The Efficiency of Occupational Safety Provision at Agricultural Cooperatives

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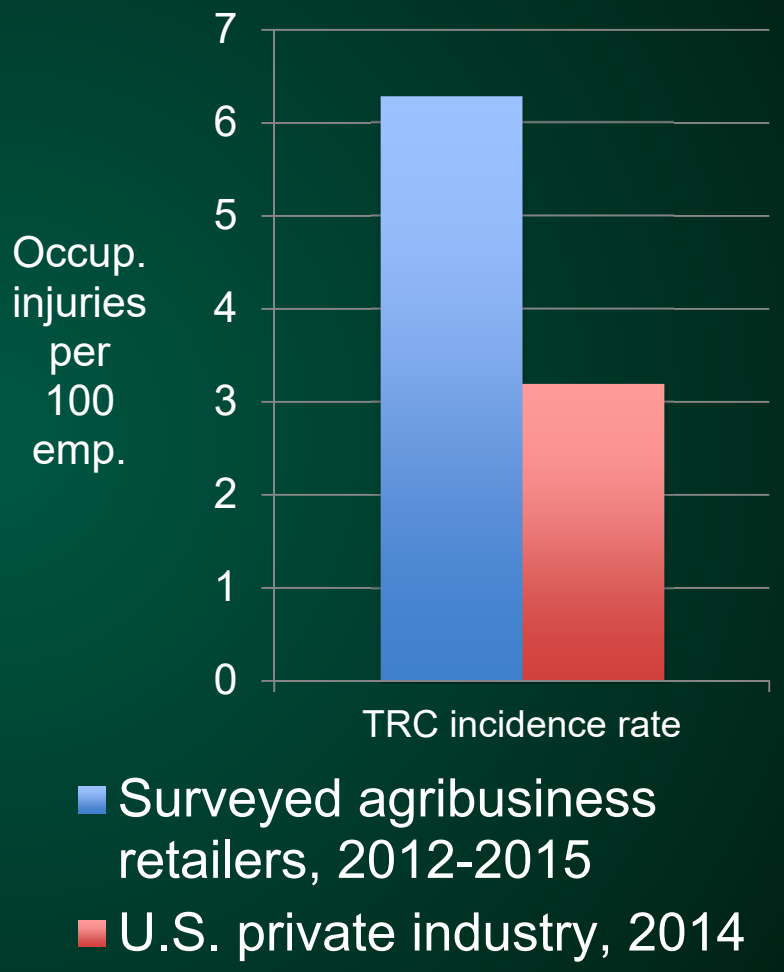
Motivation

- Agricultural dangers are well-known
  - Chemicals, grain elevators, machinery, etc.
  - Injury rates well above private industry
- Agricultural safety receives much attention from government, media

Motivation

- Although similar to production agriculture, less attention paid to agricultural cooperative safety
- Injury rates at surveyed agricultural cooperatives exceeds private industry rate



