ECONOMIC EFFICIENCY OF OCCUPATIONAL HEALTH AND SAFETY INVESTMENTS AT AGRICULTURAL COOPERATIVES

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Thilani Kaushalya Wearaduwa Vidana Kankanamge

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department:
Agribusiness and Applied Economics

June 2018

Fargo, North Dakota

North Dakota State University
Graduate School

Title

Economic Efficiency of Occupational Health and Safety Investments at Agricultural Cooperatives

By

Thilani Kaushalya Wearaduwa Vidana Kankanamge

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Dr. Erik Hanson
Chair

Dr. Michael Boland

Dr. Frayne Olson

Approved:

7/5/2018	Dr. William Nganje
Date	Department Chair

ABSTRACT

Industries related to agricultural cooperatives record some of the highest injury rates in the U.S. Therefore, agricultural cooperatives are highly motivated to invest in occupational health and safety (OHS). This thesis examines the economic efficiency of OHS investments at agricultural cooperatives and identifies cooperative characteristics leading to greater economic efficiency of OHS investments. A multiple input-output data envelopment analysis (DEA) is used to estimate technical efficiency. The effects of cooperative characteristics on the efficiency of OHS investments are estimated using ordinary least squares, censored regression, truncated regression, and the Simar and Wilson (2007) bootstrap procedure. Results show that the mean technical efficiency score was 0.833. Furthermore, a cooperative's annual insurance premia has a significant, negative relationship with technical efficiency. In contrast, the experience levels of a cooperative's top safety person and top managerial person and a location's total workers employed have significant, positive relationships with efficiency in all estimated models.

ACKNOWLEDGEMENTS

I would like to thank my adviser Dr. Erik Hanson and my graduate committee members Dr. Michael Boland and Dr. Frayne Olson for their guidance in completing this thesis. My special thank goes to agricultural cooperatives who completed the survey. Further, this study is funded by the Department of Agribusiness and Applied Economics at the North Dakota State University. I am very grateful for the department's financial support in completing this thesis. I am also grateful to my family and friends for their encouragement and support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

LIST OF APPENDIX FIGURES

1. INTRODUCTION

1.1. Background

Agriculture is one of the most hazardous industries in the United States (Centers for Disease Control and Prevention, 2018). For example, 593 farmers and farm workers died from work-related injuries in 2016, resulting in a fatality rate of 23.2 deaths per 100,000 workers (U.S. Department of Labor, 2017a).[1] Compared to other industries, farmers and farm workers are at a high risk of experiencing severe injuries and death. Agricultural cooperatives play a significant role in the U.S. economy, especially in rural areas. These firms also experience health and safety challenges similar to those on the farm. However, occupational injuries in agriculture create more public attention than occupational injuries at agricultural cooperatives. Moreover, very few studies look at the economic costs and benefits of occupational injuries at agricultural cooperatives. Therefore, the purpose of this thesis is to estimate the economic efficiency of occupational health and safety (OHS) investments at agricultural cooperatives.

Cooperatives are a unique business model where the firm is owned by its user-members rather than external investors. Agricultural cooperatives may function as marketing, supply, or service cooperatives. Marketing cooperatives are business organizations owned by farmers to collectively sell their products (U.S. Department of Agriculture, 2000). Supply cooperatives provide farmers access to affordable, quality production supplies such as feed, fuel, fertilizer, and seed. Service cooperatives provide support to farmers through production services such as agronomy and crop harvesting or general services including credit provision (U.S. Department of Agriculture, 2002).

[1] Unless otherwise specified, "injuries" is used to represent both injuries and illnesses in this thesis.

In 2016, there were 1,953 agricultural cooperatives in the United States. These cooperatives controlled nearly $92 billion in assets and employed 187,335 workers. Moreover, the total sales volumes of marketing, supply, and sales cooperatives were $104.2 billion, $79.2 billion, and $2.8 billion, respectively, in 2016 (U.S. Department of Agriculture, 2016). Over the past decade, full-time workers at agricultural cooperatives increased by 9.7 percent and total workers increased by 3.2 percent. During the same time period, agricultural cooperatives' net business volume increased by 22.2 percent. Overall, agricultural cooperatives remain an integral part of the U.S. agricultural economy.

1.2. Motivation for Research

1.2.1. The Magnitude of Occupational Injuries at Agricultural Cooperatives

Many agricultural cooperatives belong to North American Industry Classification System (NAICS) industries 1111 (oilseed and grain farming), 1151 (support activities for crop production), 4245 (farm product raw material merchant wholesalers), and 4249 (miscellaneous nondurable goods merchant wholesalers). A comparison of incidence rates between these industries and U.S. private industry may allow us to understand the magnitude of injuries at agricultural cooperatives.[2] Figure 1.1 shows total recordable case (TRC) incidence rates for U.S. private industry and other selected industries.[3] TRC incidents rates for private industry declined by 31 percent between 2007 and 2016 (U.S. Department of Labor, 2007-2016). Over the same period, TRC incidence rates for industries such as support activities for crop production and miscellaneous nondurable goods merchant wholesalers decreased by 19 percent and 20 percent,

[2] Incidence rate is defined as the annual number of injuries per 100 full-time workers and is calculated as: (TRCs ÷ total hours worked by all workers during the calendar year) × 200,000 where 200,000 represents the base for 100 full-time workers who are assumed to work 40 hours per week for 50 weeks per year (U.S. Department of Labor, 2016a).

[3] TRC incidence rate includes work-related injuries that result in death, days away from work, restricted work activity or job transfer, loss of consciousness, and medical treatment beyond first aid (U.S. Department of Labor, 2016a).

respectively. Moreover, the TRC incidence rate for support activities for crop production is almost double the incidence rate for U.S. private industry in 2013 and 2015.

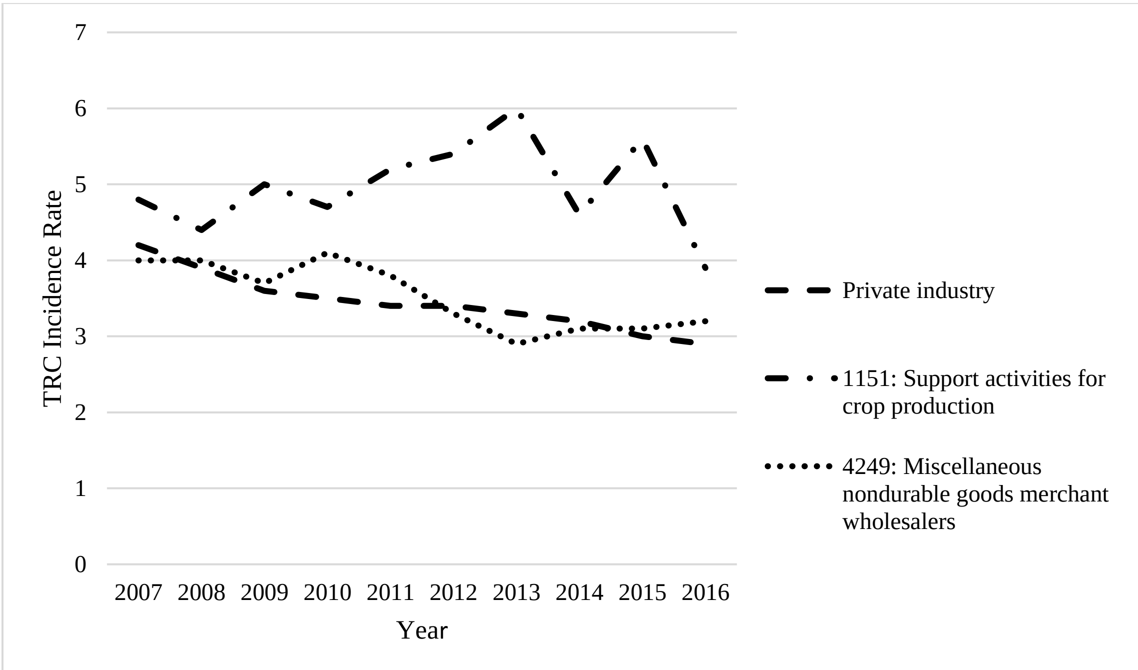


Figure 1.1. TRC incidence rates for U.S. private industry and other selected industries, 2007-2016
Note: Industry classifications 1111 (oilseed and grain farming) and 4245 (farm product raw material merchant wholesalers) are excluded because data were not available for several years.
Source: Industry Injury and Illness Data (U.S. Department of Labor, 2007-2016)

Surveyed agricultural cooperatives, including those analyzed in this thesis, also have high average TRC incidence rates.[4] Figure 1.2 shows the average TRC incidence rate at surveyed agricultural cooperatives from 2012 to 2017. The high average TRC incidence rates in Figure 1.2 confirm that workers at agricultural cooperatives are more likely to experience work-related injuries than those who work in U.S. private industry.

[4] Surveyed agricultural cooperatives include those surveyed by Hanson (2016) and those surveyed for this thesis.

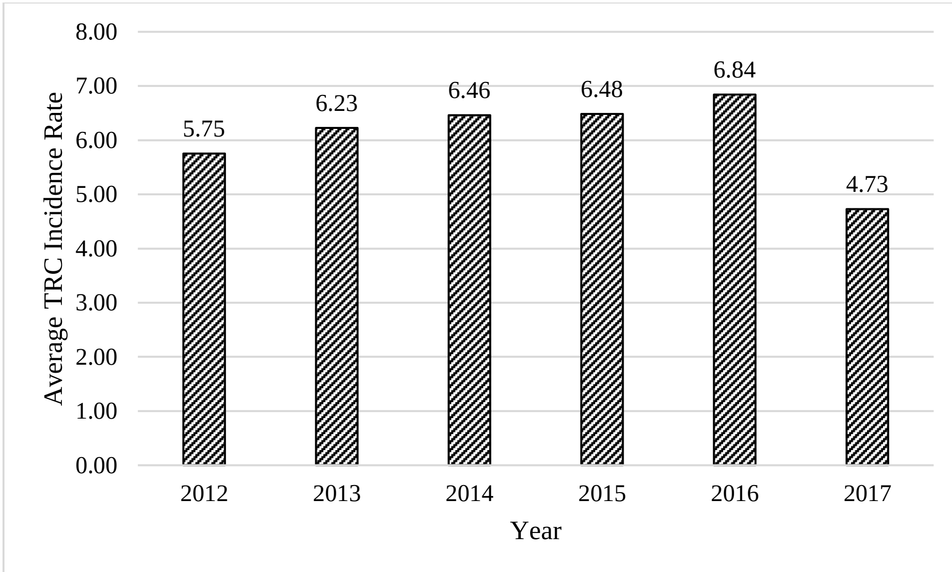


Figure 1.2. Average TRC incidence rates at sampled agricultural cooperatives, 2012-2017
Source: OSHA 300A data from surveyed agricultural cooperatives, 2012-2017

1.2.2. Agricultural Cooperatives' Motivation to Invest in Occupational Health and Safety

Barton, Boland, Chaddad, and Eversull (2011) argue that "irrespective of its purpose and role, a cooperative should strive to be as profitable as possible and then distribute those profits to its patrons" (p.1). Investments in OHS enable agricultural cooperatives to increase their profit margins in multiple ways. A reduction in injuries can decrease the direct costs attached to injuries such as medical expenses, worker's compensation claims, lost production time, equipment repair cost, and worker replacement costs. Several researchers evaluate the relationship between safety interventions and their economic returns. For example, Goetzel, Ozminkowski, Baase, and Billotti (2005) conduct a cost-benefit analysis of Dow Chemical's health program in the United States. The authors find that "even small reductions in health risks for Dow employees would yield large savings in health care costs for the company" (Goetzel et al., 2005, p. 762). Similarly, Thiede and Thiede (2015) examine the economic feasibility of investing in OHS at a shipbuilding company in Bangladesh. The authors find that OHS interventions reduce the direct and indirect costs of injuries.

With the introduction of the Occupational Safety and Health Act in 1970, Congress created the Occupational Safety and Health Administration (OSHA) to ensure safe, hazard-free work environments for all workers in the U.S. (U.S. Department of Labor, n.d.a). OSHA conducts frequent inspections on safety standards. Violations of safety standards result in citations and penalties. For example, U.S. agricultural cooperatives were cited in at least 303 cases with penalty from January 2013 to December 2017.[5] The total value of these initial penalties was nearly $5 million. Table 1.1 shows the frequency distribution of cases by their initial penalty. Although 70 percent of cases were reported with an initial penalty of less than $10,000, nearly 9 percent of cases had an initial penalty greater than $30,000. Therefore, maintaining OSHA standards and reducing occupational injuries may increase profit margins at many agricultural cooperatives.

Table 1.1

Frequency distribution of cases by their initial penalty 2013-2017

Initial Penalty	Frequency	Share of Cases
Less than $10,000	212	69.97%
$10,000-$19,999	44	14.52%
$20,000-$29,999	21	6.93%
$30,000-$39,999	9	2.97%
$40,000 or greater	17	5.61%

Source: U.S. Department of Labor – Establishment Search, 2013 – 2017

Agricultural cooperatives must also purchase insurance to cover their potential liabilities. According to Thomason and Pozzebon (2002), firms with experience-rated workers' compensation aim to reduce their insurance premia. Similarly, firms can reduce the cost of compensating wage differentials by reducing the risk of occupational injuries (Viscusi, 1978). Compensating wage differentials are higher wages paid to attract workers for risky jobs.

[5] See Appendix A and Appendix B for more information on OSHA inspections and types, respectively.

1.3. Problem Statement and Research Question

As discussed previously, agricultural cooperatives play an important role in the U.S. agricultural economy. However, the profitability, and therefore long-term existence of these cooperatives, may be determined in part by the well-being of their workers. Hence, it is crucial to look at occupational injuries among workers at agricultural cooperatives. Industries related to agricultural cooperatives record some of the highest injury rates in the U.S. Therefore, agricultural cooperatives are highly motivated to invest in OHS. This thesis examines the economic efficiency of OHS investments at agricultural cooperatives and identifies cooperative characteristics leading to greater economic efficiency. The findings of this thesis will be insightful for cooperative managers attempting to reduce occupational injuries and minimize the forgone profits caused by injuries.

1.4. Objectives and Hypotheses

The overall objective is to examine the economic efficiency of OHS investments at agricultural cooperatives. More specific objectives are:

1. Categorizing and quantifying the OHS investments being made by agricultural cooperatives;
2. Calculating and evaluating the technical efficiency of OHS investments;
3. Determining the cooperative characteristics associated with efficient OHS investments;
4. Describing the barriers and motivations related to investing in OHS.[6]

The following hypotheses align with the research objectives of this thesis. The research hypotheses are:

[6] Refer to Appendix G for relevant results.

1. A positive relationship exists between efficient OHS investments at agricultural cooperatives and the total experience of the top safety person (e.g. safety director) at the cooperative;
2. A positive relationship exists between efficient OHS investments at agricultural cooperatives and the total experience of the top managerial person (e.g., CEO/general manager) at the cooperative;
3. A positive relationship exists between efficient OHS investments at agricultural cooperatives and the total number of workers at the cooperative;
4. A negative relationship exists between efficient OHS investments at agricultural cooperatives and the total annual insurance premia paid by the cooperative.

1.5. Organization of the Thesis

Chapter one of this thesis provides this study's rationale, research problem, and research objectives. Chapter two reviews existing literature and identifies research gaps. Chapter three presents a detailed methodology illustrating the theoretical and empirical models used in this study. Results are discussed in chapter four, which is followed by a summary and conclusion in the fifth and final chapter.

2. LITERATURE REVIEW

This chapter elaborates on literature relevant to OHS. The first part of this literature review explains safety culture and its relevance to safety performance at agricultural cooperatives. Firm and employee characteristics associated with occupational injuries at the firm level are also discussed. The second part of this literature review focuses on the economic efficiency of safety investments at the firm level. The final part of this literature review highlights gaps in the literature that will be addressed by this thesis. This literature review draws on economics, medicine, sociology, and safety science disciplines.

