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Economic Consequences of Workplace Injuries and Illnesses: Lost Earnings and Benefit Adequacy

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Background *This is the first study based on individual data to estimate earnings lost from virtually all reported workplace injuries and illnesses in a state.*
Methods *We estimated lost earnings from workplace injuries and illnesses occurring in Wisconsin in 1989–90, using workers' compensation data and 6 years of unemployment insurance wage data. We used regression techniques to estimate losses relative to a comparison group.*
Results *The average present value of losses projected 10 years past the observed period is over $8,000 per injury. Women lose a greater proportion of their preinjury earnings than do men. Replacement of after-tax projected losses averages 64% for men and 50% for women.*
Conclusions *Overall, workers with compensated injuries and illnesses experienced discounted pre-tax losses projected to total over $530,000,000 (1994 dollars), with about 60% of after-tax losses replaced by workers' compensation. Generally, groups losing over eight weeks' work received workers' compensation benefits covering less than 40% of their losses.* Am. J. Ind. Med. 36:487–503, 1999.

KEY WORDS: occupational injuries; occupational diseases; workers' compensation; cost of illness; disability; employment; economics

INTRODUCTION

Background

In 1996, employers in the United States reported 6.2 million workplace injuries and illnesses, of which 2.8 million involved restricted work activity or at least one day lost from work [Bureau of Labor Statistics, 1997]. Although the importance of the impact of workplace injuries and illnesses on employment and earnings is well-understood [National Institute for Occupational Safety and Health, 1996], no statistical studies based on individual data have estimated these impacts for the full range of lost-time injuries and illnesses. These impacts have two components: a physical component caused by reduced work capacity and a labor-market component caused by the long-term impact of work absence during the recovery period. The labor-market component may be caused by a loss of seniority, by a change from a unionized job to a nonunion job, by stigma attached to people who have been injured at work, or simply because injured workers miss valuable labor market experience while off work.

In Wisconsin, workers who miss more than three days of work because of a work-related injury or disease can receive temporary total disability (TTD) benefits. TTD benefits are paid at a rate of two-thirds of the worker's preinjury weekly wage, subject a maximum benefit. Some workers never fully recover from their occupational injuries. When this occurs, Wisconsin requires payment of perma-

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nent partial disability (PPD) benefits related to this lasting physical impairment. PPD benefits are paid based on PPD ratings between 0–100%. A rating of zero would mean no permanent disability, while a rating of 100% would mean total disability. Four percent of workers' compensation claims in this study involve legal dispute and are resolved with compromise agreements, which settle all issues (including income and medical benefits) related to the claim with a payment to the injured worker. Most compromised cases involve disagreements about the degree of permanent disability. Therefore, compromised claims are largely a subgroup of PPD claims.

Previous Studies of Lost Earnings

Several studies of income losses have been published based on statistical analyses of data on claims filed in various workers' compensation systems. All these studies measure losses by subtracting a measure of expected earnings from actual post-injury earnings. However, all published studies to date have focused exclusively on injuries and illnesses involving permanent disability benefits [Cheit, 1961; Johnson et al., 1978; Ginnold, 1979; Berkowitz and Burton, 1987; Reville, 1999].[1] Among the 50 states, PPD claims comprise about one quarter of injuries involving time lost from work and average about three quarters of income benefit payments [Burton and Schmidle, 1994]. Still, many lost-time injuries fall outside the PPD category. Because these studies do not include them in the analysis, important impacts may be lost from view, and estimates of losses are likely to be biased. Also, comparisons of losses across states will be misleading if the probability of receiving PPD benefits varies by state.

Leigh et al. [1997] recently published a study that calculated lost earnings for workplace injuries in the U.S. However, they did not statistically estimate lost earnings. Rather, the authors calculated income losses by assuming specific ratios between income benefit payments and losses. They assumed this ratio was 60% for temporary disability claims, 50% for permanent partial, and 40% for permanent total disability claims. Except for our study, there are no recent empirical analyses to support or refute these assumptions for both the permanent partial and temporary disability groups.