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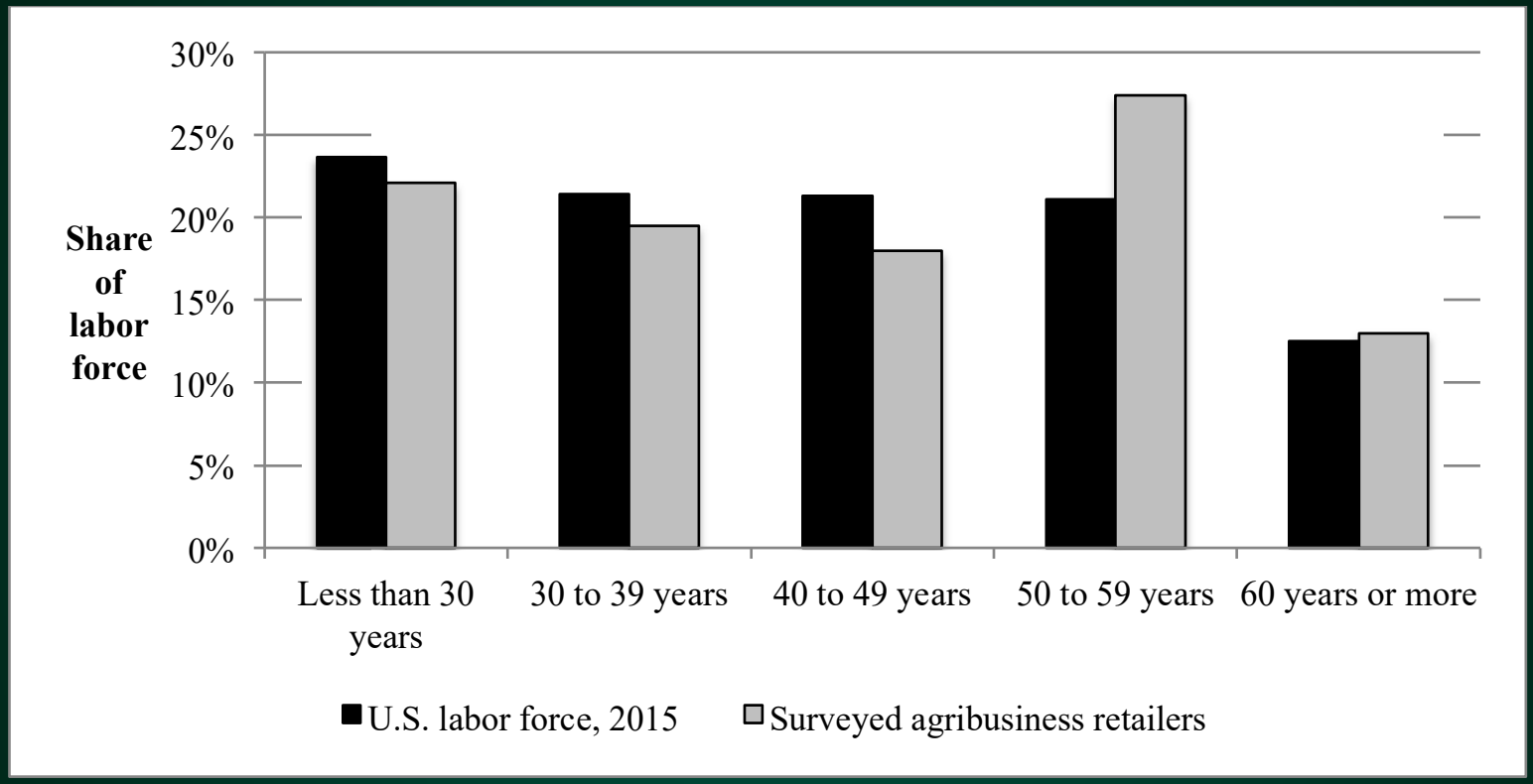
Motivation

- Several motivations for occupational safety
  - Short-term and long-term utility of employees
  - Financial considerations: Insurance, fines, legal settlements, productivity, etc.

Motivation



Source: U.S. Department of Labor, Bureau of Labor Statistics (2016)

Aging cooperative workforce means new employees in future (less experienced, opportunity to change culture).

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Antecedents

- Occupational safety literature in many fields
- Risch et al. (2014) investigate safety at agricultural cooperatives
  - Safety climate positively associated with several safety system elements
  - Injury rates negatively related to managerial safety climate

Objective and Hypothesis

- Objective: Determine whether occupational safety programs improve safety outcomes at agribusiness retailers

- Hypothesis: Efficiency of safety investments determined by managerial experience