2.1. Safety Culture and Safety Performance

The relationship between accidents and managerial or organizational failures is widely acknowledged (Kennedy & Kirwan, 1998). Regulatory bodies emphasize the importance of a positive health and safety culture for creating better safety performance for companies (Clarke, 1999). Constructing a common definition for safety culture is challenging because of its subjective nature and measurement issues related to safety culture. Many scholars identify safety culture as a sub-element of overall organizational culture and broadly define it as a set of beliefs and values that refer specifically to matters of health and safety (Clarke, 1999; Kennedy & Kirwan, 1998). Pidgeon (1991) provides a more comprehensive definition of safety culture as "the set of beliefs, norms, attitudes, roles, and social and technical practices that are concerned with minimizing the exposure of employees, managers, customers and members of the public to conditions considered dangerous or injurious" (p.134).

Researchers claim that senior managers' attitudes and behaviors regarding the safety and well-being of workers form the basis for the safety behavior of workers, thereby influencing safety performance. Specifically, these positive social forces will act upon the individual worker's cognitions, perceptions, and behavior in relation to health and safety at work, resulting in reduced accidents (Clarke, 1999). Positive safety culture can be used as an effective tool for improving the safety performance of any organization. The challenge is developing a culture that promotes good safety performance (Choudhry, Fang, & Mohamed, 2007). Hale (2000) lists elements of a good safety culture including: workers, and particularly top managers, giving importance to safety; workers feeling involved in the process of defining, prioritizing and controlling risk; appropriate safety staff roles; open communication about failures and potential dangers at the workplace.

Risch, Boland, Crespi, and Leinweber (2014) examine the relationship between safety culture and safety performance. They also identify determinants of safety culture at agricultural cooperatives. Following Oi (1974), the authors define the safety performance of a firm as a function of safety culture and safety investment. The authors find that "investments in labor inputs such as increased training, consistent discipline, and recognition of safety achievements all increase safety culture" (Risch et al., 2014, p.1). In addition, improvements in employee perceptions of safety culture have a positive impact on reducing employee injuries (Risch et al., 2014). Hanson (2016) finds similar results, providing further evidence that investing time and financial resources into safety system elements generates improved safety culture.

2.2. Firm Characteristics and Occupational Injuries

Firm leadership is considered to be an important part of effective safety management. Safety responsibilities vary according to management level. For example, Flin and Yule (2004) find that the most effective leadership style for senior managers is transactional, meaning leaders creating compliance through incentives and punishments. In addition, senior managers needs to demonstrate a visible and continuous commitment on safety. Middle managers needs to engage in open communication and ensure compliance with safety systems. Moreover, middle managers must allow supervisors a degree of freedom for safety initiatives (Flin & Yule, 2004).

Some research shows an association between firm size and work place injury rates (Leigh, 1989; McVittie, Banikin, & Brocklebank, 1997). Evidence shows that injury frequency and firm size are negatively related, meaning larger firms have lower injury rates than small firms (Fenn & Ashby, 2004; McVittie et al., 1997). In-house health and safety experts, access to external occupational health and safety support services, and effects of scale are some reasons for low injury rates at large firms (McVittie et al., 1997). In contrast, Leigh (1989) finds that in the manufacturing sector, “very small firms (1-19 employees) and very large firms (1,000 employees or more) have the fewest injuries and illnesses, and medium sized firms, 20 to 999 employees, have the most” (Leigh, 1989, p.44). Leigh (1989) suggests that small firms are more likely to under-report workplace injuries as OSHA standards are not as strict for small firms. Furthermore, small firms are often owner-operated and they may want to maintain a high level of safety since the owner-operator is also exposed to dangers. Small firms may also hand-pick their employees from among friends and relatives, perhaps because of their overall good health and safety awareness (Leigh, 1989).

2.3. Worker Characteristics and Occupational Injuries

Work-place injuries are often associated with worker characteristics. Multiple studies find that occupational injury risk varies with worker age (Breslin, Koehoorn, Smith, & Manno, 2003; Hard & Myers, 2006; Mitchell, 1988). Based on a descriptive analysis, Hard and Myers (2006) find that 15 year olds have the highest fatality rates in the crop production sector, a rate which is six times higher than that of all 15-year-old workers. Similarly, using 1980 data, Mitchell (1988) finds that there is a negative, significant relationship between the age of the worker and the worker's injury risk. Moreover, Mitchell finds that the risk of occupational injuries is highest among very young workers rather than old workers. According to Mitchell, workers under 25 years old are more vulnerable to work injuries than their more senior counterparts, although these injuries are often temporary. In contrast, she finds that older workers are more likely to suffer from serious job-related injury risks. Mitchell reports that permanent disabilities and fatalities are 1.1 percent and 1.6 percent higher, respectively, for workers age 65 and above compared to workers of the sample average age.

Evidence shows that both age and experience influence work injuries (Butani, 1988; Oh & Shin, 2003). Based on a 1986 study of U.S. mining workers, Butani (1988) finds that a worker's experience with their current employer plays a more significant role regarding occupational injury rates than the worker's age. Moreover, the author finds that extremely inexperienced (1 year or less of experience) workers are at high risk for occupational injuries regardless of their age. In contrast, Butani (1988) indicates that workers with more than 15 years of experience are at low risk for occupational injuries.

Human capital is also associated with work place injuries. According to Oh and Shin (2003), education level is significantly associated with non-fatal work place injuries. The authors find that employees with 15 or fewer years of schooling are more than twice as likely to experience non-fatal occupational injury compared to more educated employees (Oh & Shin, 2003).

Several researchers find mixed results when looking at how gender differences affect occupational injuries. Islam, Velilla, Doyle, and Ducatman (2001) explore gender using 1996 workers compensation data from West Virginia. They find significantly lower injury or illness rates for females in all major industries except for service and agriculture. In addition, compared to males, a greater proportion of females were observed with back, ankle, hand, neck, shoulder, and wrist injuries. Moreover, the U.S. Department of Labor claims that women experience fewer job-related injuries and deaths than men (U.S. Department of Labor, 1988). Recent statistics from the U.S. Department of Labor show similar results (U.S. Department of Labor, 2017b; U.S. Department of Labor, 2016b).

Exposure to occupational injuries varies based on whether an employee is seasonal, full-time, or part-time (Benavides et al., 2006; Risch et al., 2014). For example, Risch et al. (2014) find that seasonal employees are associated with higher accident rates at agricultural cooperatives. The authors contend that this could be due to seasonal employees receiving less training than full-time employees and not performing their tasks routinely.

2.4. Economic Efficiency of Safety Investments at Agricultural Cooperatives

Comprehensive economic assessments of safety investments are uncommon in the existing literature. Scholars from disciplines such as medicine, safety science, and management have looked at these economic aspects mostly using cost-benefit analyses based on pre-intervention and post-intervention data (Oxenburgh & Marlow, 2005; Tengs et al., 1995; Thiede & Thiede, 2015). Difficulty in collecting firm level data and the ambiguous nature of safety intervention costs and benefits are reasons for limited economic analysis.

Few researchers have looked at safety investments using an efficiency approach. From an efficiency perspective, the optimal safety level is identified at the point where marginal prevention cost equals marginal damage cost (Henderson, 1983; Tang, Lee, & Wong, 1997).[7] Although data envelopment analysis (DEA) does not identify this optimal safety level, it

[7] Marginal prevention cost is the additional prevention cost caused by an increase in safety level. Marginal damage cost is the additional damage cost caused by a decrease in safety level. These concepts are discussed in greater detail in chapter 3.

calculates relative efficiency scores based on an efficient frontier. Details of the DEA method are discussed in chapter 3. Hanson (2016) applies DEA to analyze and understand the technical efficiency of safety investments at agribusiness retailers.

This study will build upon previous research by investigating the economic efficiency of safety interventions through an efficient frontier model, DEA, which involves linear programming. In addition, this study will identify cooperative characteristics which lead to efficient safety investments.

3. METHODOLOGY

3.1. Theoretical Background

This section describes a theoretical background for the economic efficiency of safety investments. Considering the efficiency perspective, firms have the simple objective of minimizing the costs of occupational injuries. Henderson (1983) argues that two conditions need to be satisfied to achieve this objective. First, the costs involved need to include both opportunity costs and direct financial expenses. In economics, opportunity cost is defined as the value of the next best alternative choice. Second, the total cost of injury must include both post-factum and ante-factum costs and the sum of these costs needed to be minimized. Post-factum costs of an injury occur after an accident (e.g., medical costs and reduced production) and can simply be called damage costs. Ante-factum costs are involved in preventing accidents (e.g., safe equipment and safety procedures) and can simply be called prevention costs. The author further argues that ante-factum costs also include opportunity costs and thereby such opportunity costs must be included in the total cost of occupational injuries (Henderson, 1983).

Figure 3.1 shows that as the level of safety increases prevention cost also increases. A higher level of safety can be achieved by allocating more resources to occupational health and safety. Note that the prevention cost illustrated in Figure 3.1 increases at an increasing rate. This occurs because, once a certain level of safety is achieved, it becomes increasingly difficult to further increase the level of safety. Therefore, further increases in safety levels are costly. In contrast, damage cost decreases as the level of safety increases. This occurs because, as the level of safety increases, the probability of a worker experiencing an injury is reduced or the severity of an injury is lessened. In addition, damage cost declines at a decreasing rate (Henderson, 1983).

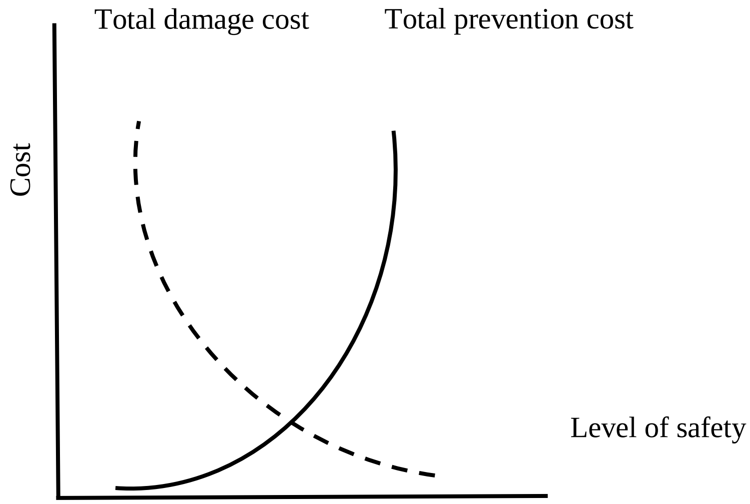


Figure 3.1. Level of safety vs. total damage cost and total prevention
Source: Henderson, 1983, p. 78

The minimum total safety cost (i.e., the summation of prevention cost and damage cost) occurs at the point where the marginal prevention cost equals the marginal damage cost. This point is marked as S^* in Figure 3.2. At levels of safety lower than S^*, total costs can be reduced by increasing safety, because a marginal increase in safety will reduce the damage cost by more than it will add to the prevention cost. At levels of safety higher than S^*, total costs can be reduced by reducing safety, because a marginal decrease in safety will reduce the prevention cost by more than it will add to the damage cost. Therefore, a firm with a cost minimization objective must achieve safety level S^* for that firm to be considered cost efficient (Henderson, 1983).

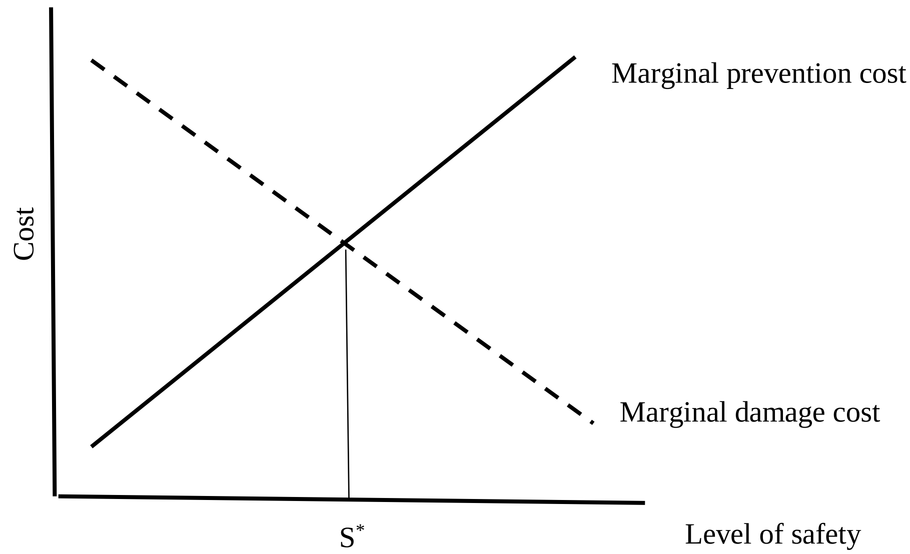


Figure 3.2. Level of safety vs. marginal prevention cost and marginal damage cost
Source: Henderson, 1983, p. 79

3.2. Technical Efficiency of Safety Inputs and Outcomes

Conventional production theory in economics can be applied to define technical efficiency between safety inputs and safety outcomes. For simplicity, assume a firm with a single safety input and a single safety outcome. The relationship between the safety input and safety outcome can be mathematically represented as:

$$O = f(I) \qquad (3.1)$$

where O is the level of the safety outcome and I is the level of safety input being employed. Equation 3.1 describes the level of a safety outcome a firm can achieve using a given level of safety input. Similar to a production function, the safety input-outcome relationship also depends on exogenous technological conditions. Specifically, safety technologies are a key determinant of safety performances. Over time, technology may improve and shift the safety input-outcome relationship upward.

Figure 3.3 depicts the safety input-outcome relationship graphically. It helps to identify firms with technically efficient and inefficient safety investments. The safety outcome set is made up of points on or below the specified function (frontier). This set depicts the technically feasible (observed) combinations of safety inputs and outcomes. Points such as A and B in the Figure 3.3 are technically inefficient because, at these points, the firm achieves a lower level of safety outcome from a given quantity of safety input than it could achieve. Points similar to C and D on the frontier are technically efficient. At these points, compared to other observations, the firm achieves the maximum possible level of safety outcome at a given quantity of safety input.

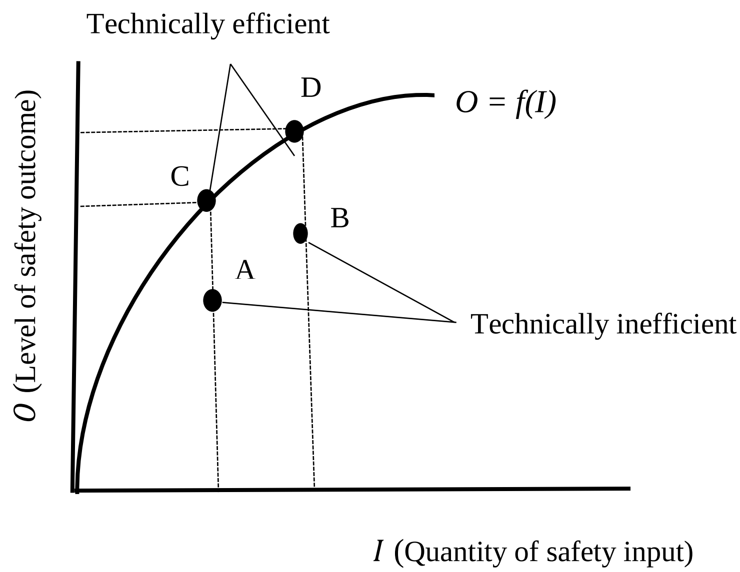


Figure 3.3. Technical efficiency and inefficiency of safety input and outcome

A firm's technical efficiency can be explained through an input-oriented approach or an output-oriented approach. The input-oriented approach determines the minimum amount of safety input required to achieve a given level of safety outcome. Mathematically, the input-oriented efficiency function is represented by the inverse of equation 3.1:

$$I = g(O) \tag{3.2}$$

Equation 3.2 is known as an input requirement function. In contrast, the output-oriented approach determines the maximum amount of safety outcome that could be achieved using a given set of safety inputs. This thesis uses an input-oriented approach because firms have more control of safety inputs than safety outcomes and the input-oriented approach may create results that are easier to interpret.

