Costs of Occupational Injuries in Agriculture

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SYNOPSIS

Objective. This study was conducted to estimate the costs of job-related injuries in agriculture in the United States for 1992.

Methods. The authors reviewed data from national surveys to assess the incidence of fatal and non-fatal farm injuries. Numerical adjustments were made for weaknesses in the most reliable data sets. For example, the Bureau of Labor Statistics (BLS) Annual Survey estimate of non-fatal injuries is adjusted upward by a factor of 4.7 to reflect the BLS undercount of farm injuries. To assess costs, the authors used the human capital method that allocates costs to direct categories such as medical expenses, as well as indirect categories such as lost earnings, lost home production, and lost fringe benefits. Cost data were drawn from the Health Care Financing Administration and the National Council on Compensation Insurance.

Results. Eight hundred forty-one (841) deaths and 512,539 non-fatal injuries are estimated for 1992. The non-fatal injuries include 281,896 that led to at least one full day of work loss. Agricultural occupational injuries cost an estimated $4.57 billion (range $3.14 billion to $13.99 billion) in 1992. On a per person basis, farming contributes roughly 30% more than the national average to occupational injury costs. Direct costs are estimated to be $1.66 billion and indirect costs, $2.93 billion.

Conclusions. The costs of farm injuries are on a par with the costs of hepatitis C. This high cost is in sharp contrast to the limited public attention and economic resources devoted to prevention and amelioration of farm injuries. Agricultural occupational injuries are an underappreciated contributor to the overall national burden of health and medical costs.

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Several studies have attempted to describe the nature of injuries on American farms.[1,2] These injuries include strains from chronic stooping, eye injuries from debris ejected from machines, knife cuts, amputations, and fractures, among others. Farming has been estimated to be among the most hazardous of industries in terms of number of fatalities, fatality rates, number of non-fatal injuries, and non-fatal injury rates.[3-6] It is documented that tractor roll-overs are the leading cause of fatalities and that the temporary work assignments in farming are at least partly responsible for agriculture's high injury rates.[7-9] In addition, studies show that it is likely that farming contributes a disproportionate number of injuries to minors.[2,10,11] In one of the few studies that looked at costs, Ciesielski et al. found that employers, through workers' compensation, covered only roughly 38% of workers for medical expenses and roughly only 20% of workers were paid indemnity for work loss.[12] As we will show, these studies have a number of limitations. For example, none of them have taken proper account of economic incentives that lead to underreporting of injuries by both employees and employers. Nevertheless, they provide a useful context for this study.

In contrast to the knowledge of the nature of injuries, inter-industry comparisons, and workers' compensation (WC) costs, little is known about the overall national burden of agricultural injuries. We are familiar with only one recent study devoted to farm injuries and two simple national estimates generated as part of much larger studies. A National Institute for Occupational Safety and Health (NIOSH) report focusing on farm injuries estimates that roughly 210,000 agricultural injuries occur per year involving at least one-half of one day of work loss.[13] The National Safety Council (NSC) estimates that there were roughly 230,000 non-intentional injuries in the early 1990s.[14] The Bureau of Labor Statistics (BLS) Annual Survey estimated 109,400 in the early 1990s.[15] But, as this article will show, the NIOSH report may have underestimated farm employee injuries, and the National Safety Council does not count murders or assaults. The BLS Annual Survey reflects only a fraction of those who farm. A literature search did not uncover a single study for which the main purpose was to estimate the national costs of agricultural injuries, yet costs have become critical statistics in the national debate on medical care.

Objectives

The primary purpose of this article is to provide an estimate of these costs, together with estimates of numbers of fatal and non-fatal injuries. Because we used conventional cost methods, our estimates can be compared to other estimates of injuries and illnesses in the literature.[16-20] In developing these estimates, we drew on our national study of occupational injury and illness for all industries combined, which was originally a NIOSH report and subsequently became an article and book.[18-20] An important but secondary purpose is to point out strengths and weaknesses of surveys and data sets that have been used to investigate farm injuries.

METHODS AND RESULTS

Year for analysis

The most comprehensive cost data apply to 1992. In addition, and more importantly, a source of data on non-fatal injuries inside and outside agriculture that has been heavily relied on is the Bureau of Labor Statistics' Annual Survey.[18-20] As we will show, however, the Annual Survey non-fatal injury data need to be adjusted by both the Annual Survey fatality data and the NIOSH fatality data from 1992 and 1990. Unfortunately, the most recent Annual Survey fatality data are from 1990. As a result, our epidemiologic and economic data apply to 1992 and 1990. Because we were able to adjust the Annual Survey for changes from 1990 to 1992, all of our estimates apply to 1992.

Sources of data

For the present analysis, we used data from the Census of Fatal Occupational Injuries (CFOI)[6] for 1992, the NIOSH National Traumatic Occupational Fatality Survey (NTOF) for 1990 and 1992[21] (Personal communication, S. Kisner, February 3, 1999), the BLS Annual Survey[15, 23] for 1990 and 1992, and the national study for all industries combined,[19] to develop estimates of the incidence of fatal and non-fatal disabling and non-disabling injuries for 1992. We also used data from our all-industry national study for average medical and administrative costs, for lost wages, home production, and re-hiring for 1992.[19] We used agriculture-specific information on fringe benefits and wages from the US Bureau of the Census for 1992.[24]

Counting deaths

In 1992, the CFOI counted a total of 6,083 civilian deaths in all industries.[5] Of these, 800 (13.2%) were within the broad (one-digit) industry category of Agriculture, Forestry, and Fishing. This 13.2% is the figure we used to develop our estimate of the number of fatal injuries.

The Agriculture, Forestry, and Fishing division comprises several sub-categories. Within agricultural crops production (SIC 01), 401 deaths (6.6%) were counted;

within agriculture livestock production (SIC 02), 164 deaths (2.7%) were counted; within agricultural services (SIC 07), 136 (2.2%) were counted; and within hunting, fishing, and trapping (SIC 09), 81 (1.3%) were counted. The agricultural services category, which includes workers who prepare soil and managers who supervise labor contracts, contributes 37.5% of all employment in the broad one-digit category.

