tag{2}$$
$$\text{subject to}$$
$$x_{11}z_1 + x_{12}z_2 + \cdots + x_{1k}z_k \leq x_{1i}^*$$
$$\ldots\ldots$$
$$x_{n1}z_1 + x_{n2}z_2 + \cdots + x_{nk}z_k \leq x_{ni}^*$$
$$y_{11}z_1 + y_{12}z_2 + \cdots + y_{1k}z_k - y_{1i} \geq 0$$
$$\ldots\ldots$$
$$y_{m1}z_1 + y_{m2}z_2 + \cdots + y_{mk}z_k - y_{mi} \geq 0$$
$$z_1 + z_2 + \cdots + z_k = 1;\ \ z_k \in R^+$$

where y_i is a vector of output levels for the *i*th cooperative, *k* is the number of cooperatives, and *z* is an intensity vector (i.e. the weight of each cooperative) and the remaining notations are as previously defined. The sum of the intensity vector is one under variable returns to scale (VRS). Cost efficiency and revenue efficiency without and with risk were estimated only under the VRS specification.

Revenue efficiency is a ratio of observed total revenue (TR_i) to the optimal revenue (R_i) obtained from the LP program as given in equation (4). The RE score lies between zero and one. A cooperative with a RE score of one is operating on the production possibility frontier, which indicates that the cooperative is producing the optimal output mix (Coelli et al., 2005). Mathematically,

$$\text{RE}_\text{i} = TR_i/R_i = p_i' y_i / p_i' y_i^* \tag{3}$$

where *p* is a vector of output prices, y_i^* is a vector of optimal output levels, and the remaining notations are as previously defined. The optimal revenue under VRS is estimated using the following LP program (Coelli et al., 2005; Färe et al., 1985).

$$Max\ \ R_i = p_i' y_i^* \tag{4}$$
$$\text{subject to}$$
$$x_{11}z_1 + x_{12}z_2 + \cdots + x_{1k}z_k \leq x_{1i}$$
$$\ldots\ldots$$
$$x_{n1}z_1 + x_{n2}z_2 + \cdots + x_{nk}z_k \leq x_{ni}$$
$$y_{11}z_1 + y_{12}z_2 + \cdots + y_{1k}z_k - y_{1i}^* \geq 0$$
$$\ldots\ldots$$
$$y_{m1}z_1 + y_{m2}z_2 + \cdots + y_{mk}z_k - y_{mi}^* \geq 0$$
$$z_1 + z_2 + \cdots + z_k = 1;\ \ z_k \in R^+$$

The notations are as previously defined. CE without risk is computed by dividing optimal cost obtained from equation (2) by observed total cost of cooperatives, while RE without risk is computed by dividing observed total revenue by optimal revenue obtained from equation (4).

2.2 Efficiency with Risk

This section first explains a measure of downside risk before explaining the optimization with risk. This study used the semi-variance (SV) of return on equity (ROE) as a measure of downside risk for estimating CE and RE following the approach of Markowitz (1959). Mathematically,

$$SV = \frac{1}{k}\sum_{n=1}^{k}(ROE - \overline{ROE})^2 \quad (5)$$

$$= \begin{cases} ROE - \overline{ROE} & if\ ROE - \overline{ROE} \leq 0 \\ 0 & if\ ROE - \overline{ROE} > 0 \end{cases}$$

where $\overline{ROE}$ is the average rate of return on equity (i.e. $\overline{ROE} = E(ROE)$) and the remaining notations are as previously defined.

The efficiency scores were computed for each cooperative from 2005 to 2014 using standard inputs and outputs and then re-estimated those scores including the semi-variance of return on equity as a measure of downside risk (a non-discretionary input). A non-discretionary input is equivalent to a "bad output" indicating that managers have little or no control over it. The optimization model is constructed to account for only inputs that managers have control over (Coelli et al., 2005). A paired t-test was used to examine whether the CE and RE scores without risk were different from those scores including risk.

The minimum cost under VRS including downside risk is estimated using equation (6) that is the modification of equation (2). Yeager and Langemeier (2013) used a similar approach to estimate efficiency for Kansas farms including risk.

$$\text{Min } C_i = w_i' x_i^* \quad (6)$$

subject to

$$\begin{aligned} x_{11}z_1 + x_{12}z_2 + \cdots + x_{1k}z_k &\leq x_{1i}^* \\ &\cdots\cdots \\ x_{n1}z_1 + x_{n2}z_2 + \cdots + x_{nk}z_k &\leq x_{ni}^* \\ r_1z_1 + r_2z_2 + \cdots + r_kz_k &\leq r_i \\ y_{11}z_1 + y_{12}z_2 + \cdots + y_{1k}z_k - y_{1i} &\geq 0 \\ &\cdots\cdots \\ y_{m1}z_1 + y_{m2}z_2 + \cdots + y_{mk}z_k - y_{mi} &\geq 0 \\ z_1 + z_2 + \cdots + z_k = 1;\ z_k &\in R^+ \end{aligned}$$

where *r* is downside risk that is measured by the semi-variance (SV) of return on equity (ROE) and the remaining notations are as previously defined. Note that downside risk is included as an input constraint, but it is not allowed to change during cost minimization.