DATA AND METHODS

Data

This study is based on lost-time injury data from workers' compensation records for injuries in the State of Wisconsin between April 1, 1989 and September 30, 1990. We matched over 97% of the injured workers to their unemployment insurance wage records. These wage records provide us with quarterly earnings of workers employed in Wisconsin, excluding the self-employed, from the beginning of 1988 through the end of 1993.[2] From them, we created a data set with 24 quarterly records for each worker, including quarterly earnings as well as personal, injury, and employer characteristics. For injuries and illnesses in April 1989, we have income data for 5 quarters before and 18 quarters after the injury date; for injuries in September 1990, we have income data for 10 quarters before and 13 quarters after the injury date. Therefore, our data are an unbalanced panel.

We estimated losses only for injured workers with matched earnings records who had temporary total disability benefits of eight days or more or PPD benefits or compromise benefits, for a total of 47,910 men and 22,467 women. We excluded from this part of our analysis 110 workers who received permanent total disability payments or who suffered fatal injuries. We further excluded 4,138 workers otherwise eligible for the comparison group but who had more than one injury in the observed period. This leaves 44,899 men and 21,340 women with temporary disability greater than 7 days or PPD or compromise benefits. Of these, our estimates use 36,283 men and 18,026 women. The difference of 16–19% is attributable to missing values — most frequently on the tenure or age of the injured workers — and removing 158 outliers from our estimates of losses. Table I presents descriptive statistics for the administrative data analyzed in this study, including median values where distributions are skewed. On average, the workers studied were 37 years old and had 6 years of tenure with the preinjury employer. Almost half were unskilled blue-collar workers. Only 24% were employed in firms with fewer than 50 employees and 10% were employed in the public sector. The most frequent injuries were back injuries (29%). Finally, 17% did not return to the preinjury employer.

To calculate marginal tax rates, we impute marital status and number of dependents using data from a telephone survey of a stratified random sample of 1,473 people with workers' compensation claims in Wisconsin for back injuries in 1989 or 1990. The survey sample is stratified by gender and by the type and duration of workers' compensation income benefits payments. We randomly impute marital status and number of dependents from records in the survey data with the same age, gender, and type of claim, using the Bayesian bootstrap [Rubin, 1992]. We assume that the missing data are drawn from the same distribution as the observed data.

[1] From this point forward, as a matter of style, we will use the term "injuries" to refer to both injuries and illnesses.

[2] Unobservability of out-of-state earnings is a limitation of this study. However, among the survey subpopulation described in the data section, only 4.2% held an out-of-state job in the 5–6 years between their injuries and the interviews. This percentage was equal for the comparison group and the other groups studied.

TABLE I. Summary Statistics for Wisconsin 1989–1990 Injuries with 1+ Weeks of Lost Time (Standard Deviations in Parentheses)

	All claims	Men	Women
Individual characteristics			
Age in years	36.71 (11.66)	36.32 (11.51)	37.47 (11.91)
Tenure in years	5.87 (7.72)	6.29 (8.25)	5.01 (6.41)
Median	2	2	2
Occupation type (proportion)			
Skilled blue collar	0.22 (0.41)	0.29 (0.46)	0.08 (0.26)
Unskilled blue collar	0.49 (0.50)	0.54 (0.50)	0.39 (0.49)
Agricultural, military, or other	0.02 (0.13)	0.02 (0.15)	0.01 (0.09)
Employer characteristics			
Number of employees	1,169 (2,324)	989 (2,105)	1,531 (2,675)
Median	237	162	421
Proportion of employees in firms with 50 or fewer employees	0.24 (0.43)	0.30 (0.46)	0.12 (0.32)
Proportion in public sector	0.10 (0.29)	0.08 (0.28)	0.12 (0.33)
Part of body injured			
Head, neck, or back	0.32 (0.46)	0.32 (0.46)	0.32 (0.47)
Back only	0.29 (0.45)	0.29 (0.45)	0.29 (0.45)
Upper extremities	0.28 (0.45)	0.25 (0.43)	0.33 (0.47)
Carpal tunnel syndrome	0.04 (0.20)	0.02 (0.15)	0.08 (0.27)
Trunk, multiple, or different injuries	0.23 (0.42)	0.23 (0.42)	0.23 (0.42)
Lower extremities	0.18 (0.38)	0.21 (0.40)	0.13 (0.33)
Claim characteristics			
Proportion with permanent partial disability	0.18 (0.39)	0.19 (0.39)	0.17 (0.37)
Proportion with only temporary total disability	0.78 (0.41)	0.78 (0.42)	0.79 (0.41)
Proportion of claims compromised	0.04 (0.19)	0.03 (0.18)	0.05 (0.21)
Earnings and employment			
Pretax earnings one quarter before injury	$5,499 ($3,420)	$6,179 ($3,547)	$4,129 ($2,666)
Median	$5,112	$6,015	$3,736
Frequency of preinjury employer change	0.09 (0.15)	0.09 (0.16)	0.08 (0.15)
Proportion changing employer after injury	0.17 (0.44)	0.18 (0.45)	0.16 (0.43)
Total number of observations	54,309	36,283	18,026