We focused our attention on the major division of Agriculture, Forestry, and Fishing and simply refer to this broad category as "agriculture" or "farm" for two reasons. First, numerator, denominator, and cost data are available and reliable for this broad category. This is not the case for the sub-categories. Second, the non-agricultural elements—fishing, hunting, and trapping—contribute only 1.3% to the total.

We did not use the CFOI 800 death count as our estimate of deaths in agriculture; rather, we multiplied the 13.2% by the national death estimate for all industries combined (6,371).[19] We believe that CFOI death counts in all industries are underestimates for reasons explained in the Discussion section of this article; for example, the CFOI likely undercounts minority workers.

Counting non-fatal injuries

Estimates for non-fatal injuries are available in the Traumatic Injury Surveillance of Farms (TISF)[13] and the BLS Annual Survey.[15] As presented in the Discussion, these data sets have flaws. Nevertheless, unlike the TISF, the flaws in the BLS Annual Survey can be minimized because it is likely to be internally consistent for several years of data gathering. We used the BLS Annual Survey after adjusting for these flaws.

The Annual Survey produces an undercount by explicitly excluding small farms, and by the economic incentive created for farm owners and employees to underreport injuries. High injury rates can result in high workers' compensation premiums for owners. Employees may be afraid to report injuries for fear of employer reprisal. We therefore adjusted for this undercount by assuming *(a)* that the same percentage undercount applies to BLS Annual Survey *deaths* as applies to BLS Annual Survey *non*-fatal injuries; (*b*) that our estimate of deaths in agriculture (841), based on the CFOI, is the best fatality estimate; and *(c)* that the estimates in the NIOSH NTOF[21, 22] are proportional to those in the CFOI. We believe that the BLS Annual Survey estimate for non-fatal injuries should be adjusted upward by the same percentage that the best fatality estimate (841) exceeds the BLS Annual Survey estimate of fatalities. The last published Annual Survey estimate for fatalities applied to 1990.[15]

We used the following adjustment formula:

Equation 1:

$$841 \times [NTOF90/NTOF92] / [0.89 \times BLSAS90]$$

The first number, 841, is our fatality estimate for agriculture in 1992. NTOF90 and NTOF92 are the fatality estimates in Agriculture, Forestry, and Fishing from the NIOSH NTOF study for 1990 and 1992.[21,22] BLSAS90 is the BLS Annual Survey death estimate from 1990 that includes diseases and illnesses. The next number, 0.89 (or 89%), is the estimate of the percent of injury deaths among all deaths recorded in the Annual Survey.[13] The NTOF adjustment in the numerator is used to account for the fact that the most recent BLSAS year is 1990. We assumed that, over time, CFOI, NTOF, and BLS Annual Survey estimates were proportional. The CFOI primarily relies on the death certificates and the NTOF exclusively relies on the death certificates. Our factor given by Equation 1 is:

$$[841 \times (598/603)] / [.89 \times 200] = 834 / 178 = 4.6849$$

The 834 is our estimate of the number of deaths in 1990. We therefore estimated that the BLS Annual Survey would have underestimated agricultural injury deaths by a factor of 4.6849 in 1990 and 1992. Because we assumed that non-fatal injuries in the BLS Annual Survey in 1992 were underestimated by the same percentage, this 4.6849 can be multiplied by the BLSAS *non*-fatal injury estimate for agriculture for 1992 (109,400). Therefore, our estimate of non-fatal injuries attributable to agriculture in 1992 is $109,400 \times 4.6849 = 512,539$. This 4.6849 implies that the Annual Survey missed 79% of fatalities. We assume the Annual Survey also missed 79% of all non-fatal injuries.

This roughly 79% undercount appears large; there are a number of reasons for it, however. First, in counting deaths, small farms (fewer than 11 employees) are excluded by the BLS. But small farms (fewer than 10 employees) represented 27% of the agricultural workforce in 1992.[25] If we assume that an additional 3% are omitted moving from farms with fewer than 10 employees to farms with fewer than 11 employees (27/10 = roughly 3), then the "fewer than 11 employees" restriction would eliminate 30% (27% + 3%). We divided by 10 assuming an equal percentage of firms with one employee, two employees, three employees, and so on. If we assume that deaths are proportional to employment, we have thus accounted for 30% of the 79% undercount.

Next, the number of farms within the 11 to 19 employee group may also account for some of the

undercount. Some farms may have only recently hired that 11th or 12th worker. Not only does agriculture have a high percentage of farms with 10 or fewer employees; agriculture, compared with most other industries, also has a higher percentage of farms with 10 to 19 employees. In agriculture, 27% of workers are employed in firms (farms) with fewer than 10 workers and 17% of workers are employed in firms (farms) with 10 to 19 workers. The corresponding statistics outside agriculture are 15% (< 10 workers) and 11% (10–19 workers). These newly expanded firms may not yet be aware of the BLS requirement, or they may reason that employment will soon fluctuate below the 10-worker threshold. If half of this 17% does not report, then we have an additional 8.5% that does not report. We can now thus account for 8.5% + 30%, or 38.5% of the 79% undercount.

Apart from these legal or administrative reasons for undercounting, there are difficulties farm owners, especially owners of small farms, face in recording injuries. The paperwork can be burdensome. Seligman et al. found that OSHA records are poorest at the smallest firms.[26]

It is alarming to contemplate whether deaths go unreported when the BLS asks employers to report them, e.g., in firms (farms) with 11 or more employees. But this kind of underreporting may be more common in agriculture than in any other industry, again, in part, because of the great number of small firms in agriculture.

Many small firms are exempt from OSHA regulations, as well as WC coverage.[19] Oleinick, Gluck, and Guire suggest that small firms are simply less likely to report fatalities than larger firms.[27] Given the abundance of small firms in agriculture with 11 to 50 employees, the general association between small firms and reporting may explain some additional portion of total underreporting.

Finally, when adjustments are made for underreporting for small firms, they are found to have fatality rates two to three times as large as those for firms with more than 50 employees.[19] Our assumption about employment and deaths being proportional in small firms may therefore be conservative, suggesting that the underreporting may be much higher than 38.5% because small firms are more dangerous than large firms.