The following LP program includes the risk constraint, which is the modification of revenue maximization under VRS from equation (4).

$$Max\ R_i = p_i' y_i^* \quad (7)$$

subject to

$$\begin{aligned} x_{11}z_1 + x_{12}z_2 + \cdots + x_{1k}z_k &\leq x_{1i} \\ &\cdots\cdots \\ x_{n1}z_1 + x_{n2}z_2 + \cdots + x_{nk}z_k &\leq x_{ni} \\ r_1z_1 + r_2z_2 + \cdots + r_kz_k &\leq r_i \\ y_{11}z_1 + y_{12}z_2 + \cdots + y_{1k}z_k - y_{1i}^* &\geq 0 \\ &\cdots\cdots \\ y_{m1}z_1 + y_{m2}z_2 + \cdots + y_{mk}z_k - y_{mi}^* &\geq 0 \\ z_1 + z_2 + \cdots + z_k = 1;\ z_k &\in R^+ \end{aligned}$$

where *r* is downside risk and the remaining notations are as previously defined. CE and RE with downside risk can be calculated by dividing optimal cost obtained from equation (6) by observed total cost and observed total revenue by optimal revenue obtained from equation (7), respectively.

3. Data

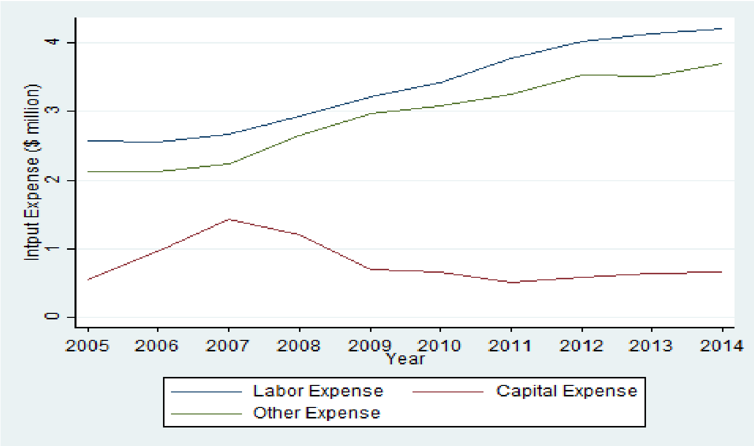
This study used financial data from CoBank, part of the Farm Credit System. The CoBank data include financial information of agricultural cooperatives that borrow from CoBank. The data consist of agricultural grain marketing and farm supply cooperatives from 36 states in the United States from 2005 to 2014. To estimate CE and RE using the DEA method, inputs, input prices, outputs, and output prices are required. All nominal values of input expenses and output revenues were converted to 2014 constant U.S. dollar values using gross domestic product (GDP) price deflator (BLS, 2016). Annual producer price indices (PPI) for inputs and outputs were used to convert expenses and revenues to input and output quantities (indices). Three inputs were used in the analysis: labor, capital, and variable (other) expense. Labor expense consisted of wage expense and fringe benefit expense. Average hourly earnings for the manufacturing sector (BLS, 2016) were used to transform labor expense to labor quantity (index). Total assets were used as the quantity (index) of capital and the U.S. real interest rate (World Bank, 2016) was used as the cost of capital. The other (variable) expense consisted of utility cost, advertising cost, lease, and rent, etc. The other quantity (index) was obtained by dividing other expense by general PPI (BLS, 2016).

The four outputs used in the analysis were grain sales (aggregation of sales commodities and grain), farm input supply sales (aggregated form of fertilizer, chemicals, petroleum, etc.), service income (aggregated form of storage and handling revenues), and other product sales. All output revenues were converted to quantities (indices) using PPI. To be specific, the PPI for grains, PPI by commodity for crude materials for further processing, PPI by commodity for finished goods, and general PPI (BLS, 2016) were used to convert grain sales, farm input supply sales, other product sales, and service income into output quantities (indices), respectively. More details about input and output data can be found in Pokharel (2016).

