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BRIEF REPORT

Economic Benefit and Cost Valuations for Occupational Injury and Fatality Prevention in Agriculture: A Generalizable Framework

Anita Alves Pena

Department of Economics, Colorado State University, Colorado School of Public Health, High Plains Intermountain Center for Agricultural Health and Safety, Fort Collins, CO, USA

ABSTRACT
Cost-benefit analysis (CBA) is a toolkit based in applied economic analysis to provide net impact values in dollar terms for direct and indirect benefits minus costs associated with a policy or intervention. CBA can include valuations of lives saved and of lives preserved via fatality and injury avoidance. The application of conceptually correct CBA to agricultural health and safety to date is limited. This article reviews how economic "shadow prices" can be used to estimate costs and benefits of interventions adjusted for farmwork populations relative to a "do nothing" status quo. The article provides a generalizable framework for future analyses of specific interventions, as well as background on tangible valuation methodologies that could contribute to impact analyses and funding requests highlighting the importance of farm health and safety.

KEYWORDS
Agricultural injuries and fatalities; cost-benefit analysis

Introduction

Calls for government investments to address disproportionate injury, morbidity, and mortality in agriculture are common. This includes requests for the network of university programs that concentrate research and outreach efforts on occupational health and safety applied to agriculture. Cost-benefit analysis (CBA) is a toolkit based on applied economic analysis to provide net impact values in dollar terms for direct and indirect benefits minus costs associated with a policy or intervention. CBA can include valuations of lives saved and of lives preserved via fatality and injury avoidance.[1] In 1996 in *Science*, Nobel Prize in Economics winner Dr. Kenneth Arrow and colleagues concluded that CBA had "potential to save significant numbers of lives while using fewer resources … a reallocation of priorities among these same regulations could save many more lives at the given cost, or alternatively, save the same number of lives at a much lower cost" (p. 222).[2]

The importance of economic cost for occupational injuries in agriculture has been recognized,[3–5] as have adjustments for undercounting of farm injuries in official statistics used in evaluations.[4–7] Systematic review of U.S.-based non-fatal agricultural injury surveillance systems identifies gaps in data release timing, data quality, and compatibility across platforms.[8,9] While regional data can fill some gaps,[10,11] approaches to broad economic valuation remain critical.[12] However, conceptually correct CBA has not been applied consistently to agricultural health despite the potential of these methods to assist in microeconomic decision making at the producer level.

Methods

CBA methodology includes costs to and wellbeing (benefits) derived by *all* people impacted directly and indirectly by safety and health in the agricultural operation. This is inclusive of employers, employees, coworkers, friends, and family. Assuming markets are competitive and well-functioning by definitions from the economics discipline, market prices provide a relevant estimate of economic benefits and costs.[1] Secondary market effects associated with individual farm actions are unlikely to be large, allowing focus on primary effects.

CBA estimates social surplus changes, defined as gains associated with participating in a market

CONTACT Anita Alves Pena anita.pena@colostate.edu Department of Economics, Colorado State University, Colorado School of Public Health, High Plains Intermountain Center for Agricultural Health and Safety, Fort Collins, CO, USA

when one's willingness to pay or accept differs from prices paid. When valuing a safety intervention, costs are measured in terms of opportunity costs that equal the value of output produced under the case that resources are not used for the intervention. The benefits side corresponds to the theoretical payments made or received to achieve indifference between being with and without a policy. Economic benefits include existence values even if the valuer is not a consumer. For example, knowing that someone else has a lesser chance of injury is an altruistic value based on others consuming "safety."

Results

Adapting frameworks developed in the economic field of cost-benefit analysis,[1] a stylized model was developed to illustrate two cases: (1) do nothing (status quo) and (2) do something (agricultural intervention).

Do nothing

The status quo corresponding to a baseline strategy of "doing nothing" was defined. In the farm's status quo, there are positive probabilities of both no injury and costly injury cases.[13] Table 1 summarizes economic costs contingent on injury. Direct costs relate to resources lost in the case of a farm accident. Indirect costs capture responses in other markets. Past cost studies of injuries and illnesses in farmwork can provide estimates of economic value corresponding to the do nothing case.[5,7]

The total economic valuation in the do nothing case mathematically is an expected value. This valuation equals the probability of an accident times the value associated with the loss (summation of all direct and indirect costs in Table 1) plus the probability of no accident times a zero valuation. An implication is the employer strategy of doing nothing is associated with a negative expected value when the accident probability is positive.