We return now to our estimate of non-fatal injuries (512,539). The 512,539 can be divided into disabling and non-disabling injuries. We defined *disabling* as resulting in at least one day of work loss. In the all-industry estimate, prior to our undercounting adjustments, we relied on the BLS Annual Survey percentage estimate that 46% of injuries in all industries are disabling.[19] The BLS Annual Survey indicates, however, that agricultural injuries generate a greater percentage of disabling injuries—51%. The higher percentage of disabling injury in agriculture is consistent with the observation that injuries in agriculture generate much higher death-to-employment ratios than in almost all other industries (13.2% of all job-related deaths, but employment contributes only 2.7% of the workforce in agriculture; ratio is 4.9:1).[28,29] The national, all-industry estimate assumed that non-disabling injuries were undercounted by 35%; disabling injuries, by 20%.[19] As a result, the all-industry study estimated that 40%, not 46%, of injuries were disabling. The all-industry estimate thus indicated a 6% decline from 46% to 40%. Applying the same 6% decline to agricultural injuries yields 45% (51% – 6%). Consequently 0.45 × 512,539 yields 230,643 cases of disabling injury in 1992. Non-disabling injuries would then be 512,539 − 230,643 = 281,896.

Cost method

We used the Human Capital (Cost-of-Illness) method to calculate costs. General discussions of advantages and disadvantages of the Human Capital method are available elsewhere.[30] In the interest of brevity, we avoid those discussions here and simply note that, despite its weaknesses, it is still the most popular method for estimating the cost of any illness or injury. According to this method, costs are broadly split into direct and indirect components. Direct costs include spending on hospitals, doctors, and drugs as well as insurance overhead for both medical and indemnity insurance. Indemnity insurance overhead covers Social Security Disability Insurance administration costs, Welfare, and private disability insurance overhead.

Lost wages are the largest category of indirect costs. Fringe benefits and home production are the second and third largest components. Home production refers to unpaid domestic work such as rearing children, cooking meals, cleaning, fixing pipes, and so on. Finally, some account needs to be taken of expenses by the firm for retraining and recruiting and is included in our measure of indirect costs.

As a category, Lost Wages is meant to capture not just injury-related financial hardship on the person and family without the wages, but the cost to the economy in terms of lost output. Lost fringe benefits are included for the same reason. The total economic loss is assumed to be what is required for the business to attract a qualified person to the job.

Direct costs

Our estimate of medical costs is derived from Equation 2:

$$\text{Medical costs} = (\text{deaths} \times \text{avg\$deaths}) + (\text{disablinjuries} \times \text{avg\$disablinjuries}) + (\text{nondisablinjuries} \times \text{avg\$disablinjuries})$$

where "avg$" refers to the average costs for deaths ($20,700), disabling injuries ($5,046), or non-disabling injuries ($347). These average cost figures are derived from the all-industry national estimates.[19] The all-industry estimates, in turn, are derived from National Council on Compensation Insurance estimates of WC medical costs for: deaths; permanent total, permanent partial, and temporary total and partial disabilities; and "medical only" categories. In this agriculture study, we also adjusted for lower WC coverage in farming (farming, 21.3% coverage; all US industry, 45.0% coverage). This 21.3% coverage in farming is an estimate based on the assumption that WC coverage is equal to the ratio of the BLS Annual Survey figure for non-fatal injuries for farming (109,400) to our best estimate for non-fatal injuries (512,539), i.e., 190,400/512539 = 21.3%. We assumed, in other words, that all the injuries reported to the BLS were also reported to WC authorities. The average cost figures are weighted averages of costs per death and per injury when the weight is the percentage of WC coverage assumed in agriculture (21.3%). The medical costs are weighted by WC coverage because there is evidence that WC injuries are more serious than non-WC injuries and that treatment of WC injuries is more expensive than treatment of non-WC injuries.[31] We assumed that non-WC injuries would cost 10.1% less than WC injuries.[31]

The numbers for Equation 2 are:

$$\$17.41 \text{ million} + \$1{,}163.82 \text{ million} + \$97.82 \text{ million} = \$1{,}279.05 \text{ million, or } \$1.279 \text{ billion}$$

To calculate medical administration (overhead) costs, we assumed that the same ratio of medical administrative costs to medical costs applies here as calculated in the all-industry study, after adjusting for the lower WC coverage in agriculture compared to other industries. We adjusted for WC coverage because WC insurance administration is more expensive than that for non-WC insurance, in part because of the litigious nature of WC.[32] We assumed 31% (over benefits) for WC administration and 15% (over benefits) for non-WC administration. The 31% figure was calculated with national estimates of WC premiums and benefits, and the 15% was estimated by Cutler in his widely cited paper on medical care costs.[33,34]

We calculated indemnity administration (overhead) costs by calculating the ratio of indemnity administration costs to lost earnings that was estimated for all industries and then by adjusting for the low WC coverage in agriculture.[19] We assumed the same administration cost percentages for indemnity as we did for medical administration, i.e. 31% for WC and 15% for all others.

Indirect costs

To calculate lost earnings, we began with the all-industry estimates per injury: fatalities ($422,069), disabling injuries ($14,815), and non-disabling injuries ($0). Again, non-disabling means no work loss, i.e., no earnings lost. Lost earnings for fatalities were calculated with a present value formula that assumes that, had the person not died, he or she would have earned the same amount as others with the same age and gender over their working lifetimes, adjusted for the probability of survival from one age to the next. The working lifetime extends to age 75, but only 18% of people were assumed to work beyond age 65. Lost earnings for disabling injuries involved multiplying estimates of WC indemnity benefits (from National Council on Compensation Insurance data in the all-industry study) by the reciprocal of the WC replacement rate.[19] We assumed a replacement rate of one-half. This replacement rate was for lost pre-tax earnings.