Table 1. Production and Financial Measures for Agricultural Cooperatives, 2005-2014

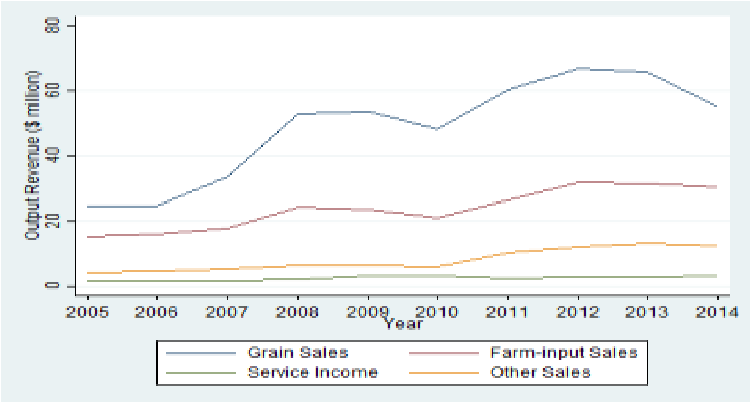
	Mean	Median	Std. Dev.
Inputs ($ million)			
Labor expense	3.50	1.62	5.21
Capital expense	0.74	0.32	1.21
Other expense	3.04	1.33	4.75
Outputs ($ million)			
Grain sales	51.36	14.61	104.65
Farm-input sales	25.07	10.20	42.67
Service income	2.59	1.10	4.41
Other sales	8.93	1.77	36.13
Financial measures			
Return on equity	0.13	0.13	0.11
Return on assets	0.08	0.08	0.05
Profit margin	0.03	0.02	0.03

Note: Total number of observations (N) = 3,511.



Source: Pokharel (2016)

Figure 1. Annual Average of Input Expenses for Agricultural Cooperatives



Source: Pokharel (2016)

Figure 2. Annual Average of Output Revenues for Agricultural Cooperatives

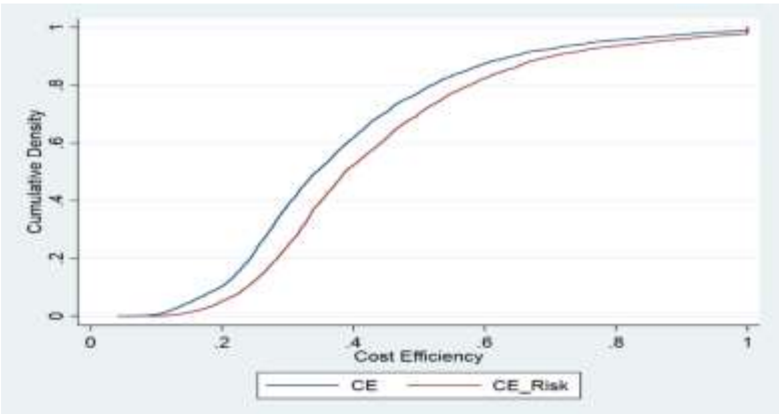


Figure 3. Cumulative Density of Cost Efficiency without and With Risk

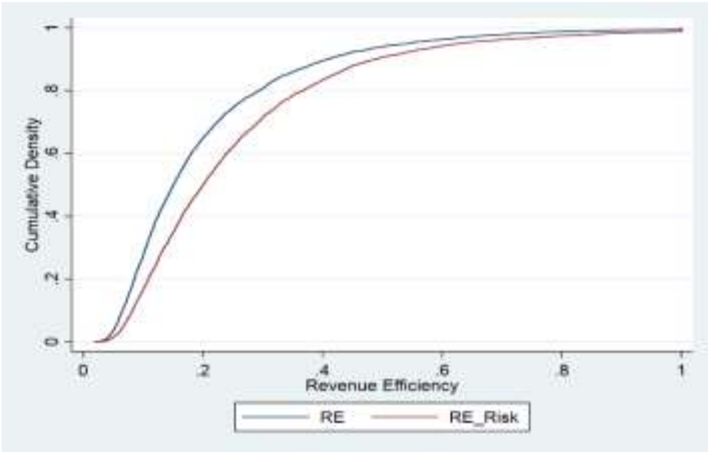


Figure 4. Cumulative Density of Revenue Efficiency without and With Risk

Table 1 presents the summary statistics of input expenses, output revenues, and financial ratios. The cost of labor accounted for more than 45% of total input cost. Labor and other expense showed an increasing trend over the study period while capital showed an increasing trend from 2005 to 2007 and a decreasing trend after 2008 (Figure 1). The largest revenue was obtained from grain sales while the contribution of service income was lowest on total returns, on average. The income obtained from farm input sales showed an upward trend except in 2009 and 2010 whereas the income received from grain had significant variations over the sample period. Grain sales decreased from 2009 to 2010 and after 2013 (Figure 2). The average return on equity, return on assets, and profit margins were 13%, 8%, and 3%, respectively for the sample period.