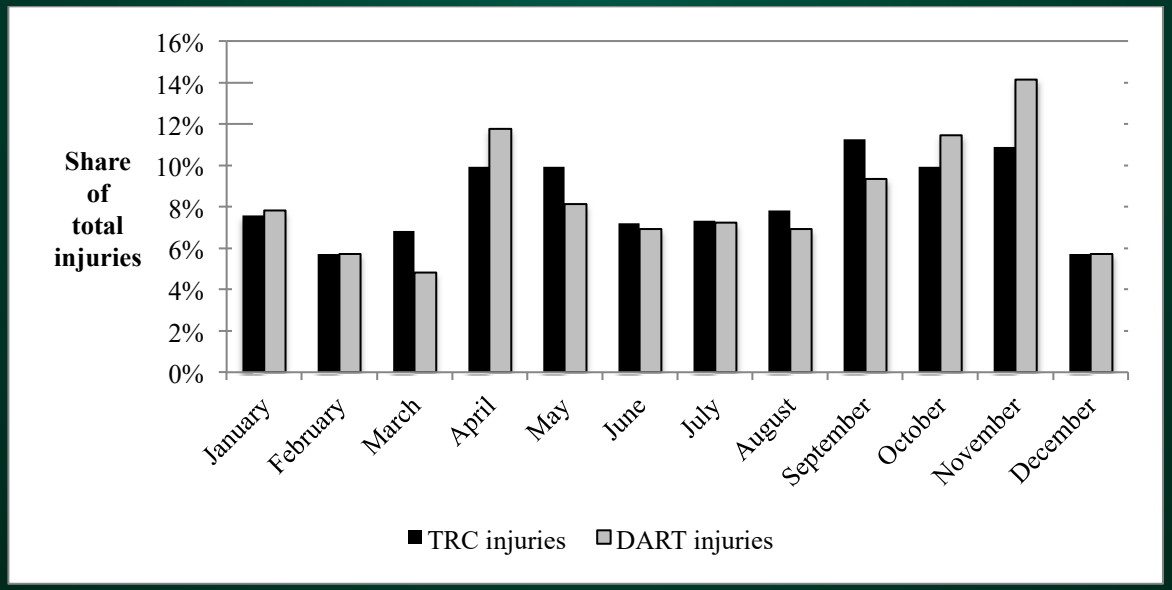
Surveyed Firms

- Surveyed 15 agricultural cooperatives with business locations in 7 states
  - Employed an annual average of 3,220 workers during the 2012 to 2015 period
- Injury data collected via OSHA forms 300 and 300A

Injuries at Agricultural Cooperatives

- Injuries frequent relative to private industry TRC rate (6.3 vs. 3.2 per 100 employees) and DART rate (2.6 vs. 1.7)

- Injuries more common during plant/harvest



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Injuries at Agricultural Cooperatives

Distribution of DAFW injuries at surveyed agribusiness retailers

Year	1 day	2 days	3-5 days	6-10 days	11-20 days	21-30 days	31+ days
2012	9.4%	11.3%	28.3%	13.2%	15.1%	3.8%	18.9%
2013	19.1%	10.6%	19.1%	17.0%	17.0%	4.3%	12.8%
2014	8.1%	12.9%	21.0%	12.9%	19.4%	6.5%	19.4%
2015	22.2%	4.4%	20.0%	11.1%	11.1%	2.2%	28.9%
Total	14.0%	10.1%	22.2%	13.5%	15.9%	4.3%	19.8%

Theoretical Model of Safety Efficiency

- Firm *h* chooses level of occupational safety that solves: *min Total Damage Costs*$_h$ *+Total Prevention Costs*$_h$
  - Damage costs: fines, insurance premia, lost production, etc.
  - Prevention costs: safety meetings, training, personnel, etc.
- If prevention costs unnecessarily high, total injury-related costs also too high

Empirical Model of Safety Efficiency

- Data envelopment analysis can measure efficiency of decision making unit (DMU) producing outputs via inputs
  - Data-driven
  - Compatible with multiple inputs and multiple outputs

Empirical Model of Safety Efficiency

- This application uses firm-level data from 2012-2014
  - 14 firms x 3 years = 42 DMUs
  - Inputs: compensation investment, safety system investment
  - Outputs: uninjured employees, non-DART injuries, DART injuries

Empirical Model of Safety Efficiency

Definitions for safety efficiency model inputs and outputs

Input or output (symbol)	Definition	Source
Compensation investment (I_1)	Firm's total compensation (in 2014 dollars) for managerial time devoted to occupational safety.	Interview
Safety system investment (I_2)	Firm's total expenditures (in 2014 dollars) on safety meetings, training, etc.	Interview
Uninjured employees (O_1)	Firm's total employees (calculated as firm hours/2,000) less total injuries.	300A
Non-DART injuries (O_2)	Firm's injuries not requiring days away from work, restriction, or transfer.	300A
DART injuries (O_3)	Firm's injuries requiring days away from work, restriction, or transfer.	300A