In this study on agriculture costs, we multiply the all-industry estimates ($422,069 and $111,815) by number of deaths (841) and number of disabling injuries (230,643). The sum of these products is then multiplied by the ratio of wages in agriculture to wages in the rest of the economy: 0.5842. This 0.5842 assumes that the lost productivity, or "value of life," for the typical farm worker and farm owner is only 58.42% of the typical non-farm worker in the American economy. These calculations can be shown as:

$$[(\$422{,}069 \times 841) + (\$14{,}815 \times 230{,}643)] \times 0.5842 = 2203.57, \text{ or } \$2.204 \text{ billion.}$$

Alternatively, we could assume the same "value of life" applies to all workers in the economy.[35] This would imply *not* multiplying by 0.5842, but rather by 1.0, which suggests an estimate of $3.77194 million.

We assumed the same ratios apply to agriculture as apply to the all-industry study for home production (13.8% of lost earnings) and restaffing (3.2% of lost earnings). Home production and restaffing therefore are estimated to be .138 × 2.20357 = $0.304 billion and .032 × 2.20357 = $0.07 billion. The all-industry study estimates assumed a fringe benefit rate of 23.3%. Fringe benefits in agriculture are less, however. We assumed the rate generated by a ratio of total compen-

sation in agriculture ($19.438 million) to wages and salaries in agriculture for 1992 ($16.748 million).[36] The ratio, or percentage, is 16.1%, and this percentage multiplied by $2.20357 is $0.355 billion.

Summary tables

Injury estimates are summarized in Table 1. We estimated 841 deaths and 512,539 non-fatal injuries, of which 281,816 are non-disabling and 230,643 are disabling. Table 1 gives the percent of contribution by agriculture to all industries. These percentages can be compared with economic and employment contributions. The economic contribution of the broad category of Agriculture, Forestry, and Fishing to Gross Domestic Product (GDP) was about 1.8% in 1992.[24] The employment contribution of Agriculture, Forestry, and Fishing to total US employment was about 2.7% in 1992, according to government estimates.[24] Our fatal injury percent contribution to the "all industry" estimate (13.2%) is some five to seven times larger than either the economic (GDP) or the employment contribution. Our findings suggest that agricultural work is uncommonly dangerous. Our non-fatal percent contribution (3.843%) is more than double the GDP contribution, and 42% greater than the employment contribution.

Results on costs appear in Table 2. Direct costs are estimated at $1.64 billion, or roughly 35% of total costs for agriculture. Approximately 77% of direct costs result from medical expenditures and 23% from insurance overhead. Indirect costs are estimated at $3.09 billion or 65.1% of total costs. Lost wages contribute roughly 71% of all indirect costs.

Total costs are estimated to be $4.753 billion, which represents 3.58% of all occupational injury costs for all industries in 1992.[19] This figure is roughly twice the size of the economic contribution for agriculture.

Sensitivity analysis

Table 3 presents our sensitivity analysis. We entertain seven new assumptions. The first five (rows one to five) alter existing assumptions in our model. The last two (rows six and seven) suggest new estimates for caregivers' time and pain and suffering—two estimates that are seldom applied in cost-of-illness or cost-of-injury studies. These last two assumptions lie outside our model.

Table 1. Estimates of agricultural injuries, 1992

	Number	*Percent of contribution to all industries*
Deaths	841	13.2
Nonfatal injuries	512,539	3.843
Non-disabling	281,896	3.519
Disabling	230,643	4.331

Table 2. Costs

Costs	*$US (billions)*
Direct	1.640
Medical	1.279
Administration for medical insurance	0.246
Administration for indemnity insurance	0.115
Indirect	2.933
Lost earnings	2.204
Lost fringe benefits	0.355
Lost home production	0.304
Training, re-staffing	0.070
Total	4.573

The first assumption (row one) applies to the value of indirect costs. Our preferred estimate assumes the value of lost earnings, fringe benefits, home production, and retraining is 58% of the typical American average wage in the workforce. Gold et al. suggest that for a variety of reasons, including discrimination and ethics, all lost productivity should be treated equally so that the same wage, fringe benefits, and so on should apply to all workers.[34] The upward adjustment is substantial. This "equal productivity" assumption would increase our preferred estimate by about $2.1 billion.

The second assumption (row two) allows for the possibility that underreporting of non-fatal injuries occurs at twice the rate as underreporting of fatalities. The idea is simple: it is easier for the person recording the injury (typically the owner or manager) to forget or ignore a non-fatal injury than a fatal one. But an assumption of a doubling difference would result in an estimate of 1.024 million non-fatal injuries per year as opposed to our preferred estimate of 512,539. Given that the BLS Annual Survey estimates 109,400 and the TISF estimates 201,081, the jump to over a million injuries appears extreme. We prefer our estimate of 512,539 because it is closer to the BLS and TISF estimates.

Our preferred estimate assumes that, with proper adjustment for undercounting, the Annual Survey can produce a credible estimate for non-fatal injuries and costs. Alternatively, it could be that our fatality estimate, which relies heavily on the CFOI, more accurately reflects non-fatal injuries and costs. We could alternatively assume (row three) that a percentage midway between the fatality percent (13.2%) and the non-

Table 3. Sensitivity analysis

	$US (billions)		
	Cost estimate	*Amount above (+) or below (−) preferred estimate*	*Percent above (+) or below (−) preferred estimate*
Preferred estimate	4.573	0	0
Alternative assumption, inside model			
1. Allow farm work to equal average wage for all industries, not 58% of average wage.	6.661	+ 2.088	+ 45.7
2. Assume the underreporting percent of non-fatal injuries is double that of Annual Survey fatal injuries, as opposed to equal to the percent of fatal injuries (overlap with row 3).	8.806	+4.233	+ 92.6
3. Assume percent of non-fatal injuries is midway between the CFOI adjusted estimate (13.2%) and the preferred non-fatal injury percent (3.845%). Would be true if CFOI is better than Annual Survey or TISF in estimating non-fatal injuries (overlap with row 2).	9.603	+5.030	+ 110.0
4. Assume TISF estimate, adjusted for disability definition of 1/2 day (overlap with row 5).	3.349	−1.224	− 26.9
5. More likely that WC reported disabling injuries than nondisabling; Assume 30% disabling (not 45%) and 70% (not 55%) nondisabling (overlap with row 4).	3.141	−1.432	−31.3%
Alternative assumption, outside model			
6. Caregivers' time; 20% of medical costs	4.829	+ 0.256	+ 5.6%
7. Pain and suffering; 3 times medical costs plus lost earnings	15.022	+ 10.449	+ 228.5%
Range, inside model, using rows 1 and 3 (upper) and row 5 (lower)		$3.141—$13.99	