3.3. Measuring Technical Efficiency

Over the past decades, the concept of frontier is the focus of methods in measuring technical efficiency. This section discusses the theoretical background of the DEA method. Advantages and disadvantages of DEA are also discussed in this section.

3.3.1. Data Envelopment Analysis

DEA is used to estimate frontier functions and evaluate the relative efficiencies and inefficiencies of peer decision-making units (DMUs) (Zhu & Cook, 2007) . In DEA models, the unit of analysis is the DMU. Generally, a firm is a DMU which produces outputs using inputs. DEA involves mathematical programming methods, specifically linear programming. Charnes, Cooper, and Rhodes (1978) first used the term DEA and proposed a model for input-oriented technical efficiency, where they assumed constant returns to scale (CRS). The CRS assumption is only appropriate when all DMUs are operating at an optimal scale. But this restrictive assumption does not hold in the real world where a DMU often operates at sub-optimal scale (Coelli, Rao, O'Donnell, & Battese, 2005). The use of a CRS model when some DMUs are not operating at the optimal scale can cause the technical efficiency measure to be confounded by scale efficiencies (Coelli et al., 2005). Hence, accounting for variable returns to scale (VRS) as suggested by Banker, Charnes, and Cooper (1984) permits the calculation of pure technical efficiency measures.

Figure 3.4 illustrates a simple example that differentiate CRS and VRS. Assume there are five firms, labeled A through E, achieving various safety outcome levels, O, using various safety input levels, S. Using an input-oriented approach, firm C is the only efficient firm if CRS is assumed. However, firms A, C, and E are technically efficient if VRS is assumed. Firms B and D are inefficient under both CRS and VRS technologies (Coelli et al., 2005).

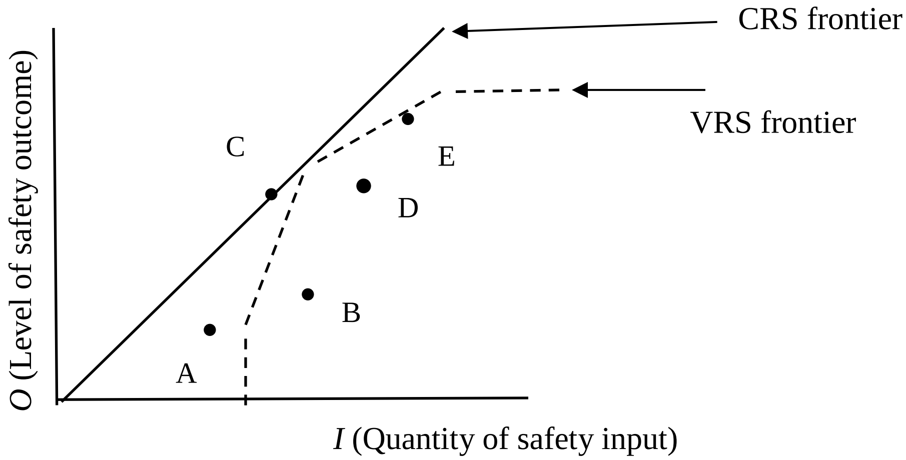


Figure 3.4. Input-oriented DEA for VRS and CRS
Source: Coelli et al., 2005, p. 175

DEA models do not impose a specific functional form on safety inputs and safety outcomes. In addition, DEA models can be applied to multiple safety inputs and multiple safety outcomes. Safety inputs and outcomes described with different units can also be incorporated into DEA models without any transformation. However, DEA models are non-parametric and therefore cannot test hypotheses. Moreover, the omission of important safety inputs and outcomes may result in biased efficiency scores. Another issue is the non-stochastic (i.e., deterministic) nature of the DEA frontier, which does not account for measurement errors and other forms of statistical noise. Therefore, all deviations from the frontier are considered to be a result of technical inefficiency (Coelli et al., 2005). As a solution to this limitation, stochastic frontier analysis (SFA) introduces another random variable to represent statistical noise. However, the SFA model is not applicable to this thesis due to the complex nature of safety inputs and safety outcomes. Specifically, there are both favorable and unfavorable safety outcomes in the model. In SFA the inefficiency term for both favorable and unfavorable safety outcomes cannot be included in the same functional specification.

3.3.2. DEA with Undesirable Outputs

A conventional DEA model assumes that the DMU desires to minimize inputs and maximize outputs. However, in reality some undesirable outputs are often present in the production function. These undesirable outputs should be reduced to improve efficiency in the production function. Undesirable outputs also need to be treated differently in evaluating production performances. There are several approaches to treat undesirable outputs in a DEA model (Zhu & Cook, 2007). One such approach treats undesirable outputs as inputs and therefore seeks to minimize those undesirable outputs rather than maximize them. However, Seiford and Zhu (2002) argue that the resulting DEA model does not reflect the true production process.

Another approach to undesirable outputs is the hyperbolic output efficiency measure developed by (Faere, Grosskopf, Lovell, & Pasurka, 1989). This approach aims to increase desirable outputs and decrease undesirable outputs simultaneously. Faere et al. developed non-linear transformation for both with a strongly disposable technology and a weakly disposable technology.

Seiford and Zhu (2002) developed a linear transformation for undesirable outputs in the DEA model. Two approaches for transforming undesirable outputs are a linear monotone decreasing transformation and a nonlinear monotone decreasing transformation. However, a non-linear transformation will disrupt the convexity relationship. Therefore, Seiford and Zhu suggest a linear monotone decreasing transformation. The authors propose a transformed undesirable outputs vector, O_j^*, defined as:

$$O_j^* = -O_j + v \geq 0 \tag{3.3}$$

where O_j is the original bad output vector, and v is a translation vector that satisfies $O_j^* > 0$. This translation vector converts negative data to non-negative data. This thesis uses the linear transformation in equation 3.3 for undesirable safety outcomes.

3.3.3. Simar and Wilson Bootstrap Procedure for Explanatory Variables

Many researchers use a two-stage procedure to identify and estimate the exogenous factors that might affect firms' efficiency performances. Researchers regress efficiency scores on explanatory variable using ordinary least square (OLS), censored regression (tobit), or truncated regression. However, Simar and Wilson (2007) argue that inferences made from the aforementioned two-stage procedures are invalid due to the complicated, unknown correlation among the estimated efficiencies. The authors propose a single or double bootstrap procedures, both of which permit valid inferences. Moreover, the double bootstrap procedure improves statistical efficiency in the second-stage regression (Simar & Wilson, 2007). The Simar and Wilson (2007) procedure constructs and simulates a sensible data generating process, resulting in independent and identically distributed bootstrap samples from an artificial data generating process. Once efficiency scores are estimated, the Simar and Wilson procedure uses a truncated regression to estimate coefficients and standard errors for explanatory variables.

3.4. Empirical Models

The linear program model for the input-oriented DEA with VRS is:

$$Min\ \Theta$$

$$Subject\ to: \qquad (3.4)$$

$$\sum_{j=1}^{n} \lambda_j I_{ij} \leq \Theta I_i,\ \forall_i$$

$$\sum_{j=1}^{n} \lambda_j O_{rj} \geq O_{ro}, \forall_r$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0,\ \forall_j$$

where *n* is the total number of DMUs, I_{ij} and O_{ij} are safety input and safety outcome components, respectively, for the *j*th DMU, *i* represents the number of safety inputs and *r* represents the number of safety outcomes in the model forming safety input and outcome matrixes of I_{ij} and O_{ij}, respectively, λ_j is a non-negative scalar, and Θ represents the efficiency score of a DMU. The value of Θ varies from 0 to 1, where 1 indicates a point on the frontier and hence a technically efficient DMU. In contrast, Θ equal to 0 represents the least efficient DMU (Coelli et al., 2005).

The effect of cooperative characteristics that may determine the efficiency of OHS investments are estimated using OLS, censored regression, truncated regression, and the Simar and Wilson (2007) bootstrap procedure. The following regression specification is used for the OLS:

$$\theta_j = \beta_{0j} + Z_{1j} + Z_{2j} + Z_{3j} + Z_{4j} + \varepsilon_j \qquad j = 1, \ldots, n \qquad (3.5)$$

where θ_j is the *j*th DMU's technical efficiency score, β_0 is the constant term, Z_1 is the natural log of annual premium paid, Z_2 is the total experience of the cooperative's top safety person, Z_3 is the total experience of the cooperative's top manager, Z_4 is the total number of workers employed by the cooperative location, and ε_j is the error term.[8]

3.5. Data Sources and Model Variables

Primary data were gathered from three agricultural cooperatives using an online survey during early 2018.[9] Surveyed cooperatives are involved in farm supply, farm product marketing, and other business lines such as retail nurseries and garden supply. Each cooperative had six to twenty business locations, resulting in a total sample size of 44 business locations. The unit of analysis, or DMU, examined in this study is the business location. Two separate surveys were distributed with the top safety personal and the top managerial person at each agricultural cooperative in order to increase the reliability of safety and financial data.[10] The reported data are relevant to 2017. In addition, occupational injury data were gathered from each business location using OSHA 300 and OSHA 300A forms.[11]

A low response rate is one of the key limitations of data. In addition, inability to gather firm characteristics at each business location is another limitation of data. For example, in the DEA model, data for safety outcome variables were gathered at cooperative location level and safety input data were adjusted to each cooperative location based on their total number of workers. However, cooperative characteristics such as experience of the safety director and the

---

[8] Regression specifications for the tobit, truncated, and the Simar and Wilson bootstrap procedure regressions are similar to the functional specification of OLS represented by equation 3.5.

[9] A cooperative which had 40 cooperative locations were removed from the above two-input, three-output DEA model due to missing data for the variable, *OHS PERSONNEL INVESTMENT* (I_1). A similar DEA model was estimated without the input variable I_1 to test for robustness of results. Appendix I includes a summary of results obtained for all 84 DMUs included in that estimation.

[10] Appendix C and Appendix D include the surveys that were distributed.

[11] Appendix E and Appendix F includes OSHA 300 and OSHA 300A forms, respectively.

experience of the top managerial person were gathered at cooperative level. Gathering cooperative characteristics at the business location level is challenging. However, such data will provide more reliable results.

The estimated DEA model includes three safety outcome variables and two safety input variables[12]. The first safety outcome variable is *UNINJURED WORKERS* and it is calculated by subtracting a cooperative location's total injuries from its annual average number of workers. The second safety outcome variable is *TOTAL DART DAYS* and it is calculated by adding a cooperative location's total number of days away from work and total number of days with job transfer or restriction caused by workers' occupational injuries. The third safety outcome variable is *DART INJURIES* and it is defined as a cooperative location's annual injuries requiring days away from work, work restriction, or job transfer. Unlike *UNINJURED WORKERS*, *TOTAL DART DAYS* and *DART INJURIES* are bad safety outcomes. Therefore, the variables for *TOTAL DART DAYS* and *DART INJURIES* were transformed according to Seiford and Zhu (2002). Refer to section 3.3.2 for further detail on the transformation process.

The first safety input variable, *OHS PERSONNEL INVESTMENT*, includes a cooperative location's annual expenditures for salaries and consultancy fees paid to workers involved in OHS. The second safety input variable, *OHS SYSTEM INVESTMENT*, includes a cooperative location's annual expenditures for safe machinery and equipment, safety meetings and safety trainings, etc.

[12] Refer to Table 3.1 for definitions and data sources for the variables used in the DEA model.

Table 3.1

Definitions and data sources for DEA model variables

Variable (Symbol)	Definition	Data Source
UNINJURED WORKERS (O_1)	Cooperative location's annual average number of workers less total injuries	OSHA 300A
TOTAL DART DAYS (O_2)	Cooperative location's total number of days away from work plus total number of days with job transfer or restriction (days)	OSHA 300A
DART INJURIES (O_3)	Cooperative location's annual injuries requiring days away from work, work restriction, or job transfer	OSHA 300A
OHS PERSONNEL INVESTMENT (I_1)	Cooperative location's annual expenses for salaries and consultancy fees paid to workers involved in OHS	Survey
OHS SYSTEM INVESTMENT (I_2)	Cooperative location's annual expenses for safe machinery, safety meetings, training, etc.	Survey

Four cooperative characteristics are used analyze the efficiency of OHS investments. Table 3.2 includes definitions and data sources for the efficiency determinant variables. The first variable, *PREMIUM*, is the log of annual insurance premium paid by each cooperative location.[13] It is expected that higher insurance premiums are negatively associated with safety performances at cooperatives and the expected sign of the coefficient *PREMIUM* is negative. Intuitively, one could argue that the experience of the cooperative's top OHS person and the cooperative's top manager has a positive effect on occupational safety provision. Therefore, the expected signs of the variables *SD EXPERIENCE* and *GM EXPERIENCE* are positive. The variable *WORKERS* represents the total number of workers employed at a cooperative location. The existing literature provides mixed results for the effect of total number of workers on OHS. Therefore, the expected sign of the variable *WORKERS* cannot be predicted.

[13] *PREMIUM* was log-transformed to minimize scale-related issues in the data.

Table 3.2

Definitions and data sources for efficiency determinant model variables

Variable	Definition	Expected Sign	Data Source
PREMIUM (LOG)	Log of annual insurance premium paid	(-)	Survey
SD EXPERIENCE	Total years of experience of cooperative's top OHS person (e.g., safety director)	(+)	Survey
GM EXPERIENCE	Total years of experience of cooperative's top manager (e.g., general manager)	(+)	Survey
WORKERS	Total number of workers employed at a cooperative location	(+/-)	Survey

Table 3.3

Summary statistics for DEA model variables

Variable (symbol)	Observations	Mean	Standard Deviation	Min	Max
UNINJURED WORKERS (O_1)	44	14.32	13.65	1	69
TOTAL DART DAYS (O_2)	44	94.30	26.03	1	108
DART INJURIES (O_3)	44	3.48	0.76	1	4
OHS PERSONNEL INVESTMENT (I_1)	44	5,500	8,175.83	333.33	51,764.15
OHS SYSTEM INVESTMENT (I_2)	44	2,215.91	2,927.34	37.74	11,520

Table 3.4

Summary statistics for efficiency determinant model variables

Explanatory variable	Observations	Mean	Standard Deviation	Min	Max
PREMIUM (LOG)	44	10.30	1.08	7.71	12.86
SD EXPERIENCE	44	11.59	2.89	9	15
GM EXPERIENCE	44	6.36	9.91	2	31
WORKERS	44	15.27	14.31	1	71

4. RESULTS AND DISCUSSION

This chapter discusses the results obtained from estimating the models outlined in the preceding chapter. In the first section of this chapter, the technical efficiency of OHS investments is discussed. Specifically, input-oriented efficiency scores estimated by the DEA procedure are interpreted. Output-oriented technical efficiency scores are also estimated for comparison purposes. The second section of this chapter is used to discuss the effects of business location characteristics that may determine the efficiency of OHS investments. Results generated from OLS, censored regression, truncated regression, and the Simar and Wilson (2007) bootstrap procedure are used for this purpose.