Note: Regression estimates are based on these data

METHODS

Conceptual Basis

Let y_{i1} represent earnings when person i is injured, and y_{i0} earnings when person i is uninjured. Either of y_{i0} or y_{i1}—but not both—can be observed for any person, since we cannot observe the same person at the same moment both injured and uninjured. Let I_i be an indicator of injury ($=1$, if injured; $=0$, otherwise). Then the observed outcome for person i is $y_i = I_i y_{i1} + (1-I_i) y_{i0}$. The injury effect or loss for person i is:

$$\lambda_i = y_{i1} - y_{i0}, \tag{1}$$

where time relative to injury is implicit in the specification. We can rewrite the impact of injuries on the injured population as:

$$\lambda|_{I=1} = E(y_{i1}|I_i = 1) - E(y_{i0}|I_i = 1) \quad (2)$$

This cannot be estimated directly since we do not observe y_{i0}, post-injury earnings if the injured workers had not been injured.

Statistical methods developed in the nonexperimental evaluation literature allow estimation of a change in earnings relative to a counterfactual, in this case relative to what the worker would have received if the injury had not occurred. Typically, nonexperimental evaluation involves comparing a treatment group with a nonexperimental comparison group, which may have different characteristics than the treatment group. We assume selection on observable covariates [Rubin, 1974], that is $\{y_{i1},\ y_{i0} \perp\!\!\!\perp I_I\}|X_i$ (where $\perp\!\!\!\perp$ indicates independence).

In the context of estimating the impact of a workplace injury, injured workers are analogous to the treatment group. The comparison group could be uninjured workers or workers with very minor injuries. The assumption of selection on observables implies that, conditional on the observable covariates, X_i, there is no systematic preinjury difference between the groups assigned to treatment and control. This allows us to identify the effect of injuries on earnings for the injured:

$$\lambda|_{I=1} = E[E(y_i|X_i, I_i = 1) - E(y_i|X_i, I_i = 0)|I_i = 1], \quad (3)$$

where the overall expectation is over the distribution of $X_i|I_i = 1$, the distribution of preinjury variables in the injured population.

In this study, we compare actual post-injury income between a comparison group and other groups of injured workers, using regression methods to control for observed and unobserved worker and employer characteristics and labor-market conditions. The treatment groups are chosen, with the administrative data at hand, to reflect the type of income benefits received and, within the temporary disability group, the duration of income benefits. These groups reflect administrative decisions about injury-related losses, but they do not necessarily reflect actual losses or injury severity.

The comparison group

We choose as our comparison group workers with short-duration injuries or illnesses. These are defined by the receipt of workers' compensation temporary disability benefits for 7–10 days. Our estimates of losses are based on the assumption that losses in the comparison group are limited to the period of their temporary disability benefits. Estimates may be biased downward if some workers in the comparison group experience injury-related losses that extend past this period.

Estimates based on workers with short duration injuries and illnesses will also be biased if unobserved factors affect both workers' earnings and injury-related time off work. For example, a poor employer–employee relationship could lead both to lower earnings growth and a longer duration of time lost from work following injury. If the unobserved factors are unchanging over the study period, fixed-effects or first-differences estimates may eliminate the bias (or at least its linear component).

Because workers' compensation data provide information on several important personal characteristics, including gender, age, occupation, and job tenure, if we use workers with short duration injuries and illnesses as a comparison group, we can condition our estimates on these covariates. Using matched unemployment insurance data, we also can control for other factors, including industry, employer size, and workers' preinjury employment patterns.

The comparison group consists of workers who meet three criteria: (1) they had a single workplace injury from April 1, 1989 through September 30, 1990 and no subsequent injuries through 1993, (2) they lost eight to ten days from work and then returned, and (3) they received no permanent disability or compromise payments.