Summary statistics for safety efficiency model inputs and outputs

Input or output (symbol)	Mean	St. dev.	Min.	Max.
Compensation investment (I_1)	109,378.65	32,709.90	69,660.00	248,803.36
Safety system investment (I_2)	5,097.11	2,763.40	2,000.00	12,640.78
Uninjured employees (O_1)	199.39	87.97	45.42	482.13
Non-DART injuries (O_2)	8.31	5.42	0.00	21.00
DART injuries (O_3)	5.81	4.84	0.00	23.00

Empirical Model of Safety Efficiency

- In DEA, outputs should be maximized
- Here, there are two undesirable outputs (non-DART and DART injuries)
  - Strategies exist for dealing with undesirable outputs (Seiford and Zhu 2002)
  - Here, injuries are transformed by subtracting from maximum value across all DMUs and adding one

Empirical Model of Safety Efficiency

- Variable returns to scale, input-oriented DEA solves a linear program for each DMU:

$$\text{Min } \tau$$

$$\text{Subject to: } \sum_{q=1}^{42} \varphi_q O^*_{u,q} \geq O^*_{u,0}, \quad u = 1, 2, 3;$$

$$\sum_{q=1}^{42} \varphi_q I_{v,q} \leq \tau I_{v,0}, \quad v = 1, 2;$$

$$\sum_{q=1}^{42} \varphi_q = 1;$$

$$\varphi_q \geq 0, \quad q = 1, \ldots, 42$$

Empirical Model of Safety Efficiency

- DEA yields scores that reveal how much inputs can be scaled down for each DMU
- Scores provide reference DMUs for inefficient DMUs
- Scores can be used as dependent variable in safety efficiency regressions

Scores from Safety Efficiency Model

DMU	Rank	Technical eff. score	DMU	Rank	Technical eff. score
Firm 1, 2012	1	1.000	Firm 10, 2012	22	0.750
Firm 13, 2013	1	1.000	Firm 12, 2014	23	0.747
Firm 14, 2014	1	1.000	Firm 2, 2013	24	0.699
Firm 15, 2013	1	1.000	Firm 2, 2014	25	0.698
Firm 15, 2014	1	1.000	Firm 12, 2012	26	0.667
Firm 6, 2014	1	1.000	Firm 6, 2013	27	0.664
Firm 7, 2014	1	1.000	Firm 12, 2013	28	0.662
Firm 8, 2012	1	1.000	Firm 9, 2014	29	0.660
Firm 15, 2012	9	0.999	Firm 6, 2012	30	0.655
Firm 7, 2013	10	0.967	Firm 9, 2012	31	0.627
Firm 1, 2014	11	0.928	Firm 9, 2013	32	0.576
Firm 13, 2012	12	0.923	Firm 5, 2012	33	0.567
Firm 8, 2013	13	0.921	Firm 3, 2014	34	0.529
Firm 14, 2013	14	0.899	Firm 5, 2014	35	0.528
Firm 8, 2014	15	0.889	Firm 3, 2013	36	0.525
Firm 14, 2012	16	0.886	Firm 3, 2012	37	0.524
Firm 1, 2013	17	0.871	Firm 4, 2013	38	0.518
Firm 13, 2014	18	0.848	Firm 5, 2013	39	0.511
Firm 7, 2012	19	0.776	Firm 4, 2014	40	0.504
Firm 10, 2014	20	0.762	Firm 4, 2012	41	0.500
Firm 10, 2013	21	0.754	Firm 2, 2012	42	0.368

Key Results from Safety Efficiency Model

- 8 of 42 DMUs technically efficient
- Efficient firms include DMUs with lowest TRC and DART incidence rates in 2012-14 period
- One firm efficient in 2 separate years
  - Also has negative firm effect in safety outcome model – excellent safety worthy of future study

Uses of Technical Efficiency Scores

- Context for comparing against other firms, self
- Efficiency scores and reference DMUs create starting point for safety conversations
- What are determinants of safety efficiency?
  - Hypothesis: Efficiency determined by managerial experience

Analysis of Technical Efficiency Scores

- Regress scores on managerial experience variables

Definitions for safety efficiency score explanatory variables

Explanatory variable	Definition
Safety director tenure	Years of experience for a firm's primary occupational safety official.
Chief executive tenure	Years of experience for a firm's top manager (chief executive officer, general manager, etc.).