NOTES: Annual Survey = Bureau of Labor Statistics Annual Survey; CFOI = Census of Fatal Occupational Injuries; TISF = Traumatic Injury Surveillance of Farms; WC = worker's compensation.

fatal injury percentage (3.845%) applies to non-fatal costs after adjustments for lesser WC coverage on farms, lower wages for farm workers, and a greater ratio of disabling to non-disabling injuries in agriculture than elsewhere in the economy. This would generate a cost roughly 2.1 times larger than the preferred $4.573 billion estimate, or $9.603 billion. This higher estimate would be the more reasonable estimate if the CFOI characterized non-fatal injuries more accurately than either the Annual Survey or the TISF. Again, we are somewhat skeptical of assigning such a strong weight to the CFOI given that it was designed to count deaths, not non-fatal injuries.

The fourth sensitivity assumption relies on the TISF. The TISF estimated 201,081 lost-time work injuries in 1993, defining lost-time injuries as those resulting in one-half or more of one day of work lost. The "disabling" term used in many other analyses of injuries refers to at least one full day of work loss.[4,14,16-20] Obviously, the number associated with a half-day or more will be bigger than the number associated with one day or more. A personal communication with the author of the TISF study (Myers, January 28, 1999) indicated that requiring one or more full days of loss to qualify as a disabling injury would yield a figure roughly 16% smaller than one-half of one day of work loss. Subtracting 16% yields 168,908 full-day disabling injuries. If we assume that the same disabling to non-disabling injuries ratio applies to the TISF as applies to our estimates in Table 1, the TISF would generate an estimate of 206,442 non-disabling injuries, for a total of 375,350 non-fatal injuries. This 375,350 is 73%

of our estimate of 512,539. Assuming that the same percentage applies to costs, our TISF-generated lower cost estimate would be $3.349 billion. For reasons highlighted in the Discussion, we prefer our Annual Survey-based estimate to this TISF-based estimate.

It is likely that WC-reported injuries are more serious than non-WC-reported injuries.[35] Our preferred estimate already somewhat accounts for this likelihood. The preferred estimate relies on the all-industry estimate, which assumed a higher underreporting rate (35%) for non-disabling injuries than disabling ones (20%) due to economic incentives alone. These assumptions result in preferred estimates of 45% and 55% for disabling and non-disabling injuries. But it could be that the 45% is an overestimate. Sensitivity assumption five (row five) assumes that 30% of our total non-fatal count is disabling and 70% is non-disabling. A decrease in the number of disabling injuries results in costs that are roughly 31% less than those of the preferred estimate. We nevertheless prefer our 45%/55% ratio because the BLS suggests that there is a higher reported percent of disabling than non-disabling injuries in agriculture compared to other industries.[4]

The last two assumptions involving caregivers' time and pain and suffering are listed in rows six and seven. These are outside our model, which is to say they do not alter any parameters we used to generate our preferred estimate. They are almost always ignored in cost-of-illness/injury studies because they are so difficult to estimate. Nevertheless, we do address them briefly in the Discussion.

Finally, at the bottom of Table 3, we offer our lower and upper bounds. Because rows two and three essentially involve altering the same assumption, we cannot use them both. We selected row three, the one that allows for the widest interval, and combined it with the assumption in row one (for which there is no overlap). Rows four and five also involved the same assumption (but not the same as rows two and three), hence we could not select them both. We again selected the one that allows for the widest interval (row five). Our estimated range is, then, $3.141 to $13.99 billion.

DISCUSSION

Comparisons with other studies

In this section we review a number of studies and data sets. We first compare the cost estimate of $4.57 billion to that of other diseases. Second, we consider some CFOI studies. Third, we consider the data set from TISF. Fourth, we examine a study that deals with a ranking of industries by Workers' Compensation costs. Fifth, we compare our injury estimates to those from the National Safety Council. Finally, we consider a study that ranks occupations by disability rates.

Most cost estimates for disease use the same human capital/cost-of-illness method we use here. As a result, we can compare our 1992 $4.57 billion estimate to other diseases. Hepatitis C was recently estimated to cost $5.46 billion in 1997 dollars.[36] Medical prices have risen at an annual rate of roughly 4.5% for the years between and including 1992 and 1997, and wage inflation at 2.7%.[35] Our injury estimate is on a par with those of hepatitis C since our estimate in 1997 would be $5.4 billion. Our injury estimate is also larger than the costs of job-related circulatory disease ($3.5 billion) and chronic obstructive pulmonary disease (COPD) ($3.6 billion) in 1992.[19]

The fatality estimate compares favorably to other statistics on farming. Toscano and Windau found that farming occupations had a 5.2 relative risk of dying.[28] That is, they found the fatality rate for farming to be more than five times the occupational injury rate for all other occupations. Our equivalent estimate would be 13.2%/2.1% or 4.9 (where 13.2% is the contribution to all fatalities in all industries and 2.7% is the government employment figure on the contribution for agriculture).

The TISF survey is an ambitious attempt by NIOSH to provide a comprehensive picture of farm injuries across the United States.[13] The researchers involved in TISF began collecting data in the mid-1990s. The first publication presents data from 1993.[13] A total of 201,081 lost-time work injuries were estimated to have occurred on US farms in 1993.