To derive our estimate of losses for each individual in the sample, we first estimate the difference in changes in post-injury earnings between the comparison group and other injured workers. We then add imputed losses of that individual for a 9 day injury (the average time off work for the comparison group).[3]

One test of appropriateness of a comparison group is whether, controlling for observed covariates, the outcome variable of the group with longer-term injuries tracks the outcome variable of the comparison group in the pre-injury period. We indicate below (p. 15) that this appears to be the case for the comparison group we use. It is possible that some members of the comparison group suffer continuing losses from their injuries. If that is the case, our estimates will be biased downward.

We also considered using uninjured workers as a comparison group, using unemployment compensation

[3] Wisconsin compensates (and keeps records on) injuries with more than 3 days' lost time and lacks data on workers with medical-only claims. Some other states only track injuries with at least 8 days' lost time. For comparability with future studies in other states, we use injuries with 8–10 days' lost time for the comparison group. We compared estimates of losses of workers with more than 10 days of lost time by using 4–7 days comparison group and found that using the 4–7 days comparison group produced small (under $50 on average) and statistically insignificant differences in our estimates of losses for the longer-term injuries. Note that using 4–7 days or 8–10 days claims as the comparison group does not imply that we ignore the losses from either group. See, for example, Tables II–VI.

earnings data. If we used a random sample of all employed workers as a comparison group, our only source of data would be unemployment insurance wage records, which lack data on gender, age, occupation, and job tenure. But such factors have been proven to be very important determinants of earnings. For this reason, using uninjured workers as a comparison group would not have permitted us to use these covariates to control for important differences between injured workers and workers in the comparison group.

Other injury groups

In principle, temporary and permanent disability benefits are designed to provide replacement of injury-related lost earnings. The duration of temporary disability benefits should span the period of physical recovery and associated income losses. The existence and level of PPD benefits reflect the existence and degree of permanent impairment and related losses. The duration of workers' compensation temporary disability benefits and the permanent partial disability percentage (zero to 100) provide useful tools for creating groups of workers whose losses should be similar within a group, but are likely to differ among groups. Because most claims resolved with compromise settlements are litigated, they may differ from other claims. Thus, we analyze them as a separate group. To some degree, the duration of temporary disability, the existence and level of PPD benefits, and the use of compromise agreements are endogenous, depending on personal and employer behavior and incentives. Still, we believe that they are useful for organizing our results. We group injured workers as follows:

- Temporary disability benefits only for:
  8–10 days (comparison group), 11 days to 2 weeks, more than 2 weeks to 3 weeks, more than 3 weeks to 4 weeks, more than 4 weeks to 6 weeks, more than 6 weeks to 8 weeks, more than 8 weeks to 12 weeks, more than 12 weeks to 16 weeks, and more than 16 weeks
- PPD benefits (with or without TTD benefits)
- Compromise settlements
- Permanent total disability and death.

Specification of a model of post-injury earnings

We observe each person in our data for three to four years after injury. Figures 1 through 4 reflect average changes in earnings of injured workers compared with changes in earnings of the comparison group (those with temporary disability benefits lasting 8–10 days) and are not adjusted for covariates. We impute zero quarterly earnings in quarters for which no employer reports earnings for a person in our sample.

To construct Figures 1 through 4, we first subtracted each person's earnings in the preinjury quarter from earnings in every observed quarter and calculated the average of this value for each group in every quarter. This measures the mean change in earnings between the preinjury quarter and all other quarters. We then calculated