4. Results

The cumulative density graphs showed that CE and RE scores increased for most of the firms with the inclusion of downside risk (Figures 3 and 4). Table 2 reports the summary statistics of CE and RE without and with risk. The average CE scores without and with risk were 0.39 and 0.44, respectively. The number of cost efficient agricultural cooperatives increased from 41 to 79 with the inclusion of risk (Table 2). Similar results hold for RE. The average RE scores increased from 0.20 to 0.25 with the inclusion of risk. The number of revenue efficient agricultural cooperatives increased from 18 to 42 with the inclusion of risk (Table 2). In general, the CE and RE scores increased with the inclusion of risk. The paired t-test showed that the differences for CE and RE scores with and without downside risk were statistically significant (P-values < 0.001 for both CE and RE). The results indicate that failure to account for risk in estimating economic efficiency using DEA overestimates inefficiency which may misguide managers of agricultural cooperatives on actions needed to improve performance. The findings of this study are consistent with the results of Yeager and Langemeier (2013) for a sample of Kansas farms from 2003 to 2010, who found that CE and RE increased with downside risk.

Table 2. Summary statistics of economic efficiency for agricultural cooperatives, 2005-2014

	Efficient observations	Mean	Median	Std. Dev.
CE	41	0.389	0.344	0.186
CE with downside risk	79	0.438	0.388	0.192
RE	18	0.203	0.151	0.162
RE with downside risk	42	0.254	0.201	0.186

Note: Total number of observations (N) = 3,511. CE denotes cost efficiency and RE denotes revenue efficiency.

The percentage of inefficiency explained by downside risk was calculated as the change in inefficiency between inefficiency without and with downside risk dividing by inefficiency without downside risk for all agricultural cooperatives. Mathematically,

$$Inefficiency\ \% = \frac{Inefficiency - Inefficiency^{sv}}{Inefficiency} * 100\%$$

where $Inefficiency$ represents one minus efficiency without risk and $Inefficiency^{sv}$ represents inefficiency with downside risk. The results showed that downside risk accounted for 8.9% and 7.3% of cost and revenue inefficiencies, on average, respectively.

Past studies have shown that larger firms are more efficient than smaller firms (Ariyaratne, Featherstone, Langemeier, & Barton, 2000; Pokharel, 2016; Yeager & Langemeier, 2013). This study divided agricultural cooperatives into four categories based on their asset values to evaluate how efficiency changes with respect to size. The categories are: cooperatives with less than $10 million (m) in assets, cooperatives with greater than $10m and less than $20m in assets, cooperatives greater than $20m and less than $50m in assets, cooperatives with greater than $50m in assets.[ii] If cooperatives are realizing benefits of economies of scale, larger cooperatives are expected to be more efficient than smaller cooperatives.

Table 3. Cost and revenue efficiencies by the value of assets category, 2005-2014

		Less than $10m*	$10m - $20m	$20m- $50m	Greater than $50m
CE	Mean	0.349	0.337	0.391	0.526
	Std. Dev.	0.164	0.144	0.176	0.215
CE with downside risk	Mean	0.397	0.382	0.445	0.578
	Std. Dev.	0.167	0.151	0.187	0.217
RE	Mean	0.153	0.153	0.196	0.372
	Std. Dev.	0.134	0.103	0.119	0.194
RE with downside risk	Mean	0.201	0.200	0.262	0.414
	Std. Dev.	0.157	0.147	0.156	0.214
	N	1382	752	712	665

Notes: *The value of assets in million (m) dollars. CE denotes cost efficiency and RE denotes revenue efficiency.

Table 3 presents CE and RE scores based on the size of cooperatives. Larger cooperatives had higher CE and RE scores than those values of smaller cooperatives without and with downside risk. In other words, larger cooperatives were taking advantage of economies of scale. The result is consistent with Ariyaratne et al. (2000), who found that larger grain marketing and farm supply cooperatives were more scale efficient (X-efficient) than smaller ones from 1988 to 1992. This may indicate that the size of agricultural cooperatives within the agricultural cooperative sector will tend to increase in the future to benefit from economies of scale.