The incidence of line item elements of the model in Table 1 does not entirely fall on the owner/operator of the farm. Salary losses and medical costs can accrue to the worker or to private or social insurance. Harder to measure "less tangible" costs include pain and/or discomfort of workers in an accident and psychological impacts to family, friends, and coworkers. Increases to family burden are costs to others who substitute into home and caregiving responsibilities following a workplace injury. Costs that do accrue to a farm employer include worker replacement costs, damage-related impacts to factors of production such as equipment, infrastructure, and materials, and income loss due to decreased production and reputation.

All costs, regardless of incidence, are included in the cost-benefit framework. Many specific-line items can be valued via average cost of geographically-local provision of goods and services or other market-based estimates. Less tangible costs require best estimation using related markets (e.g., complementary or substitute products), intermediate goods, and/or various opportunity costs. Valuations associated with each line- are necessarily dependent on the nature and the parameterization of the specific economic activity being assessed.

As an example drawing from a common incident type in the agricultural sector, consider a positive probability of a tractor accident.[14] The probability of an accident can be estimated from historical frequencies for the number of accidents

Table 1. Economic costs of do nothing strategy, case of an accident leading to injury.

Direct costs:	Indirect costs:
• Medical and rehabilitation costs (including personnel, equipment, medicine, hospital/clinic supplies) • Losses of salary/benefits (net of sick pay), professional capacity, time use (time substituted to medical care/recovery) • Value of physical and psychological pain and/or discomfort (less tangible) • Value of family burden (less tangible) • Increased workload to coworkers, training time for replacement staff • Damage/repair/clean-up costs to equipment, machinery, vehicles, buildings, product/raw materials, etc.	• Income/current production losses (including changes in quality) • Loss of value associated with site compliance to health/safety regulations • Investigation/legal/litigation costs, fines • Increased insurance prices • Reputational costs (less tangible)

Source: Author's adaptation/extension of literature and techniques presented in the Boardman et al.[1] *Cost-Benefit Analysis* textbook.

per unit of economic activity or resource. Valuations for each category in Table 1 can be imputed from market-based data when available, or estimated via shadow pricing as discussed in subsequent sections. Medical costs, for example, can be estimated from average emergency room visit pricing for local-level vehicular accidents and matched to past tractor accidents specifically if available. The probability of accident and individual elements of the valuation calculation can then be adjusted in sensitivity analysis to provide confidence intervals.

Do something agricultural intervention

A "counter-factual" (hypothetical) safety or health intervention was modeled. Table 2 summarizes economic costs and economic benefits as changes that are interpretable relative to the status quo of Table 1. Changes relate to both changes in probabilities and other parameters that are interrelated with changes in strategic (and non-strategic) behaviors of agents (workers and owners) in the models. Impacts are changes relative to the status quo, cataloged into direct and indirect categories.

Table 2 illustrates tradeoffs between current expenditure and reduction in accident probability as primary benefit. Expenses to make a workplace safer are direct and tangible costs that can be valued by associated monetary outlays. Less tangible direct costs include discomfort related to program compliance. Direct benefits include lower injury risks and medical costs. Indirect benefits include increased productivity. Interventions involve high upfront and certain costs, while benefits accrue into the future and are often subject to more uncertainty.

Returning to the case of a tractor accident, consider a common safety intervention such as the installation of Rollover Protective Structures (ROPS). In this example, the presence of the ROPS does not necessarily change the probability of an accident itself. However, tractors with (versus without) ROPS are associated with lesser injury costs conditional on an accident occurring.

Discussion

Using CBA for decision making involves a significant information burden. Filling gaps requires soliciting information from additional sources. Analysis of a safety intervention requires monetization of the value of life and of reduced risk. Economic supply and demand curves are the theoretical underpinnings, though units of "safety" are hard to define. It is therefore unlikely to parameterize safety as a demand function with confidence.

Indirect valuation can be used to estimate less tangible values. Changes to time use can be linked to the analogous labor market and valued using an after-tax wage rate with adjustments. Nonwage

Table 2. Elements of CBA for an occupational health and safety intervention in agriculture.