4.1. Technical Efficiency of OHS Investments

CRS and VRS technical efficiency scores were estimated for 44 DMUs using input-oriented and output-oriented DEA. In input-oriented DEA, the mathematical linear programming model is solved to determine how much the input level used by a firm could be reduced without contracting the output, assuming inputs are used as efficiently as firms along the best practice frontier. In contrast, output-oriented DEA solves the mathematical linear program to determine a firm's potential output expansion given its current use of inputs if it operates as efficiently as firms along the best practice frontier. Summary statistics of the technical efficiency scores of input-oriented and output-oriented DEA with CRS and VRS assumptions are given in Table 4.1. The linear programming model has three outputs including a favorable output and two unfavorable outputs. Hence, interpreting the output-oriented DEA may be confusing. Furthermore, the CRS scale assumption of technical efficiencies is confounded by scale efficiencies, while the VRS assumption produces a pure technical efficiency measure. For these reasons, the subsequent analysis uses the input-oriented DEA efficiency scores with the VRS assumption.

Table 4.1

Summary statistics for technical efficiency scores

Technical Efficiency Score	Total number of DMUs	Mean	Standard Deviation	Min	Max
CRS (Input-oriented)	44	0.805	0.154	0.530	1.000
VRS (Input-oriented)	44	0.833	0.149	0.549	1.000
CRS (Output-oriented)	44	0.805	0.154	0.530	1.000
VRS (Output-oriented)	44	0.962	0.066	0.750	1.000

The average input-oriented technical efficiency (VRS) of OHS investment for the sample is 0.833. That is, on average, each DMU can contract inputs by 16.70 percent without sacrificing the current output, if the inputs are used efficiently similar to DMUs on the frontier. The average output-oriented technical efficiency (VRS) of OHS investment for the sample is 0.962, implying that, on average, firms can increase output by 3.8 percent given current input. The standard deviation of the input-oriented technical efficiency (VRS) scores is 0.15, while the minimum efficiency score is 0.549.

Frequency distributions of the input-oriented VRS and CRS efficiency scores for OHS investments are given in Table 4.2. Under the CRS assumption, many DMUs have an efficiency ranging from 0.6 to 0.69. Out of 44 cooperative locations, 12 locations are operating in this range. Under the VRS assumption, many DMUs are operating on the frontier with a technical efficiency score of one. The number of DMUs on the frontier with the VRS assumption is higher than the number of firms on the frontier under the CRS assumption. This is expected because the CRS assumption results in a lower estimate of input utilization than VRS.

Table 4.2

Frequency distribution of technical efficiency scores

	Input-oriented DEA (VRS)		Input-oriented DEA (CRS)	
Technical Efficiency	Frequency	Share of DMUs	Frequency	Share of DMUs
0.50-0.59	3	6.82	3	6.82
0.60-0.69	8	18.18	12	27.27
0.70-0.79	5	11.36	6	13.64
0.80-0.89	10	22.73	7	15.91
0.90-0.99	6	13.64	8	18.18
1.00	12	27.27	8	18.18

In general, many DMUs analyzed are operating efficiently. This could be as a result of small sample size, because a small number of DMUs in a DEA model may result in over estimation of efficiency (Zhu & Cook, 2007). In addition, it is possible that surveyed cooperative locations are allocating their safety investments efficiently.

Descriptive statistics for the efficiency scores indicate that there is substantial variation in the technical efficiency of OHS investment in the sample. While the efficiency scores give an idea of the overall efficiency of the sample and the distribution of the technical efficiency in the sample, they do not provide much information of the factors that determine the technical efficiency. The next section of this chapter analyzes the effects of cooperative characteristics on the technical efficiency of OHS investments.

4.2. Identifying Determinants of Technical Efficiency

Second-stage regressions to identify determinants of technical efficiency were run using four methods: OLS, truncated regression, tobit or censored regression, and the Simar and Wilson (2007) procedure. As noted earlier, Simar and Wilson (2007) argue that using OLS, tobit regression, or truncated regression in the two-stage procedure produces inaccurate inferences due to a weak statistical theoretical background of the data generating process of DEA. However, for comparison purpose all four methods are used in this thesis.

4.2.1. Testing for Heteroscedasticity and Multicollinearity of the OLS Specification

The OLS specification was tested for heteroscedasticity using the Breusch-Pagan/Cook-Weisberg test.[14] The test statistic, which is based on a Chi-squared distribution, had a value of 0.85, which is not significant. Hence, the null hypothesis of constant error variance cannot be rejected and White's procedure was not applied to correct standard errors.

The variance inflation factor (VIF) was used to detect the possible linear dependencies following Mansfield and Helms (1982). The mean VIF is below the rule-of-thumb threshold of 10. In addition, individual variables also had VIFs below 10. Hence, it is concluded that the specifications do not suffer from the adverse effects of multicollinearity.[15] VIF results are given in Table 4.3.[16]

Table 4.3

VIF scores of determinant variables

Variable	VIF	1/VIF
PREMIUM (LOG)	4.500	0.222
SD EXPERIENCE	1.430	0.700
GM EXPERIENCE	1.350	0.741
WORKERS	3.510	0.285
Mean VIF	2.700	

[14] This test was conducted using the hettest command in STATA.
[15] Explanatory variables representing total annual safety trainings, total annual internal safety investigations, use of paid safety consultants, networking with other OHS personnel, and safety recognition were omitted from the model due to multicollinearity.
[16] VIFs were obtained using the vif command in STATA.

4.2.2. Determinants of Technical Efficiency of OHS Investments

In determining the factors affecting the technical efficiency of OHS investments, technical efficiency scores obtained from an input-oriented DEA with a VRS assumption were regressed on four explanatory variables: the natural logarithm of annual insurance premium paid, the experience of the safety director, the experience of the cooperative's top manager, and the total number of workers at each business location.[17] In addition, each specification includes a constant term. For comparison purposes, technical efficiency scores obtained with the CRS input-oriented DEA were regressed on the same explanatory variables and a constant. More DMUs are efficient with the VRS assumption than with the CRS assumption. For this reason, in truncated regression, tobit regression, and the Simar and Wilson (2007) procedure more DMUs are excluded in VRS than in CRS as the upper limit is taken as one.

Regression results for the VRS models' technical efficiency scores are given in Table 4.4. All of the models are statistically significant. In addition, all the explanatory variables are consistently significant in all the models estimated. While the variable *PREMIUM* has a negative effect on the efficiency of OHS investments, the variables *SD EXPERIENCE*, *GM EXPERIENCE*, and *WORKERS* have a positive effect. The coefficients and standard errors in the truncated and Simar and Wilson (2007) regressions are nearly equal. The OLS and tobit regressions yield coefficients with smaller magnitudes than the coefficients obtained from the truncated and the Simar and Wilson (2007) regressions. For the remainder of this chapter's

[17] A location's business lines may be an important determinant for OHS investment efficiency. Therefore, the model specification explained in equation 3.5 was further improved by adding a group of dummy variables to represent a location's business lines. Refer to Appendix H for further details and results.

analysis, the Simar and Wilson regression outcomes are used due to the strong empirical rationale for the method's accuracy.[18]

Table 4.4

Determinants of input-oriented DEA efficiency scores (VRS)

Description	(1) OLS	(2) Truncated	(3) Tobit	(4) Simar-Wilson
PREMIUM (LOG)	-0.0720**	-0.180***	-0.174***	-0.180***
	(0.030)	(0.051)	(0.049)	(0.051)
SD EXPERIENCE	0.038***	0.040***	0.051***	0.040***
	(0.006)	(0.006)	(0.008)	(0.007)
GM EXPERIENCE	0.007***	0.013***	0.0118***	0.013***
	(0.001)	(0.00)	(0.003)	(0.003)
WORKERS	0.006***	0.0203***	0.0163***	0.020***
	(0.002)	(0.005)	(0.004)	(0.005)
CONSTANT	0.993***	1.839***	1.743***	1.839***
	(0.256)	(0.408)	(0.394)	(0.409)
SIGMA	-	0.070***	0.110***	0.070***
		(0.009)	(0.015)	(0.009)
Observations	44	32	44	32
R-squared	0.576	-	-	-
LR chi2(4)	-	57.67	40.300	58.01
Prob > chi2	-	0.000	0.000	0.000

Note: Standard errors are showed inside parentheses; *, **, and *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

As expected, the coefficient associated with the variable *PREMIUM* is negative. The negative coefficient of -0.18 implies that for a 10 percent increase in the insurance premium paid, the technical efficiency score is reduced by 0.02. In other words, higher insurance premia paid by a cooperative are associated with lower efficiency of OHS investments, which supports an intuitive argument. However, one could counter-argue that the variable *PREMIUM* exhibits

[18] Even though the Simar and Wilson (2007) procedure is theoretically-desirable because it produces valid inferences, inferences made in this thesis could be invalid because a small sample size weakens the artificial data generating process used in the bootstrap procedure. However, results obtained from the Simar and Wilson (2007) procedure were not significantly different to results obtained from OLS, truncated, and tobit models. The Simar and Wilson (2007) method may be very valuable in future work involving more DMUs.

reverse causality with efficient safety investments. This needs to be further investigated in future studies with instrumental variable adjustments.

As expected, the experience levels of safety directors and top managers have a positive effect on technical efficiency scores. A one year increase in the experience of a safety director is associated with a 0.040 increase in technical efficiency score. Similarly, a one year increase in the experience of a cooperative's top manager is associated with a 0.013 increase in technical efficiency score. These results imply that the experience of leadership has a positive effect on the technical efficiency of OHS investments, which is also intuitive. As explained earlier, *SD EXPERIENCE* and *GM EXPERIENCE* are calculated at the cooperative level. This model can be further improved by collecting data at cooperative location level (i.e., gathering data on the experience of site managers rather than the experience of a cooperative's general manager).

The number of workers at a business location has a positive effect on technical efficiency scores. Increasing a business location's workforce by one worker is associated with a 0.020 increase in the technical efficiency score. This implies that the technical efficiency of OHS investments may benefit from economies of scale. Larger business locations may have better availability of resources.

Because workers at agricultural cooperatives can be categorized as full-time, part-time, or seasonal, the *WORKERS* variable used in this analysis may not contain enough information to explain the variability of the efficiency scores. Specifically, at agricultural cooperatives, part-time workers and seasonal workers are playing a significant role during the planting and harvesting time of the year. During planting time, they are working long exhausting hours to distribute supplies and services. During harvest time also these workers are working long hours with grain handling, storage, processing, and other logistics. Moreover, part-time workers and seasonal workers generally receive less OHS training than full-time workers. Therefore, more comprehensive results can be obtained by disaggregating the variable, *WORKERS* into full-time, part-time, and seasonal workers. In this thesis, disaggregated data on different worker types are not available at cooperative location level thereby limiting further analysis.

Table 4.5 shows the results when the dependent variable is technical efficiency scores obtained with the CRS assumption in the input-oriented DEA. There is no change in the direction of the coefficients compared to the results in Table 4.4. However, the magnitudes of the coefficients are relatively smaller than those from the VRS model.

Table 4.5

Determinants of input-oriented DEA efficiency scores (CRS)

Description	(1) OLS	(2) Truncated	(3) Tobit	(4) Simar-Wilson
PREMIUM (LOG)	-0.101***	-0.092***	-0.118***	-0.092***
	(0.024)	(0.031)	(0.028)	(0.030)
SD EXPERIENCE	0.052***	0.045***	0.0568***	0.045***
	(0.005)	(0.005)	(0.006)	(0.005)
GM EXPERIENCE	0.001***	0.010***	0.011***	0.010***
	(0.001)	(0.002)	(0.002)	(0.00170)
WORKERS	0.005***	0.006***	0.005***	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)
CONSTANT	1.108***	1.055***	1.223***	1.055***
	(0.200)	(0.256)	(0.235)	(0.252)
SIGMA		0.066*** (0.009)	0.087*** (0.011)	0.066*** (0.009)
Observations	44	36	36	36
R-squared	0.760	-	-	-
LR chi2(4)	-	97.350	55.400	95.090
Prob > chi2	-	0.000	0.000	0.000

Note: Standard errors are showed inside parentheses; *, **, and *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

Finally, it is important to investigate how the models used for regressions fit the data. This is particularly useful given that different models are used. For this purpose, the correlation between the predicted values based on OLS, truncated, tobit, and Simar and Wilson (2007) models and the observed values in the data set can be used. These correlation coefficients are given in Table 4.6.

Table 4.6

Correlation coefficients between the observed technical efficiency score (VRS) and predicted technical efficiency score (VRS) from regression models

Description	Technical Efficiency (VRS)	$\hat{\theta}$-OLS	$\hat{\theta}$-Tobit	$\hat{\theta}$-Truncated	$\hat{\theta}$-Simar and Wilson
Technical Efficiency (VRS)	1				
$\hat{\theta}$-OLS	0.7588	1			
$\hat{\theta}$-Tobit	0.7076	0.9325	1		
$\hat{\theta}$-Truncated	0.6278	0.8273	0.9662	1	
$\hat{\theta}$-Simar and Wilson	0.6278	0.8273	0.9662	1	1

Note: $\hat{\theta}$ represents the predicted technical efficiency score (VRS) for OLS, tobit, and truncated, and Simar and Wilson bootstrap procedure.

The highest correlation is reported between predicted values from the OLS model and the observed technical efficiency scores from the input-oriented DEA with VRS assumption. Correlation between the predicted values from truncated regression and observed technical efficiency scores is similar to the correlation with the predicted values from the Simar and Wilson (2007) regression. These correlation results imply that OLS predicted values share a greater variance of the observed technical efficiency values. However, OLS coefficients are biased and may result in inaccurate inferences (Simar and Wilson, 2007). The other competing models such as tobit, truncated regression, and Simar and Wilson (2007) have a correlation between 0.63 and 0.70. The multiple squared correlation can be obtained by squaring the correlation coefficient. For example, the multiple squared correlation between the predicted values from the Simar and Wilson (2007) procedure and the predicted technical efficiency score with VRS is 0.394. This indicates that predicted values from the Simar and Wilson (2007) share about 39.4 percent of the variance of predicted technical efficiency scores. Therefore, a larger percentage of variance of predicted technical efficiency score is not estimated by the Simar and Wilson (2007) procedure. This may be a result of omitting important variables in the estimated model.

Overall, it appears that many surveyed agricultural cooperatives are operating at high efficiency or are nearly efficient levels in terms of OHS investments. Agricultural cooperatives should be aware of the benefits of employing experienced chief executives and safety directors. These leaders seem likely to implement better OHS policies and procedures by allocating limited OHS funds efficiently. Although empirical results show that large number of workers will have a positive effect on efficient OHS investments at a business location, one must be cautious about increasing the workers without careful planning as other OHS resources allocated by the cooperative also need to change accordingly.

5. SUMMARY AND CONCLUSION

Agricultural cooperatives record high injury rates compared to dangerous industries such as construction and mining. Accordingly, agricultural cooperatives are highly motivated to invest in OHS to reduce the potential occupational injuries at workplace. The economic efficiency of these OHS investments warrants research. Therefore, this thesis examined the economic efficiency of OHS investments at agricultural cooperatives and identified cooperative characteristics leading to greater economic efficiency of OHS investments.

This thesis used a DEA model with multiple safety inputs and safety outcomes to estimate the technical efficiency of OHS investments. Unfavorable safety outcomes were linearly transformed using the methodology proposed by Seiford and Zhu (2002). The effects of cooperative characteristics on the efficiency of OHS investments were estimated using OLS, censored regression, truncated regression, and the Simar and Wilson (2007) bootstrap procedure. Data were gathered from OSHA forms 300 and OSHA 300A in additional to two surveys distributed among the cooperative's top safety person and top managerial person.

Results showed that the average input-oriented technical efficiency of OHS investment for the sample was 0.833 in the VRS model. In that model, 27.27 percent of DMUs were technically efficient. Moreover, results showed that the statistical significance, direction, and magnitude of the determinant coefficients were similar for all estimated models. Specifically, a cooperative location's annual insurance premia has a negative effect on occupational safety efficiency while the experience levels of firm and safety leaders has a positive effect. Hence, experienced safety personal and managerial person increase the efficiency of OHS investments. The total number of workers employed by a cooperative location also has a positive relationship with occupational safety efficiency.