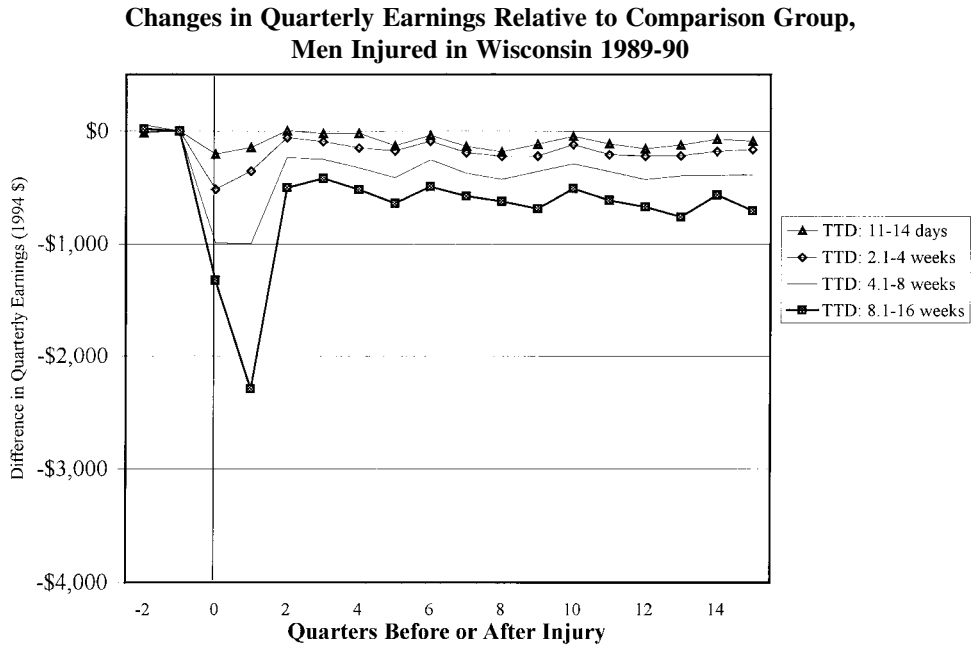


FIGURE 1.

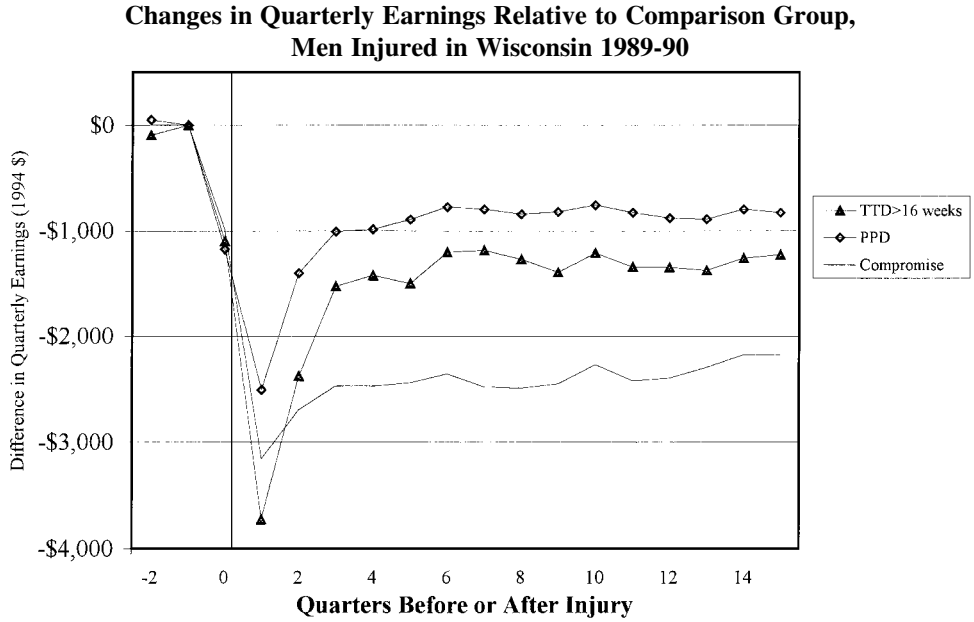


FIGURE 2.

the difference between these values for each injury group and the parallel value for the comparison group. The resulting values measure differences in average quarterly changes in earnings between people in injury groups and those in the same-gender comparison group. The preinjury quarter is marked by a vertical line.

Three and one half years after the injury, the overall average changes in earnings for men who received at most four weeks of temporary disability benefits are similar to the average changes for the 8–10 day group. However, they are substantially lower for workers with more than 4 weeks' temporary disability. Figure 2 shows that the average drop in annual earnings is largest for men with at least 16 weeks' temporary disability, PPD, or compromise payments. Average post-injury earnings of women display a similar pattern. Figures 3 and 4 show that, after their initial losses, women with 8 weeks or less of temporary disability appear to rebound to a point similar to those of the comparison group. However, those with longer temporary disability, PPD, or compromise payments continue to experience substantial losses long after the date of injury. Because Figures 1 through 4 are based on mean earnings unadjusted for covariates, part of what we observe in these graphs could be caused by differences in covariates among the groups. The estimates below account for a wide range of such covariates.