One problem is that the Traumatic Injury Surveillance of Farms survey asked for responses from only farmers or managers of farms. Owners and managers face an economic incentive to underreport injuries among their employees. High injury rates can result in high WC premiums and may also trigger Occupational Safety and Health Administration (OSHA) investigations. Moreover, the employees may underreport for fear of employer reprisal.[38] In the all-industry study we estimate that this underreporting is significant.[19] Perhaps as many as 40% of all injuries go unreported across all industries, on average. But this 40% estimate assumes that 91% of workers are employees and 9% are owners, as is the case for the economy at-large. We are not aware of any estimate of underreporting when such a high percentage of workers are self-employed, as they are in farming. The TISF estimates 63% of all farm injuries affect farm owners, operators, and their family members. Employment statistics suggest, however, that there are 17% more farm employees than

owners, farmers, and family members.[24] These employment statistics may be misleading. Many farm owners will not list their occupation as "owner" or "operator." On the other hand, government statistics likely also undercount farm workers, many of whom do not want to be noticed by a government authority. The TISF estimate could be improved by adjusting for underreporting in agriculture.

A second more serious problem plagues the TISF. A total of 25,200 farm operations were mailed questionnaires and 12,990 responded. This represents a response rate of 51.5%. Low participation rates may yield results seriously biased by self-selection. Mailed surveys and corresponding responses need to be carefully scrutinized to see if they fairly represent the population to be studied. Although the investigators conducted a study of 1,000 non-responders and found them comparable to responders (personal communication, John Myers, January 28, 1999) there remains the potential for significant selection bias. In fact, a lack of representativeness could have contributed to the observed result that 63% of all injuries were attributed to owners and family members and only 37% to farm employees.

For these two reasons we are concerned about using the TISF to estimate aggregate costs. However, despite the problems with using the TISF, the data are internally consistent and may provide important and unbiased estimates of relative differences, i.e., differences in injuries between men and women, the old and young, crop production and livestock production, and so on. Nevertheless, readers with great confidence in the TISF may prefer row four in Table 3 as a more accurate estimate of the cost of agricultural injuries.

The third study attempted to rank three-digit industries based on the costs of occupational injuries and illnesses.[39] That study looked only at WC costs in eight states and included data from only the mid-1980s. The exclusive reliance on WC statistics severely biases the results against agriculture, however, as the authors acknowledge.[39] It is likely that a larger proportion of farm workers than any other category of workers are excluded from WC statistics, given that WC frequently does not extend to small farms and that many farm workers are undocumented. Nevertheless, the rankings, given their uniqueness in the literature, have some value.

Eight broad industry divisions and 395 specific (three-digit SIC) industries were ranked by total costs. Eight broad industries and 260 specific industries were ranked by costs per worker (average cost). Manufacturing was the broad industry division that contributed the highest total cost; construction contributed the highest average cost. Agricultural industries did not rank high on these lists. Low rankings cannot be attributed to the relative safety of agriculture, however. Rather, the low rankings reflect the lack of WC coverage for many farm workers among other factors noted above.

Rankings within agriculture, on the other hand, are likely to be more reliable than the overall rankings that compared agriculture to other industries outside agriculture. Agricultural industries identified by SIC code could not be ranked on an average cost basis because we did not have reliable estimates of employment within SIC categories. However, SIC agricultural industries could be ranked based on their total WC costs (Table 4). Because this ranking is for total costs, it does not reflect average risk to workers. Nevertheless, it does provide a sketch of which industries are contributing the most and the least in terms of total WC costs.

The fourth study comes from NSC estimates.[14] The NSC estimated 700 work-related deaths on farms in 1992. Roughly 200 of these were due to motor vehicle mishaps, most of which involved overturns of tractors. The Council also estimated 230,000 disabling injuries.[14] The NSC defines "disabling" as an injury that

Table 4. Ranking of farm industries by workers' compensation costs ($US millions)

General farms, primarily crops (SIC 19)	25.5
Landscape and horticultural services (SIC 78)	22.1
Dairy farms (SIC 24)	16.7
Horticultural specialties (SIC 18)	7.3
Forestry services (SIC 85)	7.0
Livestock, except dairy and poultry (SIC 21)	5.52
Fruit and nut trees (SIC 17)	5.50
Animal services, except veterinary (SIC 75)	4.87
Vegetables and melons (SIC 16)	3.52
Crop services (SIC 72)	3.52
Poultry and eggs (SIC 25)	3.13
Field crops, except cash grains (SIC 13)	2.43
Animal specialties (SIC 27)	2.24
Veterinary services (SIC 74)	1.59
Cash grains (SIC 11)	1.50
General farms, primarily livestock (SIC 29)	.759
Forest nurseries and seed gathering (SIC 82)	.642
Farm labor and management services (SIC 76)	.381
Commercial fishing (SIC 91)	.200
Soil preparation services (SIC 71)	.156
Fish hatcheries and preserves (SIC 92)	.154
Gathering of miscellaneous forest products (SIC 84)	.039
Hunting, trapping, game propagation (SIC 97)	.038

renders the person "unable to perform their regular duties or activities for a full day beyond the day of the injury."[14]

The NSC acknowledges several limitations to these estimates. First, murders and assaults are excluded. Second, the NSC disabling injury estimates are based on the National Health Interview Survey (NHIS), which has been shown to produce inaccurate results.[19] In any given year, only a few hundred people respond that they were injured at the job. Given that roughly only 2.7% of American workers are employed in agriculture, NHIS estimates for agriculture rely on five to 15 responses from year to year.

Despite these problems, this NSC estimate appears reasonable. At the time the 1992 NSC estimate was produced, the CFOI was not yet available. The only available data were from the Annual Survey (200 deaths) and the NTOF (602 deaths). The number of fatalities from the NSC (700) proved to be closer to the CFOI estimate (800) and our own (841). The NSC estimate for disabling injuries—230,000—is also remarkably close to the TISF number—201,081.

The last study ranked occupations based on the stated disability of incumbents.[40] Samples were drawn from the National Health and Nutrition Examination Survey Epidemiological Follow-up. Disability was measured with a modified Health Assessment Questionnaire. Disability rates corresponded to persons who provided information on their longest held occupation. For women, farming occupations ranked at the top of the broad occupation list. For men, farming occupations ranked second. These results suggest that our assumption concerning a higher ratio for disabling to non-disabling injury in agriculture when compared with other industries is reasonable. That is, the typical non-fatal injury in agriculture is more serious than the typical non-fatal injury in an industry outside agriculture.