The methodology and findings of this thesis can be further improved by gathering detailed OHS input data at the business location level. Detailed OHS outcome data are readily available due to OSHA compliance needs. However, much effort is needed to gather OHS investment data at the business location level. Gathering such data will help to better estimate the economic efficiency of OHS investments. Moreover, agricultural cooperatives can be clustered geographically and in size, necessitating adjustments to reduce sample heterogeneity and create more reliable results. Finally, gathering more data on barriers and motivations to invest in OHS will help develop better OHS policies and procedures at agricultural cooperatives.

REFERENCES

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science*, *30*(9), 1078–1092.

Barton, D., Boland, M., Chaddad, F., & Eversull, E. (2011). Current Challenges in Financing Agricultural Cooperatives. Retrieved from http://www.choicesmagazine.org/choices-magazine/theme-articles/critical-issues-for-agricultural-cooperatives/current-challenges-in-financing-agricultural-cooperatives

Benavides, F. G., Benach, J., Muntaner, C., Delclos, G. L., Catot, N., & Amable, M. (2006). Associations between Temporary Employment and Occupational Injury: What are the Mechanisms? *Occupational and Environmental Medicine*, *63*(6), 416–421.

Breslin, C., Koehoorn, M., Smith, P., & Manno, M. (2003). Age Related Differences in Work Injuries and Permanent Impairment: A Comparison of Workers' Compensation Claims among Adolescents, Young Adults, and Adults. *Occupational and Environmental Medicine*, *60*(9), e10–e10.

Butani, S. J. (1988). Relative Risk Analysis of Injuries in Coal Mining by Age and Experience at Present Company. *Journal of Occupational Accidents*, *10*(3), 209–216.

Centers for Disease Control and Prevention. (2018). The National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Retrieved from https://www.cdc.gov/niosh/topics/aginjury/default.html

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research*, *2*(6), 429–444.

Choudhry, R. M., Fang, D., & Mohamed, S. (2007). The Nature of Safety Culture: A Survey of the State-of-the-art. *Safety Science*, *45*(10), 993–1012.

Clarke, S. (1999). Perceptions of Organizational Safety: Implications for the Development of Safety Culture. *Journal of Organizational Behavior*, *20*(2), 185–198.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). An Introduction to Efficiency and Productivity Analysis. *Springer Science & Business Media.*

Faere, R., Grosskopf, S., Lovell, C. A. K., & Pasurka, C. (1989). Multilateral Productivity Comparisons When Some Outputs are Undesirable: A Nonparametric Approach. *The Review of Economics and Statistics*, *71*(1), 90–98.

Fenn, P., & Ashby, S. (2004). Workplace Risk, Establishment Size and Union Density. *British Journal of Industrial Relations*, *42*(3), 461–480.

Flin, R., & Yule, S. (2004). Leadership for Safety: Industrial Experience. *BMJ Quality & Safety*, *13*(suppl 2), ii45–ii51.

Goetzel, R. Z., Ozminkowski, R. J., Baase, C. M., & Billotti, G. M. (2005). Estimating the Return-on-investment from Changes in Employee Health Risks on the Dow Chemical Company's Health Care Costs. *Journal of Occupational and Environmental Medicine*, *47*(8), 759–768.

Hale, A. R. (2000). Editorial: Culture's Confusions. *Safety Science*, *34*, 1–14.

Hanson, E. (2016). An Economic Analysis of Occupational Safety at Agribusiness Retailers (Doctoral Dissertation).

Hard, D. L., & Myers, J. R. (2006). Fatal Work-related Injuries in the Agriculture Production Sector among Youth in the United States, 1992-2002. *Journal of Agromedicine*, *11*(2), 57–65.

Henderson, J. (1983). What should be done about Occupational Accidents and Diseases? *International Journal of Epidemiology*, *12*(1), 77–83.

Islam, S. S., Velilla, A. M., Doyle, E. J., & Ducatman, A. M. (2001). Gender Differences in Work-related Injury/illness: Analysis of Workers Compensation Claims. *American Journal of Industrial Medicine*, *39*(1), 84–91.

Kennedy, R., & Kirwan, B. (1998). Development of a Hazard and Operability-based Method for Identifying Safety Management Vulnerabilities in High Risk Systems. *Safety Science*, *30*(3), 249–274.

Leigh, J. P. (1989). Firm Size and Occupational Injury and Illness Incidence Rates in Manufacturing Industries. *Journal of Community Health*, *14*(1), 44–52.

McVittie, D., Banikin, H., & Brocklebank, W. (1997). The Effects of Firm Size on Injury Frequency in Construction. *Safety Science*, *27*(1), 19–23.

Mitchell, O. S. (1988). The Relation of Age to Workplace Injuries. *Monthly Labor Review*, *111*, 8.

Oh, J.-H., & Shin, E. H. (2003). Inequalities in Nonfatal Work Injury: The Significance of Race, Human Capital, and Occupations. *Social Science & Medicine*, *57*(11), 2173–2182.

Oi, W. (1974). On the Economics of Industrial Safety. *Law and Contemporary Problems*, *38*(4), 669–699.

Oxenburgh, M., & Marlow, P. (2005). The Productivity Assessment Tool: Computer-Based Cost Benefit Analysis Model for the Economic Assessment of Occupational Health and Safety Interventions in the Workplace. *Journal of Safety Research*, *36*(3), 209–214.

Pidgeon, N. F. (1991). Safety Culture and Risk Management in Organizations: *Journal of Cross-Cultural Psychology*.

Risch, C. C., Boland, Crespi, J. M., & Leinweber, M. (2014). Determinants of Occupational Safety for Agribusiness Workers. *Applied Economic Perspectives and Policy*, *36*(3), 546–559.

Seiford, L. M., & Zhu, J. (2002). Modeling Undesirable Factors in Efficiency Evaluation. *European Journal of Operational Research*, *142*(1), 16–20.

Simar, L., & Wilson, P. W. (2007). Estimation and Inference in Two-Stage, Semi-Parametric Models of Production Processes. *Journal of Econometrics*, *136*(1), 31–64.

Tang, S. L., Lee, H. K., & Wong, K. (1997). Safety Cost Optimization of Building Projects in Hong Kong. *Construction Management and Economics*, *15*(2), 177–186.

Tengs, T. O., Adams, M. E., Pliskin, J. S., Safran, D. G., Siegel, J. E., Weinstein, M. C., & Graham, J. D. (1995). Five-hundred Life-saving Interventions and their Cost-Effectiveness. *Risk Analysis: An Official Publication of the Society for Risk Analysis*, *15*(3), 369–390.

Thiede, I., & Thiede, M. (2015). Quantifying the Costs and Benefits of Occupational Health and Safety Interventions at a Bangladesh Shipbuilding Company. *International Journal of Occupational and Environmental Health*, *21*(2), 127–136.

Thomason, T., & Pozzebon, S. (2002). Determinants of Firm Workplace Health and Safety and Claims Management Practices. *ILR Review*, *55*(2), 286–307.

U.S. Department of Agriculture. (2000). Understanding Cooperatives: Agricultural Marketing Cooperatives, Rural Business and Cooperative Service. Retrieved from https://www.rd.usda.gov/files/CIR45-15.pdf

U.S. Department of Agriculture. (2002). Agricultural Cooperatives in the 21st Century, Rural Business Cooperative Service. Retrieved from https://www.rd.usda.gov/files/publications/CIR-60.pdf

U.S. Department of Agriculture. (2016). Agricultural Cooperative Statistics 2016, Rural Development Service Report - 80. Retrieved from https://www.rd.usda.gov/files/publications/SR80_CooperativeStatistics2016.pdf

U.S. Department of Labor. (1988). Women Experience Fewer Job-related Injuries and Deaths than Men. U.S. Department of Labor. Retrieved from https://www.bls.gov/opub/btn/archive/women-experience-fewer-job-related-injuries-and-deaths-than-men.pdf

U.S. Department of Labor. (2004). OSHA Form 300 and Related Pages. Retrieved from https://www.osha.gov/recordkeeping/new-osha300form1-1-04-FormsOnly.pdf

U.S. Department of Labor. (2007-2016). Industry Injury and Illness Data. Retrieved from https://www.bls.gov/iif/oshsum.htm

U.S. Department of Labor - Establishment Search. (2013-2017). Retrieved from https://www.osha.gov/pls/imis/establishment.html

U.S. Department of Labor. (2016a). Occupational Safety and Health Definitions. Retrieved from https://www.bls.gov/iif/oshdef.htm

U.S. Department of Labor. (2016b). Fatal Occupational Injuries in 2016 (Charts), U.S. Department of Labor. Retrieved from https://www.bls.gov/iif/oshwc/cfoi/cfch0015.pdf

U.S. Department of Labor. (2017a). Table 4. Fatal Occupational Injuries Counts and Rates by Selected Industries, 2015-16. Retrieved from https://www.bls.gov/news.release/cfoi.t04.htm

U.S. Department of Labor. (2017b). 2016 Survey of Occupational Injuries and Illnesses, U.S. Department of Labor. Retrieved from https://www.bls.gov/iif/osch0060.pdf

U.S. Department of Labor. (n.d.a). Occupational Safety and Health Administration. Retrieved from https://www.osha.gov/about.html

U.S. Department of Labor. (n.d.b). Federal Employer Rights and Responsibilities Following an OSHA Inspection -1996. Retrieved from https://www.osha.gov/Publications/fedrites.html

Viscusi, W. K. (1978). Wealth Effects and Earnings Premiums for Job Hazards. *The Review of Economics and Statistics*, *60*(3), 408–416.

Zhu, J., & Cook, W. D. (Eds.). (2007). Modeling Data Irregularities and Structural Complexities in Data Envelopment Analysis. *Springer US*. Retrieved from https://www.springer.com/us/book/9780387716060

APPENDIX A. SUMMARY OF SAMPLED OSHA INSPECTIONS AT AGRICULTURAL COOPERATIVES[19]

Table A.1

Magnitude of sampled OSHA inspections at agricultural cooperatives, 2013-2017

State	Total Cases	Violations Per Inspected Firm[20]	Average Penalty[21] ($)
Alabama	3	3.67	17,463.00
California	11	3.73	9,683.18
Colorado	15	3.20	6,101.07
Idaho	2	1.50	6,283.50
Illinois	7	4.29	24,771.43
Iowa	33	4.18	15,946.21
Kansas	57	2.98	10,639.11
Kentucky	1	1.00	3,500.00
Maryland	2	4.00	4,993.50
Michigan	6	1.67	3,000.00
Minnesota	32	4.94	4,582.81
Mississippi	1	3.00	23,133.00
Missouri	2	2.50	10,680.00
Montana	7	5.43	50,853.71
Nebraska	37	3.08	25,901.00
North Carolina	6	5.50	10,308.33
North Dakota	3	2.33	4,059.00
Ohio	10	4.60	15,050.10
Oklahoma	5	2.40	5,360.00
Oregon	5	3.80	84,055.00
Pennsylvania	3	1.33	9,004.33
Tennessee	5	3.00	1,340.00
Texas	11	2.00	5,735.91
Virginia	2	1.50	3,530.00
Washington	8	3.63	3,737.50
Wisconsin	20	2.65	17,899.60
Wyoming	9	8.78	37,704.11
Total	303	90.67	41,5315.41

Source: U.S. Department of Labor – Establishment Search, 2013 – 2017

[19] Data were gathered from the OSHA enforcement inspections database. The search terms "coop", "cooperative", and "co-op" were used to extract inspections related to agricultural cooperatives from January 2013 to December 2017.
[20] The number of violations is subject to change until the inspection is closed.
[21] Average penalty is the initial penalty given when the citation was first issued to the cooperative. The initial penalty may revised based on additional investigations in the future.

APPENDIX B. TYPES OF OSHA INSPECTIONS AND VIOLATIONS AT AGRICULTURAL COOPERATIVES

B.1. OSHA Violations by Inspection Type

OSHA violations may harm a firm's finances and reputation. OSHA violations are categorized based on the following inspection types: accident, complaint, planned, referral, and other. Figure B.1 shows the frequency of these inspection types at agricultural cooperatives from 2013 to 2017.[22] A majority of violations were a result of planned inspections.

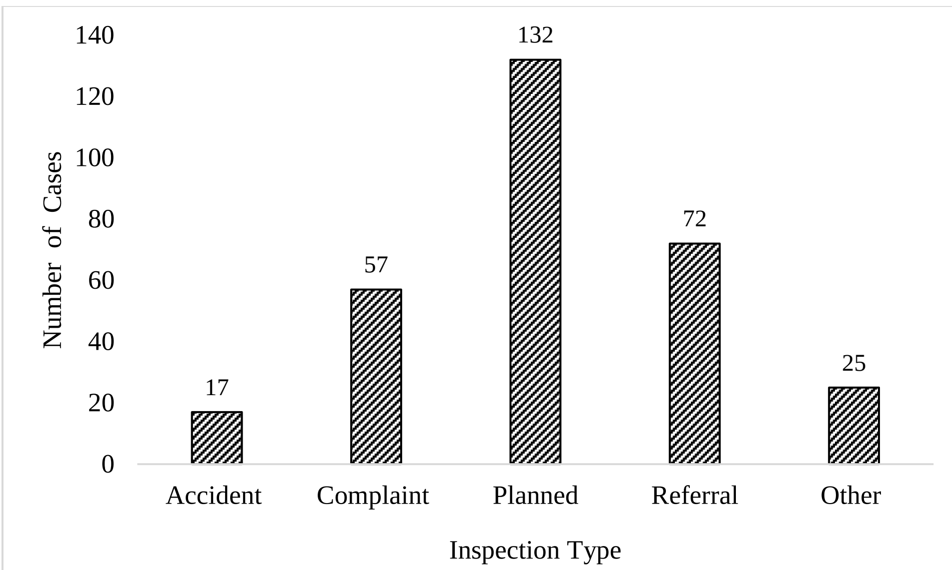


Figure B.1. OSHA violations by inspection type at sampled agricultural cooperatives, 2013-2017
Source: U.S. Department of Labor – Establishment Search, 2013 – 2017

B.2. OSHA Violation Types

Violation types indicate the severity of the hazard found during an OSHA inspection (U.S. Department of Labor, n.d.b). Violations are divided into the following categories: serious, willful, repeat, other-than serious, or unclassified. OSHA provides definitions for these violation

[22] Data were gathered from the OSHA enforcement inspections database. The search terms "coop", "cooperative", and "co-op" were used to extract inspections related to agricultural cooperatives from January 2013 to December 2017.

types. A serious violation occurs if a workplace hazard may cause an accident or illness that will likely result in death or serious physical harm to a worker. A willful violation occurs if an employer purposefully disregards or acts with plain indifference to worker's safety. A repeat violation occurs if a firm has been cited for or received notice of a similar violation with the past five years. A violation which is not serious in nature, but has a direct relationship to OHS is classified as other-than serious (U.S. Department of Labor, n.d.b). Figure B.2 shows that the majority of violations belonged to the serious category followed by other-than serious category. Only a few violations were willful, repeated, and unclassified categories.