Note: Tenure is measured by the year of service an employee is in on the final day of a calendar year. Both experience variables are capped at 20 years.

Summary statistics for safety efficiency score explanatory variables

Explanatory variable	Mean	St. dev.	Min.	Max.
Safety director tenure	5.02	3.54	1	13
Chief executive tenure	10.79	5.99	1	20

Analysis of Technical Efficiency Scores

- What if CEO experience is interacted with dummy for contracted CEO safety responsibilities?

	Coeff.	S.E.	P-values
Safety director tenure	-0.009	0.008	0.271
Chief executive tenure	-0.003	0.009	0.575
Chief executive tenure interaction	0.009*	0.005	0.085
Constant	0.793***	0.057	0.000
Observations	42		
R^2	0.083		

- Contracted safety responsibilities may matter, but full picture is murky
  - Cannot find conclusive support for hypothesis

Opportunities for Future Research

- Increase robustness of injury statistics through larger sample
- More detailed investment data for DEA
- Investigate relationship between safety efficiency and more variables

THANKS! ANY QUESTIONS?

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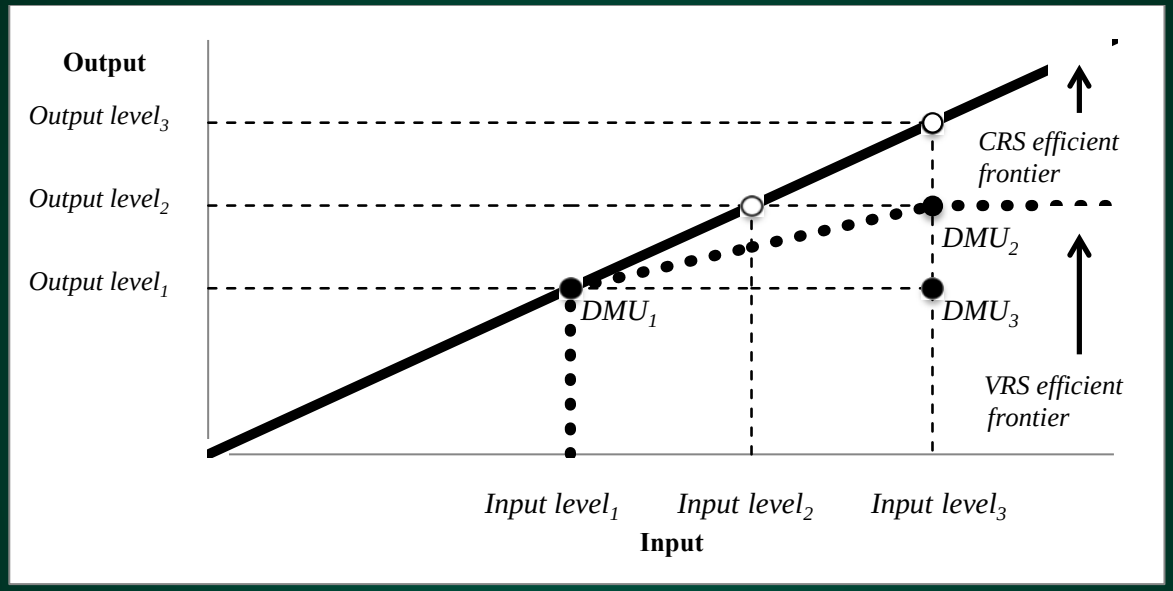
Empirical Model of Safety Efficiency

Example of efficiency analysis



- DMU_2 has CRS input efficiency of Input $level_2$/Input $level_3$
- DMU_2 has CRS output efficiency of Ouput $level_2$/Ouput $level_3$
- DMU_2 is VRS efficient for both inputs and outputs (efficiency ratio = 1)