Limitations

Our fatality estimate relies heavily on the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI), which is the gold standard for counting fatal occupational injuries.[6] A number of criticisms have nevertheless been lodged against it.[19] For example, a death is counted in CFOI only if two independent documents—e.g., a WC record, a death certificate, a police report, or a newspaper obituary—verify that the death occurred on the job. Some researchers have argued that this is too high a standard. For a variety of reasons, low-wage workers, undocumented workers, recent immigrants, African Americans, Hispanics, and others may not be counted by WC authorities, police reports, or coroners as having experienced the fatal injury on the job.

To account for some of these criticisms, we use the deaths estimate presented by Leigh and associates, who attempt to adjust the CFOI upwards to account for the high standard of two source documents.[19] The adjustment amounts to a 4.73% increase over the estimate of all industry deaths. It is referred to as the "race-ethnic adjustment." This 4.73% is reflected in our preferred 841 estimate of deaths as opposed to the 800 from CFOI.

For our purposes in this study, there may be an additional CFOI problem in undercounting the relatively high percentage of minority (Hispanic and African American) workers in agriculture. In 1992, across all industries, there were roughly 19% minority workers employed nationwide.[23] In agriculture, that figure was 23%, according to government statistics.[24] The ratio is 1.21 (23:19). Again, the race-ethnic adjustment to the CFOI for the all-industry study was 4.73%.[19] Multiplying 1.21 by 4.73 yields 5.729. Subtracting 4.73 from 5.729 yields roughly 1.0%. Therefore, had we made a separate race-ethnic adjustment for just Agriculture, our estimate would increase by approximately 1%. The 23% figure may be low, however. Nevertheless, even if we assume 40%, our estimate would increase by approximately 5%. We do not include these second race-ethnic adjustments because they are not large and because we wish to be conservative in our estimates.

Our non-fatal injury estimate relies on the BLS Annual Survey, which is frequently used in studies of on-the-job injuries. These data are available at the major division (one-digit SIC code) and narrow (two- and three-digit) industry level. In 1992, the Annual Survey identified 109,400 disabling and non-disabling injury cases in the major division of Agriculture, Forestry, and Fishing. In the narrow categories, the Annual Survey produced the following estimates: agricultural production of crops and livestock, 51,400; agricultural services, 30,100; and forestry (excluding logging), 1,100. These injuries include those requiring medical assistance (but no lost work time) as well as those that resulted in lost work with or without medical assistance. The Annual Survey also has a category of lost workday cases, including restricted workdays. The estimates are as follows: Agriculture, Forestry, and Fishing, 52,300; agricultural production of crops and livestock, 23,600; agricultural services, 27,700; forestry, 700; other, 300.

There are at least two major criticisms of the Annual Survey. First, it does not count injuries from farms with fewer than 11 employees. Second, it suffers from

economic incentives for farm owners and farm workers to underreport injuries to employees. For example, a farm owner might worry about how a WC insurance company might react to an increase in recorded injuries, and a worker might worry about the chances of a raise or continued employment after reporting an injury. These incentives are not unique to agriculture. Rosenman and colleagues found that most unionized autoworkers who would have qualified for WC for a repetitive strain injury never reported their injury to their employer.[41] We attempted to adjust for these factors by inflating the Annual Survey estimates of non-fatal disabling injuries in proportion to the ratio of NTOF to Annual Survey deaths (Equation 1).

We assumed the BLS undercount of non-fatal injuries would be the same as the BLS undercount of fatal injuries. Our calculations with Equation 1 suggest that the Annual Survey missed 79% of the deaths. Our assumption then is that the Annual Survey also missed 79% of non-fatal injuries. There is some support for this assumption: First, unlike other industries, the BLS institutional exclusions are similar for non-fatal and fatal injuries in agriculture. For non-fatal injuries, all farms with fewer than 10 employees are excluded.[15] For all other industries, non-fatal injuries are reported by all firms with one or more employees, but for fatal injuries inside and outside agriculture, the only firms or farms required to report are those with 11 or more employees.[15]

Second, our all-industry estimate, which did not use any calculation resembling Equation 1, nevertheless supports this assumption of roughly equal undercounts for fatalities and non-fatalities. In 1991, the Annual Survey counted 2,800 job-related deaths in all industries. But these deaths excluded firms with fewer than 11 employees. We do not know how many deaths occurred in small firms. We can, however, assume that deaths are proportional to employment. We know nationwide that all firms with nine or fewer employees contributed 15% of total employment.[25] To correct for the 11 employees versus the nine-employee difference, we added one percent. Our estimate of employment is then 16%. Assuming this is what the Annual Survey would have counted, our Annual Survey estimate would be 2,800/.84 = 3,333. Assuming 11% are due to illness, the BLS Annual Survey would have counted 2,967 injury deaths.[19] But our all-industry estimate of injury deaths for 1992 was 6,371.[19] The ratio is 0.466 (2,967/6,371). This death ratio can be compared to the non-fatal injury ratio. In 1992, the BLS Annual Survey estimated 6.342 million non-fatal injuries. Our all-industry estimate was 13.343-million.[19] The ratio is 0.475, which is close to 0.466, thus supporting our assumption of an equal BLS undercount of non-fatal and fatal injuries

Third, evidence indicates a substantial number of on-the-job deaths are underreported in studies of all industries combined, including those with large firms, thus lending support for our assumption that there is underreporting in agriculture for reasons other than there being many small firms. (Nationwide, 83% of farms have fewer than 10 employees. By contrast, 60% of non-farm businesses have fewer than 10 employees.)[25] These studies generally involved WC records, which are used by firms to help develop their BLS records. For example, Cone et al. identified 682 job-related deaths in California in 1983.[42] Workers' compensation insurers had records for only 294, or 43.1%. California is significant, because it has such a high percentage of agricultural employment. Stout and Bell estimated that, depending on the state, WC missed from 30% to 60% of job-related deaths.[43] The CFOI had WC documents on only 40% of injury deaths and had OSHA Form 200 reports (which are the basis for BLS records) on only 32% of injury deaths.[27]

Nevertheless, some readers may question these assumptions concerning the Annual Survey. Alternative assumptions are presented in the Sensitivity Analysis of Table 3 (rows two, three, and four).