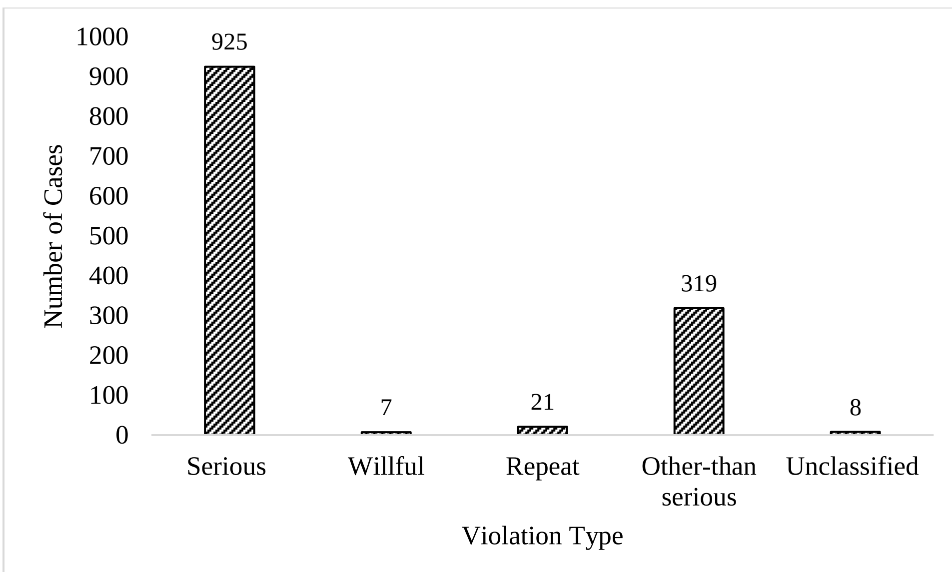


Figure B.2. OSHA violations by type at sampled agricultural cooperatives, 2013-2017
Source: U.S. Department of Labor – Establishment Search, 2013 – 2017

APPENDIX C. QUESTIONNAIRE DISTRIBUTED TO AGRICULTURAL COOPERATIVE SAFETY DIRECTORS[23]

Administrative Information:

1. Firm name:

2. What is your current title (also include all secondary or interim titles)?

Firm Characteristics:

1. What is the title of your firm's top occupational health and safety employee?

2. How many years of experience does your firm's top occupational health and safety employee have in that position at your firm? (Please round your answer to the nearest year.)

3. How many additional years of experience does your firm's top OHS employee have in that position at other similar firms? (Please round your answer to the nearest year.)

4. What percentage of your firm's top OHS employee's time is delegated to occupational health and safety responsibilities?

5. Which alternative best describes how your firm's top occupational health and safety employee divides their time (attention and activities, not necessarily physical presence) between different business locations:

A. Equally (each location gets roughly the same time)
B. Proportionately based on location size (a location with roughly double the employees of another location will receive roughly double the time of the smaller location)
C. Proportionately based on incident history or hazards (a location with roughly double the incident rate of another location or double the perceived danger of a will receive roughly double the time of less hazardous location)
D. Other (please explain :____)

6. Approximately how often does your firm's top occupational health and safety employee consult with occupational health and safety employees at other firms in the industry (for training, ideas, etc.)?

A. Once every week or every two weeks
B. Once every month
C. Once every two months
D. Once every six months
E. Once every year
F. Less than once per year

[23] This survey was approved by the NDSU Institutional Review Board.

7. If your firm's top occupational health and safety employee worked at another position(s) at your firm prior to their current position, in which department(s) did they work?

8. Using the table below, rank each of the five listed items on how much of your work time they consume. (You may only use each rank once.)

Task	Most time	2nd most time	3rd most time	4th most time	Least time
Educating self					
Planning occupational health and safety education or training					
Implementing occupational health and safety education or training					
Paperwork, recordkeeping, other administrative duties (worker's compensation claims, regulatory forms, etc.)					
Policing workplace safety violations or investigating occupational health and safety incidents					

9. Did your firm utilize one or more paid occupational health and safety consultants (from outside your firm) during 2017?

A. Yes
B. No

10. Which alternative best describes how paid occupational health and safety consultants (from outside your firm) divide their time (attention and activities, not necessarily physical presence) between different business locations:

A. Equally (each location gets roughly the same time)
B. Proportionately based on location size (a location with roughly double the employees of another location will receive roughly double the time of the smaller location)
C. Proportionately based on incident history or hazards (a location with roughly double the incident rate of another location or double the perceived danger of a will receive roughly double the time of less hazardous location)
D. Other (please explain :____)
E. Not applicable (we do not use any paid safety consultants)

11. Complete the table below to describe the composition of your 2017 safety committee or equivalent group (if there was a change in committee composition during the year, use the members that were present for the majority of 2017):

( ) Check here if your firm does not have a safety committee or equivalent during 2017

Member's job title	Member's department	Member's experience with firm (please round to the nearest year)	Member's experience with safety committee (please round to the nearest year)

Note: Additional rows added as needed.

Occupational Safety Interventions:

1. Did any of the following actions occur at your firm during 2017? (Please select all that apply.)

Action	Answer
Hired new top occupational health and safety employee	Yes/No
Hired new or additional employees that have occupational health and safety responsibilities included in their job descriptions or duties	Yes/No
Hired new or additional safety consultant	Yes/No
Conducted classroom safety training or education	Yes/No
Conducted hands-on safety training or education	Yes/No
Experienced internally-conducted occupational health and safety inspections	Yes/No
Experienced externally-conducted occupational health and safety inspections	Yes/No
Held safety committee meetings	Yes/No
Screened workers for sensitivity to hazards	Yes/No
Purchased personal protective equipment	Yes/No
Stopped making, providing, or using a hazardous product or service	Yes/No
Changed workplace occupational health and safety policies or procedures	Yes/No
Used occupational health and safety consultant	Yes/No

2. How many occupational health and safety training or education sessions were conducted at your firm in 2017? (Please count how many rounds of safety training were received by your average employee. That is, if the same session was delivered at 5 different locations on 5 consecutive days, it would count as 1 session rather than 5 sessions.)

3. How did this amount of training or education sessions compare to the amount received in 2016?

A. Less
B. Roughly the same
C. More

4. How many hours of occupational health and safety training and education did the average employee at your firm receive in 2017?

5. How many non-regulatory (i.e., internal) occupational health and safety inspections occurred at your firm in 2017?

6. Does your firm have written occupational health and safety policies or procedures?
   A. Yes
   B. No

7. How frequently are internal investigations conducted in response to occupational health and safety incidents at your firm?
   A. Never
   B. Rarely
   C. Sometimes
   D. Often
   E. Always

8. How frequently are occupational health and safety achievements by employees recognized at your firm?
   A. Never
   B. Rarely
   C. Sometimes
   D. Often
   E. Always

9. How frequently are actions taken in response to violations of occupational health and safety policies or procedures at your firm?
   A. Never
   B. Rarely
   C. Sometimes
   D. Often
   E. Always

Safety Investment Costs:

1. How much did your firm spend on the following items in 2017?

Category	Amount
Safety training and education materials directly used by employees	
Other safety training and education materials	
Salary paid for top safety employee (your salary)	
Payments to safety consultants	
Personal protective equipment or other physical items designed to reduce occupational health and safety hazards	
Rewards or recognitions for safety accomplishments	

Barriers and Drivers for Occupational Health and Safety Management:

1. In the table below, rate your perception of how relevant each barrier is to preventing strong occupational health and safety performance at your firm.

Barrier	Relevance				
	Not at all relevant	Slightly relevant	Mod-erately relevant	Very releva-nt	Ext-remely relevant
Lack of employee motivation to comply with policies and procedures	(1)	(2)	(3)	(4)	(5)
Lack of managerial motivation to comply with policies and procedures	(1)	(2)	(3)	(4)	(5)
Lack of employee awareness of policies and procedures	(1)	(2)	(3)	(4)	(5)
Lack of managerial awareness of policies and procedures	(1)	(2)	(3)	(4)	(5)
Lack of employee expertise in acting in accordance with policies and procedures	(1)	(2)	(3)	(4)	(5)
Lack of managerial expertise in acting in accordance with policies and procedures	(1)	(2)	(3)	(4)	(5)
Lack of firm resources (funding, time devoted to programming, safety personnel, etc.)	(1)	(2)	(3)	(4)	(5)

2. In the table below, rate the extent to which each reason motivates improved occupational health and safety at your firm.

Reason	Motivation for improved OHS				
	Not at all motiv-ational	Slightly motiv-ational	Moder-ately motiv-ational	Very motiv-ational	Ext-remely motiv-ational
Complying with legal or regulatory obligations	(1)	(2)	(3)	(4)	(5)
Responding to employee complaints or concerns	(1)	(2)	(3)	(4)	(5)
Retaining employees through a safe and enjoyable work environment	(1)	(2)	(3)	(4)	(5)
Improving business operations	(1)	(2)	(3)	(4)	(5)
Mitigating concerns about firm's reputation	(1)	(2)	(3)	(4)	(5)
Responding to internal safety inspections	(1)	(2)	(3)	(4)	(5)
Responding to external safety inspections	(1)	(2)	(3)	(4)	(5)
Earning improved (lower) insurance premiums	(1)	(2)	(3)	(4)	(5)
Complying with directives of firm board of directors	(1)	(2)	(3)	(4)	(5)

3. In the table below, rate the likely effectiveness of each action in improving occupational health and safety at your firm.

Action	Effectiveness				
	Not at all effective	Slightly effective	Moderately effective	Very effective	Extremely effective
Increased firm funding for occupational health and safety training or education of employees	(1)	(2)	(3)	(4)	(5)
Increased firm funding for equipment, machinery, or other material items designed to improve occupational health and safety	(1)	(2)	(3)	(4)	(5)
Increased firm funding for occupational health and safety training or education employees with occupational health and safety responsibilities (e.g., safety director)	(1)	(2)	(3)	(4)	(5)
Increased internally-imposed consequences for occupational health and safety incidents	(1)	(2)	(3)	(4)	(5)
Increased internal occupational health and safety inspections	(1)	(2)	(3)	(4)	(5)
Increased externally-imposed consequences for occupational health and safety incidents	(1)	(2)	(3)	(4)	(5)
Increased external occupational health and safety inspections	(1)	(2)	(3)	(4)	(5)

APPENDIX D. QUESTIONNAIRE DISTRIBUTED TO AGRICULTURAL COOPERATIVE CEOS/GMS[24]

Administrative Information:

1. Firm name:

2. What is your current title (also include all secondary or interim titles)?

Firm Characteristics:

1. How many business locations does your firm have?

2. What products or services does your firm offer? (Select all that apply.)
   - A. Agricultural product processing
   - B. Agronomic services
   - C. Crop production inputs
   - D. Energy
   - E. Grain or oilseed handling and storage
   - F. Livestock production inputs
   - G. Retail or wholesale outlets
   - H. Transportation services
   - J. Other products or services not described above

3. During 2017, how many people were employed (at any time) by your firm in the following categories?
   - A. Full-time:__________
   - B. Part-time:__________
   - C. Seasonal: __________

4. What is the title of your top executive (CEO, etc.)?

5. How many years of experience does your firm's top executive have in that position? (Please round your answer to the nearest year.)

6. How many additional years of experience does your firm's top executive have in that position at other similar firms? (Please round your answer to the nearest year.)

[24] This survey was approved by the NDSU Institutional Review Board.

OHS Incident Damage Costs:

1. In the table below, rate your perception of how costly each item is to your firm.

Expenditure Item	Cost				
	Not at all costly	Slightly costly	Mod-erately costly	Very costly	Ext-remely costly
Paid leave for employees suffering from occupational illness or injury	(1)	(2)	(3)	(4)	(5)
Experience-adjusted insurance premia (additional payments based on having more than zero health or safety incidents)	(1)	(2)	(3)	(4)	(5)
Medical expenses paid by your firm as a result of occupational illness or injury	(1)	(2)	(3)	(4)	(5)
Health and safety fines (from OSHA or other regulatory agencies)	(1)	(2)	(3)	(4)	(5)
Replacement and repair of facilities, machinery, or equipment involved in health or safety incidents	(1)	(2)	(3)	(4)	(5)
Lost productivity due to workers absent or restricted as a result of occupational illness or injury	(1)	(2)	(3)	(4)	(5)
Cost of replacing employees suffering from occupational illness or injury	(1)	(2)	(3)	(4)	(5)

2. What is the total dollar value of insurance premia paid by your firm in 2017?

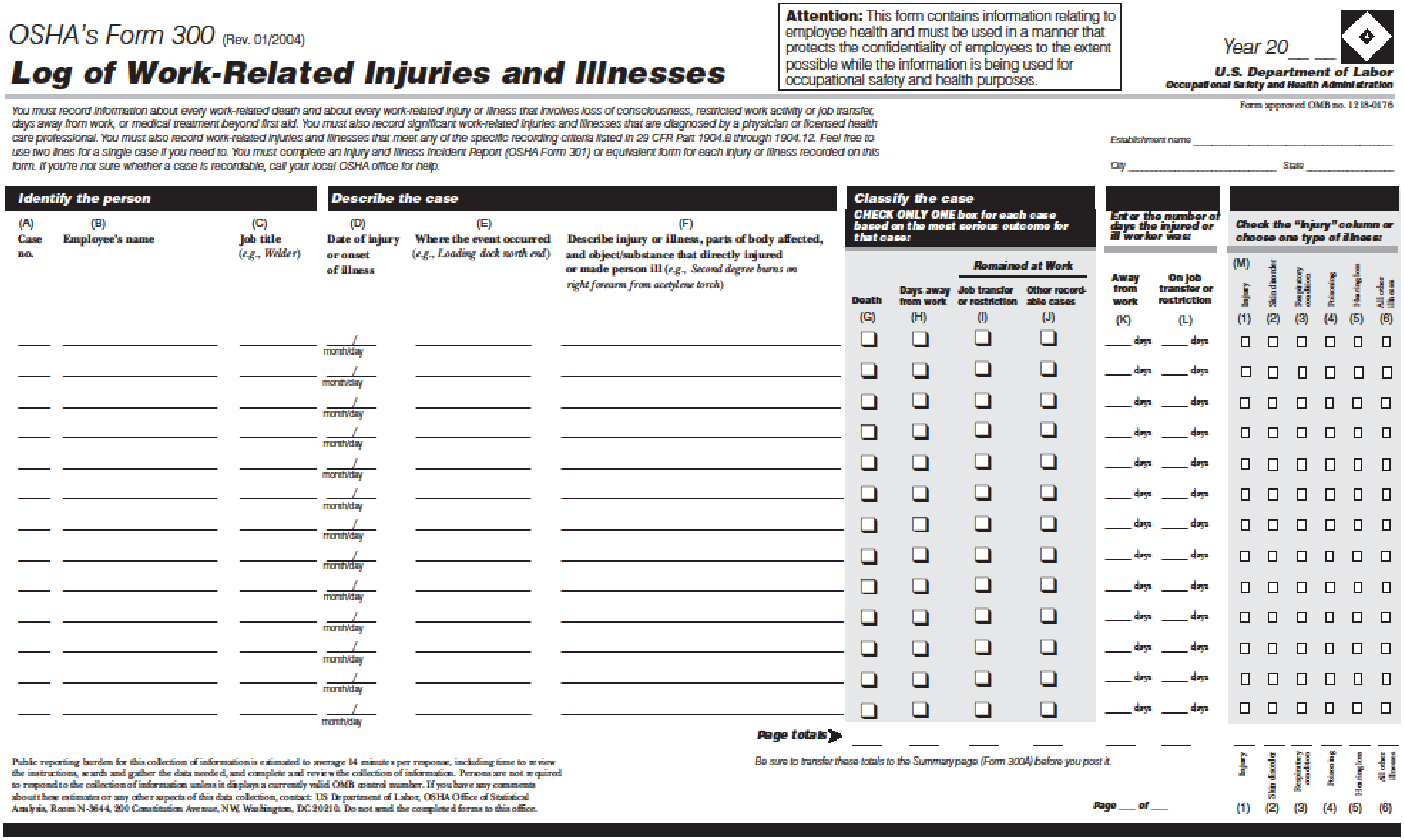
Safety Investment Costs:

1. List job titles for all employees with formal occupational health and safety responsibilities in 2017. (You will be asked for details about each employee in subsequent columns in the table; use as many or as few entries as needed.)