From an efficiency perspective, large cooperatives should be allowed to grow larger until economies of scale are exhausted. Scale inefficient small cooperatives may increase size by merging with other cooperatives or investor-owned firms or by increasing business volume. Since the number of farmers who are the primary members and users of agricultural cooperatives has been decreasing over time in the United States, increasing business volume by increasing members will be less likely in the cooperative sector (Pokharel & Featherstone, 2019). In other words, mergers in the agricultural cooperative sector will likely be an outcome as small cooperatives attempt to benefit from scale economies. However, the expansion of cooperatives should be justified by the demand for goods and services; otherwise scale economies may not be realized (Schroeder, 1992).

The productivity of the farming sector has increased substantially due to improvements in technology and innovations. If cooperatives cannot catch-up with the productivity growth of production agriculture, it may create risk, particularly for cooperatives that cannot adopt new technology and new knowledge to compete in the market. Since the members of cooperatives are farmers, production agriculture has been experiencing a period of volatile returns and the variability in price and yields is a major source of risk for farmers, cooperatives can mitigate some of the farmers' risk by managing price risk. However, if business volume decreased due to catastrophic events (e.g. crop failure), it may have double impacts on farm income. Farm income may decrease due to lower yields and the decrease in yields may reduce business volume for cooperatives resulting in lower patronage refunds to farmers-members (Zeuli, 1999). Cooperatives may use risk management tools such as futures, options to reduce the volatility of income.

Past studies that examined the impact of risk on the performance of firms indicate that the trade-off exist between size and risk (see Laeven, Ratnovski, & Tong, 2016). The balance between efficiency gains through scale economies and the impact of size on risk might be a complex trade-off for managers and directors of cooperatives. Since risk is an inherent factor of cooperative businesses, cooperatives may need an appropriate plan to deal with external shocks such as macroeconomic shocks or yields and price variation in production agriculture.

5. Discussion and Conclusions

This study contributes to literature by estimating economic efficiency with and without risk for agricultural cooperatives during a period of volatile returns in farming sector and a changing financial landscape of agricultural cooperatives. The efficiency analysis of agricultural cooperatives in changing economic environments may shed light on how higher efficiency can be achieved. The methodological advances may enable to better identify the sources of inefficiency for cooperatives. In addition, the study used a non-parametric approach that does not specify functional form on technology, the differences in inefficiency are less prone to misspecification of the cost and profit functions.

This study used the semi-variance of return on equity as a measure of downside risk. Cost and revenue efficiencies were first computed using traditional inputs and outputs and then re-computed accounting for downside risk. Downside risk was included in the estimation of CE and RE as a non-discretionary input. Downside risk is an appropriate measure of asymmetric risk as it focuses on return below a specified target return level (Markowitz, 1959). The semi-variance of return on equity incorporates all deviations below average return on equity and individual agricultural cooperatives with the rate of return on equity below the sample average may experience financial stress.

The average CE score was 0.39 without risk and increased to 0.44 with the inclusion of downside risk. Likewise, the average RE score was 0.20 without risk and the downside risk adjusted RE score was 0.25. The number of cost and revenue efficient agricultural cooperatives increased when CE and RE were adjusted for downside risk. This indicates that the DEA method for estimating CE and RE without accounting for risk overestimates inefficiency. Larger cooperatives were more efficient than smaller cooperatives. This indicates that increasing the size of cooperatives within in the agricultural sector tends to take advantage of economies of scale.

The inclusion of risk in estimating cost and revenue efficiencies helps explain inefficiency. Measuring efficiency without including risk attributes inefficiency to inadequate operations. Understanding the impact of risk in efficiency analysis helps agricultural cooperatives to improve performance in using optimal inputs to produce outputs or maximize revenue with optimal outputs.

The results show that risk is an important factor for the efficiency analysis. Variation in yields in the farming sector affects business volume of cooperatives resulting variable income. Cooperatives cannot directly manage fluctuations in yields to stabilize income. However, cooperatives can use appropriate risk management tools such futures, options, and hedging to mitigate risk. Pokharel, Archer, and Featherstone (2018) found that diversification has a positive impact on the return on equity for agricultural cooperatives. Cooperatives can diversify their business to stabilize income over time. Agricultural cooperatives, particularly small-sized cooperatives benefit from diversification (Pokharel & Featherstone, 2019), cooperatives may include grain sales and farm input supply sales in its portfolio, which may reduce fluctuations in income. While the study shows the impact of risk on economic efficiency in a changing financial environment of cooperatives, more research is required to understand the relationship between risk and scale economies for cooperatives.

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Footnotes

[i] This study follows the notations of Yeager and Langemeier (2013) for the LP programs.
[ii] The results were also analyzed with different asset groups, the conclusion of the study remain the same; larger cooperatives were more efficient than smaller ones (see Pokharel, 2016).