There are also limitations to our study because of the unique character of agriculture. First, when the farm owner or operator is off work for more than a week, serious economic consequences can ensue. Expenses of the business continue and may even increase. Farm work is seasonal. Planting, harvesting, and care of dairy cattle must be done in a timely manner. If the operator is incapacitated at one of these busy times and no replacement can be found (as is often the case in agriculture), the cost can be far more than a typical week of lost earnings in an industry outside agriculture. In addition, if family members are needed to care for the operator, their productivity loss to farm output must also figure into the cost. Finally, hired farm workers also work seasonally. At some times, that work involves 12-hour days, seven days a week. Again, a week of lost wages can be more than the typical week outside agriculture. These limitations suggest that we indeed generated a conservative indirect cost estimate by assuming a wage loss of 58% rather than 100% of the average wage of all other American industries (Table 3, row one).

There are limitations associated with the cost estimates. We did not adjust for current employment status when calculating the present value of earnings; we merely adjusted for the Labor Force Participation Rate (LFPR). In doing so, we undervalued the earnings of

those currently employed. That is, those currently employed are not a random sample of all persons in the labor market. Those currently employed probably had better lifetime employment prospects than all persons in the labor force. This limitation suggests that we underestimated costs associated with lost future productivity.

We ignored pain and suffering costs and quality-of-life issues. It is difficult to estimate costs for these, however. Lawsuits involving non-fatal injuries almost always involve some payment for pain and suffering. A rule of thumb frequently cited in the courts is that pain and suffering equal three times the non-administrative medical expenses plus lost wages.[44] This would mean adding about $13.8 billion to our costs (Table 3, row seven).

We did not include the costs of a family caregiver's time or the costs of health problems that occur among caregivers. These costs are undoubtedly large but are difficult to estimate. Nevertheless, Arno, Levine, and Memmott suggest that they are approximately 20% of medical costs.[45] Further, Covinsky et al. document the deleterious physiological, psychological, and economic consequences of caregiving on spouses.[46] These limitations suggest that we have underestimated costs (Table 3, row six).

Despite these methodological limitations, our estimates provide a useful benchmark for describing the costs of injury in agriculture. To appreciate the merits of our method, it is useful to consider the limitations of alternative methods for estimating the costs.

Ratio of farm output to GDP

A first crude estimate would assume that farm injuries are proportional to the farm output in the economy. One measure of the size of agriculture in the economy is the ratio of agricultural economic output to national economic output. In 1992, national GDP was $6,244.4 billion (or $6.2 trillion).[24] The broad category of Agriculture, Forestry, and Fishing contributed $112.4 billion.[24] The ratio is 1.8% (112.4/6244.4). This ratio (or percentage) could then be multiplied by the cost figures in the all-industry study to produce estimates, just as we used the CFOI and BLS percentages in our preferred method above.[19]

We reject this "contribution to GDP" method for three reasons. First, economic output does not measure potential numbers of victims, i.e., farmers, managers, and workers. Agriculture is a labor-intensive industry and, other things being equal, the greater the number of people at risk, the greater the number of injuries. Second, farm death and non-fatal injury rates are known to be considerably higher than death and injury rates from most other industries.[29] Third, this 1.8 ratio takes no account of the lack of WC coverage (and correspondingly high costs) that accompany farm work.

Nevertheless, this contribution to GDP method has one important advantage: it implicitly captures the low wages and intermittent work of farm workers. Low wages and intermittent work would result in low indirect costs. Other things being equal, high wages and continuous employment (i.e., 12 months per year) in an industry are associated with high economic output in that industry. In our preferred estimate of costs ($4.573 billion), we explicitly accounted for low wages and intermittent work by multiplying average US annual earnings by .5842—the ratio of average agricultural earnings to average earnings in the United States.

Ratio of farm employment to national employment

A second measure that would capture the labor-intensity of agriculture would be the ratio of employment in agriculture to employment in the nation. This could be either all employment or only the self-employed. Again, this ratio could be multiplied by the all-industry cost estimates. But this method also has serious flaws. All employment in Agriculture, Forestry, and Fishing in 1992 was 3,247,000.[24] National employment was 118,490,000.[24] The ratio is 2.74%. One problem with this ratio is the numerator. Some researchers believe that most government estimates of employment in agriculture are too low.[47] A second problem with this 2.74% is that we know the self-employed are at especially high risk for injury and this 2.74% estimate implicitly assumes that the ratio of self-employed to employees is the same in agriculture as in the rest of the economy.[19] This last assumption is not correct. The ratio of self-employment in agriculture to self-employment nationwide is 13.9%. But the self-employed constitute less than half of the total employment in agriculture and less than 10% of total employment for the US economy at-large.[24] A larger percent of employment is due to wage and salary employees in and out of agriculture. Neither of these percentages (2.74% or 13.91%), therefore, seems attractive.

CONCLUSIONS

Agriculture has high risks for job-related injury. We present estimates of the numbers of fatalities and non-fatal injuries and associated costs. Our estimates appear to be unique in the literature. Costs are useful measures as summary statistics because they combine fatalities with non-fatalities into one metric that is easily understood. Costs, in this sense, are a useful mea-

sure of the overall burden of any injury (or illness). Costs for agricultural injuries in recent years appear considerable (point estimate: $4.57 billion; range: $3.14 billion to $13.99 billion). They are on a par with the costs of job-related cancers ($9.4 billion), job-related chronic obstructive pulmonary disease ($3.9 billion), and job-related circulatory disease ($5.8 billion) for the same year.[19] They are also comparable to the costs of hepatitis C in 1997 ($5.46 billion), whether job-related or not.[36] Whereas agriculture contributes roughly 1.8% of the GDP, it accounts for roughly 3.5% of all occupational injury costs nationwide.[19] In other words, agriculture contributes twice as much to the cost of national occupational injuries as it does to national economic output. The high cost of agricultural injuries warrants greater scientific, medical, and public attention to how these injuries might be prevented and cared for in a cost-effective manner. We conclude that these costs are far more significant than indicated by the attention they receive in discussions of heath care costs, or even of injuries in general.

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