Job Title	What was the total salary paid to this employee in total during 2017?	What was the percentage of time devoted to occupational health and safety of this employee during 2017?	Which alternative best describes how this employee divides his/her time (attention and activities, not necessarily physical presence) between different business locations?
			A. Equally (each location gets roughly the same time) B. Proportionately based on location size (a location with roughly double the employees of another location will receive roughly double the time of the smaller location) C. Proportionately based on incident history or hazards (a location with roughly double the incident rate of another location or double the perceived danger of a will receive roughly double the time of less hazardous location) D. Specific location(s) (please name locations and list share of time at each:_________________________________)

Note: Additional rows available as needed

APPENDIX E. OSHA 300 FORM



OSHA's Form 300 (Rev. 01/2004)

Log of Work-Related Injuries and Illnesses

Attention: This form contains information relating to employee health and must be used in a manner that protects the confidentiality of employees to the extent possible while the information is being used for occupational safety and health purposes.

Year 20__ __

U.S. Department of Labor
Occupational Safety and Health Administration

Form approved OMB no. 1218-0176

You must record information about every work-related death and about every work-related injury or illness that involves loss of consciousness, restricted work activity or job transfer, days away from work, or medical treatment beyond first aid. You must also record significant work-related injuries and illnesses that are diagnosed by a physician or licensed health care professional. You must also record work-related injuries and illnesses that meet any of the specific recording criteria listed in 29 CFR Part 1904.8 through 1904.12. Feel free to use two lines for a single case if you need to. You must complete an Injury and Illness Incident Report (OSHA Form 301) or equivalent form for each injury or illness recorded on this form. If you're not sure whether a case is recordable, call your local OSHA office for help.

Establishment name __________

City __________ State __________

Identify the person			Describe the case			Classify the case: CHECK ONLY ONE box for each case based on the most serious outcome for that case:				Enter the number of days the injured or ill worker was:		Check the "Injury" column or choose one type of illness: (M)					
								Remained at Work									
(A) Case no.	(B) Employee's name	(C) Job title (*e.g., Welder*)	(D) Date of injury or onset of illness	(E) Where the event occurred (*e.g., Loading dock north end*)	(F) Describe injury or illness, parts of body affected, and object/substance that directly injured or made person ill (*e.g., Second degree burns on right forearm from acetylene torch*)	Death (G)	Days away from work (H)	Job transfer or restriction (I)	Other record-able cases (J)	Away from work (K)	On job transfer or restriction (L)	Injury (1)	Skin disorder (2)	Respiratory condition (3)	Poisoning (4)	Hearing loss (5)	All other illnesses (6)
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
___	___	___	__/__ month/day	___	___	☐	☐	☐	☐	__ days	__ days	☐	☐	☐	☐	☐	☐
					Page totals	___	___	___	___	___	___	___ Injury (1)	___ Skin disorder (2)	___ Respiratory condition (3)	___ Poisoning (4)	___ Hearing loss (5)	___ All other illnesses (6)

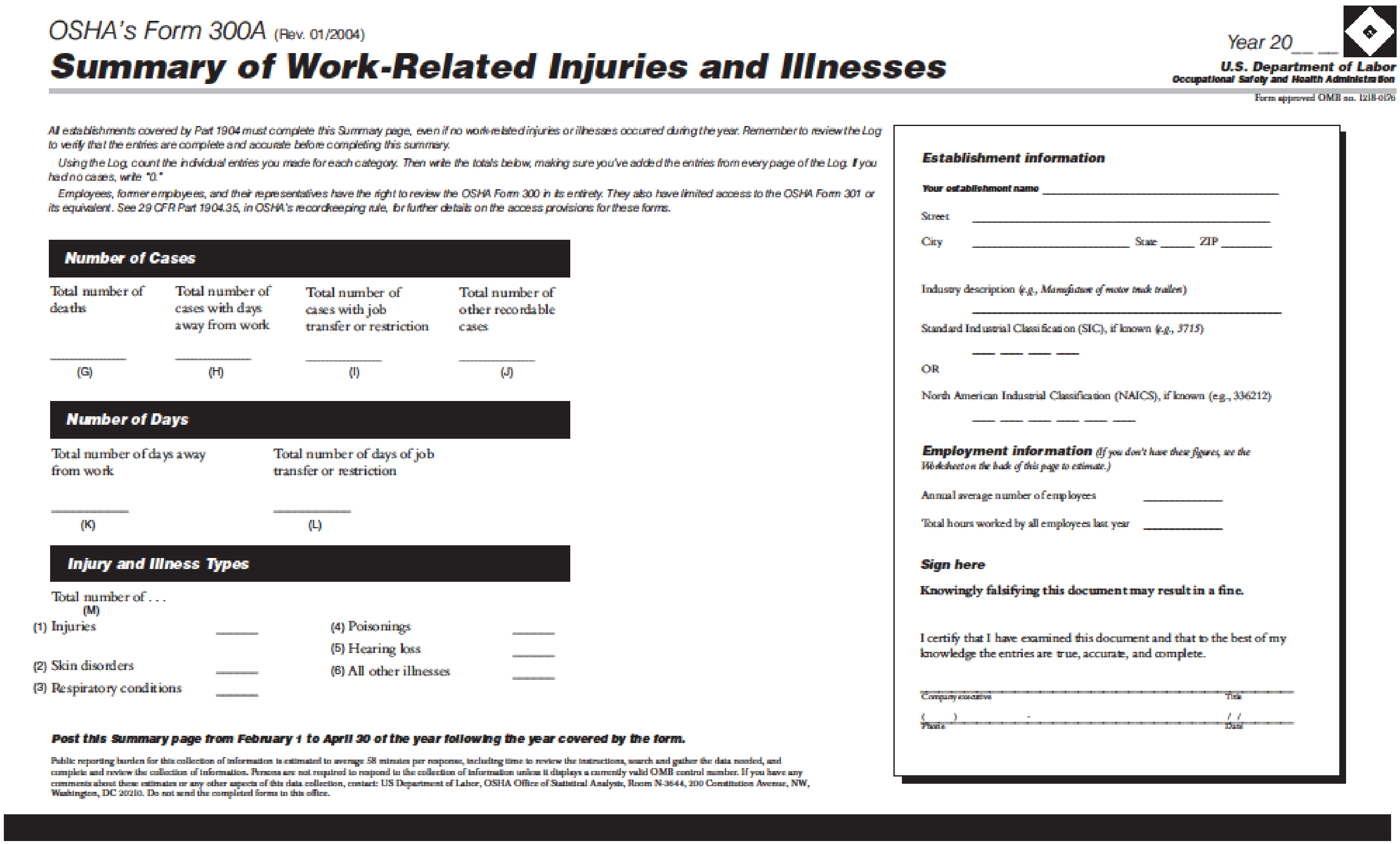
Be sure to transfer these totals to the Summary page (Form 300A) before you post it.

Page __ of __

Public reporting burden for this collection of information is estimated to average 14 minutes per response, including time to review the instructions, search and gather the data needed, and complete and review the collection of information. Persons are not required to respond to the collection of information unless it displays a currently valid OMB control number. If you have any comments about these estimates or any other aspects of this data collection, contact: US Department of Labor, OSHA Office of Statistical Analysis, Room N-3644, 200 Constitution Avenue, NW, Washington, DC 20210. Do not send the completed forms to this office.

Figure E.1. OSHA 300 form
Source: U.S. Department of Labor (2004)

APPENDIX F. OSHA 300A FORM



OSHA's Form 300A (Rev. 01/2004)

Summary of Work-Related Injuries and Illnesses

Year 20__ __

U.S. Department of Labor
Occupational Safety and Health Administration

Form approved OMB no. 1218-0176

All establishments covered by Part 1904 must complete this Summary page, even if no work-related injuries or illnesses occurred during the year. Remember to review the Log to verify that the entries are complete and accurate before completing this summary.

Using the Log, count the individual entries you made for each category. Then write the totals below, making sure you've added the entries from every page of the Log. If you had no cases, write "0."

Employees, former employees, and their representatives have the right to review the OSHA Form 300 in its entirety. They also have limited access to the OSHA Form 301 or its equivalent. See 29 CFR Part 1904.35, in OSHA's recordkeeping rule, for further details on the access provisions for these forms.

Number of Cases

Total number of deaths	Total number of cases with days away from work	Total number of cases with job transfer or restriction	Total number of other recordable cases
______ (G)	______ (H)	______ (I)	______ (J)

Number of Days

Total number of days away from work	Total number of days of job transfer or restriction
______ (K)	______ (L)

Injury and Illness Types

Total number of . . .
(M)

(1) Injuries	______	(4) Poisonings	______
		(5) Hearing loss	______
(2) Skin disorders	______	(6) All other illnesses	______
(3) Respiratory conditions	______		

Post this Summary page from February 1 to April 30 of the year following the year covered by the form.

Public reporting burden for this collection of information is estimated to average 58 minutes per response, including time to review the instructions, search and gather the data needed, and complete and review the collection of information. Persons are not required to respond to the collection of information unless it displays a currently valid OMB control number. If you have any comments about these estimates or any other aspects of this data collection, contact: US Department of Labor, OSHA Office of Statistical Analysis, Room N-3644, 200 Constitution Avenue, NW, Washington, DC 20210. Do not send the completed forms to this office.

Establishment information

Your establishment name ____________________

Street ____________________

City ____________ State ____ ZIP ______

Industry description (*e.g., Manufacture of motor truck trailers*)

____

Standard Industrial Classification (SIC), if known (*e.g., 3715*)

__ __ __ __

OR

North American Industrial Classification (NAICS), if known (e.g., 336212)

__ __ __ __ __ __

Employment information (*If you don't have these figures, see the Worksheet on the back of this page to estimate.*)

Annual average number of employees ________

Total hours worked by all employees last year ________

Sign here

Knowingly falsifying this document may result in a fine.

I certify that I have examined this document and that to the best of my knowledge the entries are true, accurate, and complete.

Company executive ____________ Title

( ) - ____________ / /

Phone ____________ Date

Figure F.1. OSHA 300A form
Source: U.S. Department of Labor (2004)

APPENDIX G. BARRIERS AND MOTIVATIONS TO INVESTING ON OHS

Questions on barriers and motivations for investment in OHS were included in the survey distributed to agricultural cooperative safety directors. These questions were arranged on a five-point Likert scale. Safety directors were asked to evaluate each statement based on their experience with OHS at their current cooperative. The following descriptive analysis is based on five responses received by safety directors. Although the sample size is small, this analysis offers context for cooperatives' challenges and motivations regarding OHS.

Figure G.1 shows the relevance of barriers preventing better OHS performances at agricultural cooperatives. It appears that a lack of firm resources such as funding, time allocated to OHS programs, etc., is generally not an extremely relevant barrier. Rather, lack of managerial awareness of policies and procedures and lack of managerial motivation to comply with policies and procedures seem to hinder better OHS performances at surveyed cooperatives. As discussed in much literature, managerial motivation and expertise in OHS are critical factors in enhancing the safety performance at agricultural cooperatives. Lack of employee experience in acting in accordance with policies and procedures and lack of employee motivation to comply with policies and procedures are also relevant barriers. Enhancing employee motivation is vital to preventing occupational injuries. Safety recognition and punishment programs may help in improving employee motivation to obey OHS policies and procedures. Moreover, employee expertise in OHS could increase with better safety training and education programs.

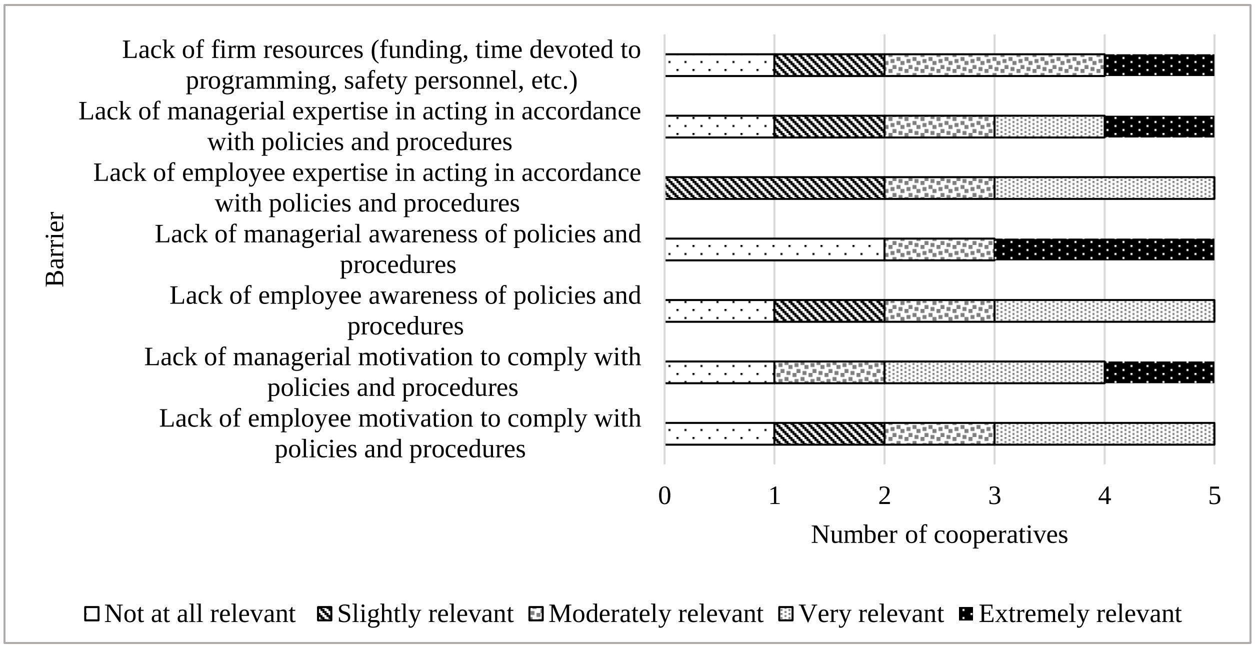


Figure G.1. Relevance of barriers in preventing strong OHS performance
Source: Survey data gathered from safety directors

It is also important to understand the reasons why agricultural cooperatives are motivated to improve OHS at work place. Safety directors were asked to rate the extent to which a variety of factors might improve OHS at their cooperative. As seen in Figure G.2, improving business operations rated as the most motivational reason for improving OHS among listed reasons. Being able to work continuously without disruptions is crucial for cooperatives, which often face heavy seasonal workloads. The next most motivating reasons are retaining employees through a safe and enjoyable work environment and responding to employee complaints or concerns. Worker retention is beneficial for cooperatives since hiring and training new workers is time consuming and costly. In addition, assuring a safe and secure work environment may increase worker productivity or attract higher quality works. Reasons such as complying with board directives, getting lower insurance premiums, and responding to safety inspections are also important for cooperative's motivation to improve OHS.