To estimate losses due to injury, we first estimated what injured workers' earnings would have been had these workers been in the comparison group, given personal and job characteristics, employer characteristics, and labor-market conditions. Then, we compared actual post-injury earnings of injured workers to these expected earnings. The difference is our measure of lost earnings. Our method resembles very closely estimation techniques used to measure the income losses of displaced workers [Jacobson et al., 1993; Stevens, 1997].

The model of earnings rests on the assumption that all workers in our study with the same (observed and unobserved) personal and employer characteristics in the same labor-market setting would have the same earnings if they had not been injured.[4] Based on this assumption, we developed a statistical model to estimate post-injury earnings. It consists of two primary elements. The first is the component of earnings that is unaffected by the injury. The second is the impact of the injury on earnings. Because in general the earnings and employment of men and women differ considerably, we estimated their earnings separately.

Noninjury-related earnings. The specification of the component of earnings unrelated to injury includes: (1) fixed calendar time effects, reflecting broad economic factors affecting all workers in each observed calendar quarter, (2) a fixed effect and a time trend to capture the impacts of unobserved characteristics common to workers in the comparison group, (3) fixed effects for periods before and after the injury quarter, and (4) a vector of characteristics of

[4] In our data, the estimated changes in preinjury earnings in the comparison group do not differ significantly from those of workers with longer-term injuries (p. 15).

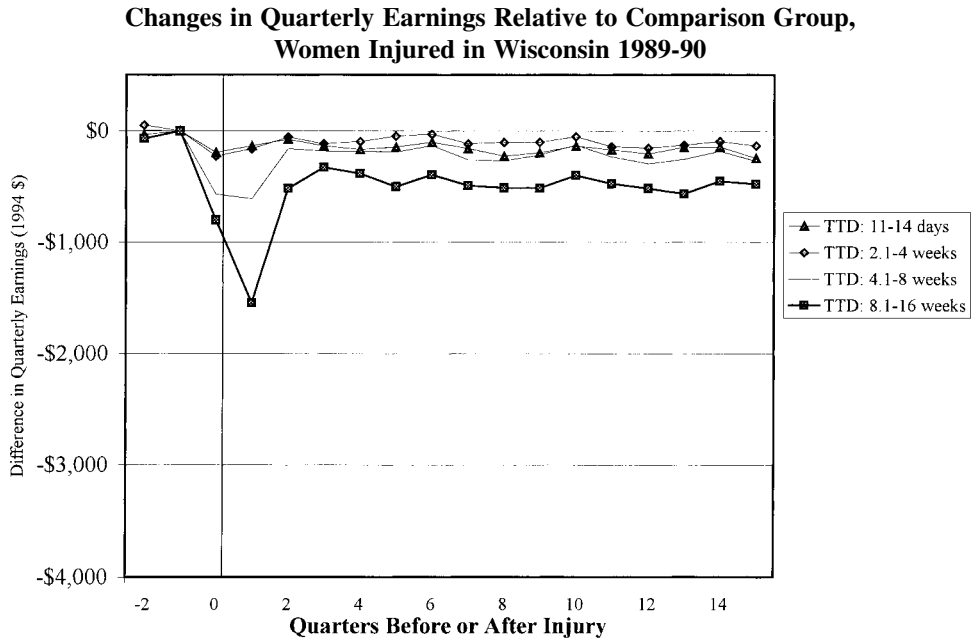


FIGURE 3.