Economic Costs	Economic Benefits
Direct costs • Intervention-related outlays (resources spent) (e.g., training/certification costs such as time of trainers, materials including first aid supplies, PPE, safety equipment, outreach/teaching tools) • "Discomfort" when wearing PPE, using new equipment, etc. (less tangible)	***Direct benefits*** • Lower mortality rates (avoided life loss) • Lower injury risk (saved medical costs) • Fewer physical damages • Insurance premium savings • Compensation claims/litigation/accident investigation savings
Indirect costs • Opportunity costs of time (time values of trainees, foregone production during training, values associated with slower or otherwise changed work practices to maintain compliance with new policy/program/intervention)	***Indirect benefits*** • Productivity increases • Less absenteeism/presenteeism (fewer lost working days/time, less sick pay) • Increased motivation, higher morale/job satisfaction, personal valuation of health benefits (less tangible) • Savings on cleaning, waste disposal • Reputation effects (savings on image improvement activities) (less tangible) • R&D value of new safety technologies

Source: Author's adaptation/extension of literature and techniques presented in the Boardman et al.[1] *Cost-Benefit Analysis* textbook.

labor compensation such as fringe benefits should be added when approximating market-level labor compensation. Additional adjustments, or "shadow pricing," based on supplementary data are necessary for market failures or rigidities.

Trade-offs between changes in fatality risk and wages can be used to measure what people would be willing to pay to avoid risks that result in one less death per population. Consumer purchase studies estimate the value of life by comparing expenditure on life-saving devices to changes in fatality probability, and labor market studies compare forgone salary in less risky versus risky jobs to determine valuation of life and physical wellbeing. These studies assume workers and consumers understand risks and that the study sample is representative of the population. These assumptions confirm that tsensitivity analysis is warranted.

A practitioner of CBA needs to predict project's impacts and multiply them by appropriate market price or shadow price. Within CBA, existing estimates of shadow prices drawn from marginal valuations can be used as "plug-ins" for lives saved and lives preserved via fatality and injury prevention. Previously estimated shadow prices can be adjusted for policy context, socioeconomics and demographics, for geographic and climate differences, and for project quality and scope that match the farm case.

An estimate of approximately $11 million is a common plug-in for the Value of a Statistical Life (VSL).[1,15] This places Value of a Life-Year (VLY) at $515,100 per person per year in 2016 USD. This calculation is based on the previous VSL of $11 million, 40 years of remaining life expectancy, and a discount rate of 3.5%. VSY can be interpreted as a "shadow price" of a life year.[16]

VSL and VLY are not without critique. For example, wages and risks that are analyzed together could be interrelated with a third unmeasured factor,[17] and VSL can vary with researcher assumptions.[18] However, VSL and VLY can be adjusted for income and other factors to derive subgroup-specific willingness to pay measures to fine-tune estimates to make them applicable for agriculture-related occupations and other specific circumstances.[19–23] VSL can also be extended to incorporate the value of good health, a feature particularly relevant to studies on interventions supporting occupational safety and one of the line items in the models here.[24,25]

Conclusion

Individual farm-level decisionmakers can impact local injury propensities via a variety of interventions. This article presented models for applications to agricultural health and safety to highlight social surplus gains from direction reductions in producer costs via policy.

Sensitivity analysis is important to ensure policy recommendations are robust to uncertainty and assumptions. Given the inherent uncertainties in CBA, particularly around shadow prices, conducting sensitivity analysis to test the robustness of results before determining policy recommendations is critical. This can be systematically approached in terms of increasing or decreasing parameters such as accident probabilities and/or the specific valuations of line items in the models presented in this article.

Similarly, increased attention to the limits of surveillance in farm applications is critical. Practitioners of CBA applied to the agricultural sector may need to provide additional sensitivity analysis to accident probabilities due to underreporting of injuries and fatalities and documented challenges associated with obtaining reliable data.[5,6,8,9,12] Furthermore, CBA estimates can be reviewed and actuarily updated to different farm activities with allowances for types of risk matched to particular tasks in future work to create agricultural-specific "plug-ins."

Conducting CBA has costs in terms of analytic time but offers benefits in the form of increasing allocative efficiency and reallocating resources to their highest value use. Allocative efficiency is an economic concept not yet fully applied to the agricultural health and safety literature to date. This article provides a generalizable framework for analyses of specific agricultural interventions and a call for action to expand this area of inquiry.

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