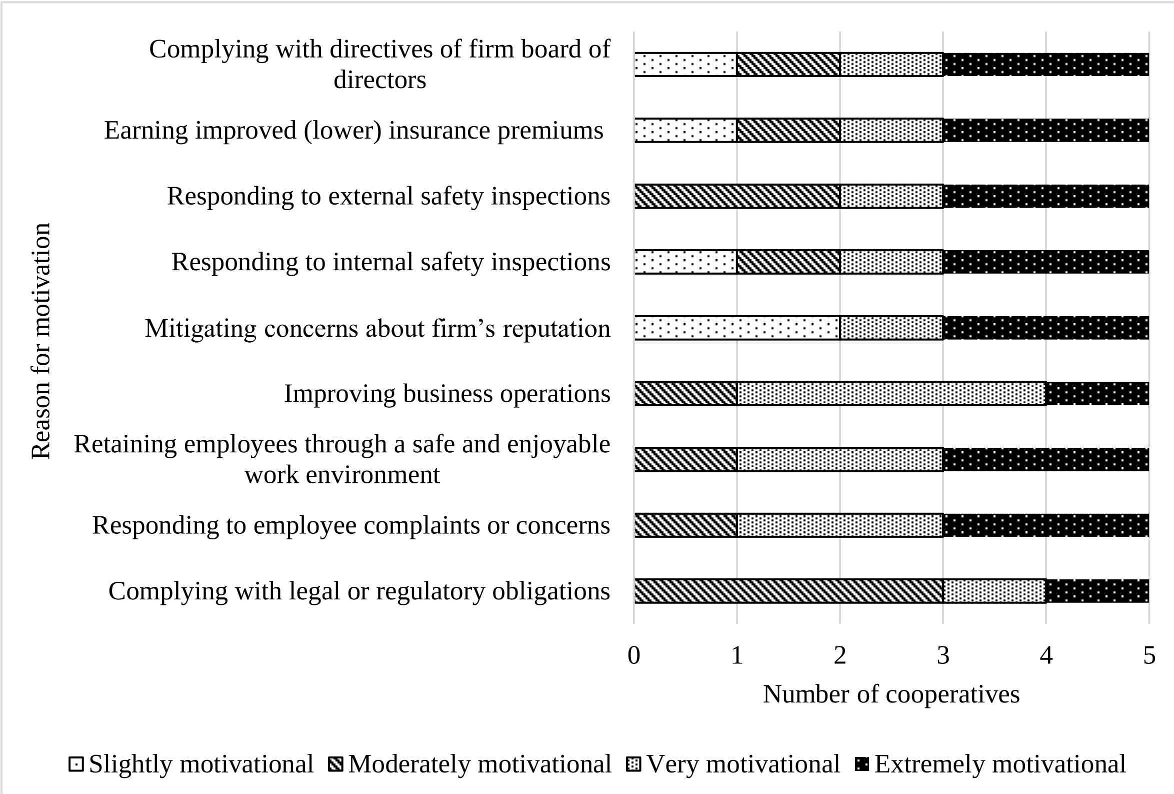


Figure G.2. Motivation to improve OHS at agricultural cooperatives
Source: Survey data gathered from safety directors

Understanding safety directors' perceptions of actions that would improve OHS is also important in designing safety policies and procedures at the workplace. Figure G.3 shows the perceived effectiveness of some actions that might improve OHS at agricultural cooperatives. Increasing internally-imposed consequences for OHS incidents seems to be the most effective action to improve OHS. Moreover, increasing firm funding for OHS trainings or educational programs for workers and safety directors is thought to be more effective than increasing funds for safe machinery and equipment.

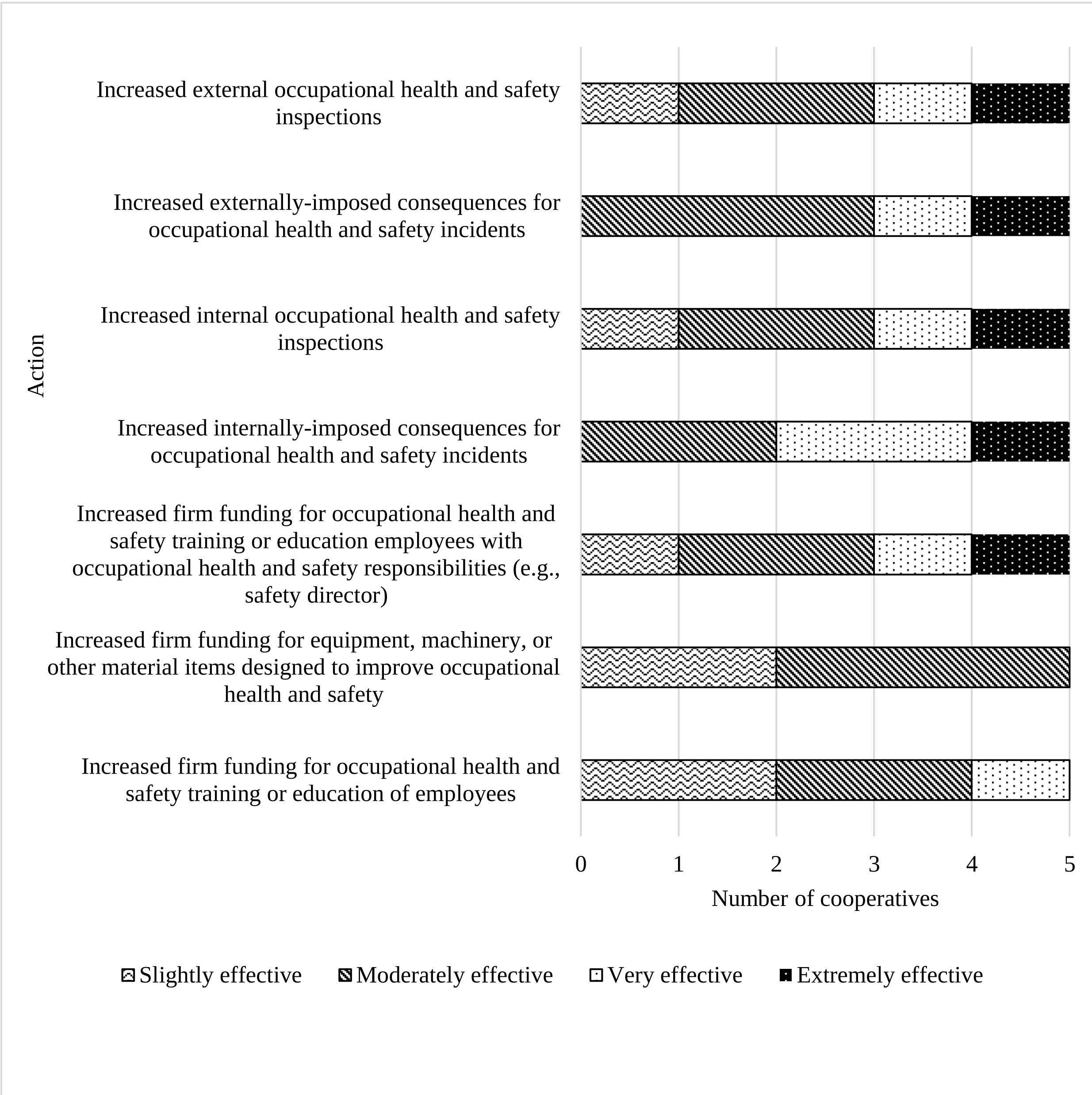


Figure G.3. Effectiveness of actions in improving OHS at agricultural cooperatives
Source: Survey data gathered from safety directors

APPENDIX H. EFFICIENCY DETERMINANT RESULTS WITH BUSINESS LINE DUMMIES

The workplace tasks performed by employees may influence occupational safety efficiency. To account for these effects, a group of dummy variables was added to the primary model explained in equation 3.5. Table H.1 explains the definitions for these dummy variables.

Table H.1

Definitions of business line dummy variables

Variable	Definition
AGRONOMY	Equals 1 if a location has employees working in agronomy, otherwise 0.
AUTO	Equals 1 if a location has employees working in automobile maintenance or tire repair, otherwise 0.
CORP AND FIN	Equals 1 if a location has employees working in corporate or financial positions, otherwise 0.
ENERGY	Equals 1 if a location has employees working in energy, otherwise 0.
FEED	Equals 1 if a location has employees working in feed, otherwise 0.
GRAIN	Equals 1 if a location has employees working in grain, otherwise 0.
RETAIL	Equals 1 if a location has employees working in agronomy, otherwise 0.
TRANSPORT	Equals 1 if a location has employees working in transportation, otherwise 0.
OTHER	Equals 1 if a location has employees working in other business lines not listed above, otherwise 0.

Model variables were tested for heteroscedasticity and multicollinearity using Breusch-Pagan test and VIF values, respectively. Results showed no heteroscedasticity and multicollinearity in the model. Table H.2 shows the determinants of input-oriented DEA efficiency scores under the VRS assumption. Coefficient signs of the variables, *PREMIUM (LOG)*, *SD EXPERIENCE*, *GM EXPERIENCE*, and *WORKERS* were similar to those results in the Table 4.4. However, the significance of these variables changed. Specially, the variable, *SD EXPERIENCE* was not significant at the 10 percent level in the truncated regression and the Simar and Wilson (2007). Magnitudes of the coefficients have changed slightly. As expected, the R-squared of the OLS model has increased after adding dummy variables.

In the OLS specification, only the *AUTO* dummy variable showed a positive, significant relationship with efficiency scores at the 10 percent level. In other words, a cooperative with workers in the auto sector generally had higher efficiency scores compared to a cooperative location with no auto workers. None of the dummy variables were statistically significant in the truncated regression model and the Simar and Wilson (2007) procedure. In the tobit model, the dummy variables *GRAIN* and *TRANSPORT* showed a negative relationship with efficiency scores at 10 percent and 5 percent significance levels, respectively. These results are intuitive because workers in grain operations and transportation may experience more occupational injuries than those who work in administrative departments. Therefore, dummy variables which represented workers with riskier business lines are expected to have a negative association with efficiency scores compared to workers in less risky business lines. Therefore, workers involved in the grain operations and transportation need to be cautious regarding occupational injuries at cooperatives. In addition, cooperatives' safety policies and procedures need to be adjusted accordingly to provide safe work environment for workers in these riskier sectors.

Table H.2 shows that workers who represented *AGRONOMY, RETAIL, CROP AND FIN, ENERGY, FEED*, and *OTHER* do not have an effect for technical efficiency scores. These findings need further analysis with a higher number of DMUs.

Table H.2

Determinants of input-oriented DEA efficiency scores with workers' business line dummies (VRS)

VARIABLES	(1) OLS	(2) Truncated	(3) Tobit	(4) Simar-Wilson
PREMIUM (LOG)	-0.080**	-0.188***	-0.188***	-0.188***
	(0.035)	(0.054)	(0.047)	(0.055)
SD EXPIRIENCE	0.035**	0.006	0.047***	0.006
	(0.016)	(0.032)	(0.015)	(0.048)
GM EXPERIENCE	0.005*	0.011***	0.012***	0.011***
	(0.003)	(0.003)	(0.003)	(0.003)
WORKERS	0.006***	0.021***	0.018***	0.021***
	(0.002)	(0.005)	(0.004)	(0.005)
AGRONOMY	-0.026	-0.067	0.029	-0.067
	(0.062)	(0.044)	(0.061)	(0.043)
AUTO	0.157*	0.064	0.136	0.064
	(0.089)	(0.064)	(0.091)	(0.066)
CORP AND FIN	-0.034	-0.033	0.018	-0.033
	(0.062)	(0.041)	(0.058)	(0.040)
ENERGY	-0.004	0.027	-0.023	0.027
	(0.050)	(0.033)	(0.051)	(0.033)
FEED	-0.015	-0.016	0.001	-0.016
	(0.065)	(0.047)	(0.061)	(0.047)
GRAIN	-0.097	-0.050	-0.115*	-0.050
	(0.071)	(0.052)	(0.067)	(0.054)
RETAIL	-0.087	0.101	-0.032	0.101
	(0.076)	(0.184)	(0.080)	(0.278)
TRANSPORT	-0.043	-0.004	-0.133**	-0.004
	(0.054)	(0.037)	(0.055)	(0.037)
OTHER	-0.017	-0.031	-0.030	-0.031
	(0.043)	(0.027)	(0.040)	(0.027)
Constant	1.224***	2.326***	1.974***	2.326***
	(0.377)	(0.673)	(0.449)	(0.758)
Sigma		0.057***	0.093***	0.057***
		(0.007)	(0.012)	(0.006)
Observations	44	32	44	32
R-squared	0.661			

Note: Standard errors are showed inside parentheses; *, **, and *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

APPENDIX I. EFFICIENCY DETERMINANT RESULTS FOR LARGER SAMPLE

Results from the efficiency determinants model were tested for robustness using an additional agricultural cooperative that added 40 business locations (DMUs) to the analysis. This cooperative had insufficient data for the safety input variable, *OHS PERSONNEL INVESTMENT (I_1).* Therefore, these 40 DMUs were dropped from the original DEA model in the chapter 4. This section shows the results obtained from the DEA model estimated for 84 DMUs without the safety input variable, I_1. Table I.1 summarizes the technical efficiency scores. Except for the output-oriented DEA (VRS), the mean technical efficiency scores are low compared to the mean technical efficiency scores in the Table 4.1.

Table I.1

Summary statistics for technical efficiency scores

Technical Efficiency Score	Total number of DMUs	Mean	Standard Deviation	Min	Max
CRS (Input-oriented)	84	0.384	0.342	0.082	1
VRS (Input-oriented)	84	0.418	0.348	0.082	1
CRS (Output-oriented)	84	0.384	0.342	0.082	1
VRS (Output-oriented)	84	0.975	0.057	0.750	1

While, the efficiency determinant variables did not suffer from perfect multicollinearity, the estimated model suffered from heteroscedasticity. Therefore, all models were heteroscedasticity adjusted except for the Simar and Wilson (2007) procedure.[25] Table I.2 shows estimates of the VRS efficiency scores' determinants. Unlike in the Table 4.4, signs and the coefficients are not consistent among all four models.

[25] This test was conducted using the robust command in STATA.

Table I.2

Determinants of input-oriented DEA efficiency scores (VRS)

Variable	(1) OLS	(2) Truncated	(3) Tobit	(4) Simar-Wilson
PREMIUM (LOG)	0.022	0.009	-0.030	-0.011
	(0.037)	(0.039)	(0.048)	(0.052)
SD EXPERIENCE	0.130***	0.130***	0.144***	0.157***
	(0.008)	(0.009)	(0.011)	(0.018)
GM EXPERIENCE	0.014***	0.012***	0.015***	0.02***
	(0.002)	(0.001)	(0.003)	(0.004)
WORKERS	0.005	0.007	0.011**	0.014**
	(0.003)	(0.005)	(0.005)	(0.006)
SIGMA	-	0.120***	0.153***	0.139***
		(0.015)	(0.018)	(0.015)
CONSTANT	-1.389***	-1.277***	-1.080***	-1.565***
	(0.298)	(0.385)	(0.375)	(0.403)
Observations	84	73	73	73
R-squared	0.831	-	-	-
Wald chi2(4)	-	204.73	74.010	106.490
Prob > chi2	-	0.000	0.000	0.000

Note: Robust standard errors are showed inside parentheses; *, **, and *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

Table I.3 shows the determinants of input-oriented DEA efficiency scores calculated under the CRS assumption. Coefficient signs and the significance are not compatible among all the estimated models. This could be due to the heterogeneity in the sample data. Moreover, omitting the input variable, I_1 might result in biased DEA estimation. Therefore, results obtained in the chapter 4 with 44 DMUs are not readily comparable to the results shown in this appendix.

Table I.3

Determinants of input-oriented DEA efficiency scores (CRS)

Variable	(1) OLS	(2) Truncated	(3) Tobit	(4) Simar-Wilson
PREMIUM (LOG)	0.014	0.020	0.016	0.021
	(0.031)	(0.032)	(0.030)	(0.035)
SD EXPERIENCE	0.145***	0.142***	0.150***	0.171***
	(0.007)	(0.010)	(0.008)	(0.016)
GM EXPERIENCE	0.014***	0.012***	0.014***	0.021***
	(0.002)	(0.001)	(0.002)	(0.003)
WORKERS	0.001	0.001	7.78e-05	0.002
	(0.002)	(0.003)	(0.002)	(0.003)
SIGMA	-	0.108***	0.123***	0.122***
		(0.015)	(0.016)	(0.013)
CONSTANT	-1.442***	-1.476***	-1.499***	-1.951***
	(0.265)	(0.336)	(0.267)	(0.309)
Observations	84	77	84	77
R-squared	0.886	-	-	-
Wald chi2(4)	-	213.57	146.12	157.01
Prob > chi2	-	0.000	0.000	0.000

Note: Robust standard errors are showed inside parentheses; *, **, and *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.