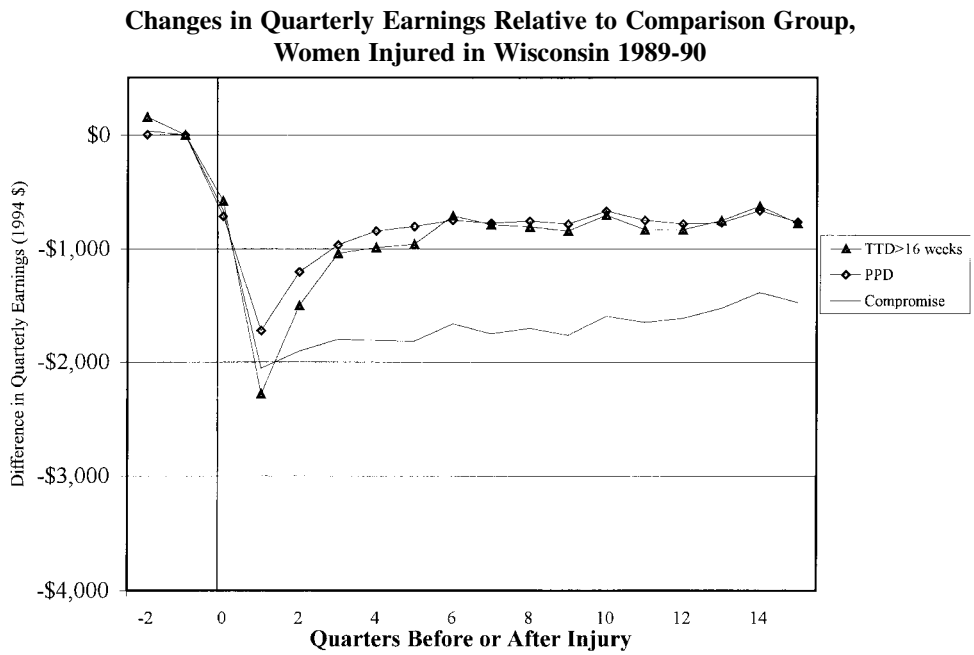


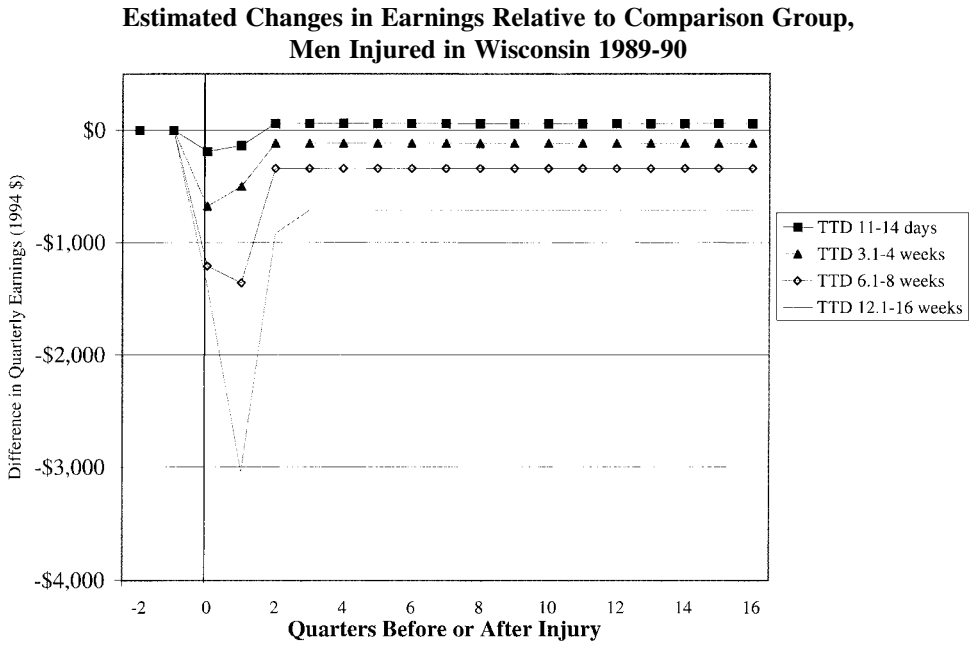
FIGURE 4.

individual workers and their employers. This vector is composed of:

- age, age^2, age^3, age^4
- Four groups representing job tenure at the time of the injury; also preinjury and post-injury earnings trends for the four tenure groups
- 2-digit industry group dummies (SIC) and time trends for each group
- 1-digit Census occupational categories and time trends for each category
- Private or public sector dummy
- Log (number of the employees of the firm at the time of the injury)

- Stability of preinjury earnings (coefficient of variation of quarterly earnings) and preinjury and post-injury trend interactions
- A measure of frequency of preinjury change of employer (number of changes divided by total changes possible) and preinjury and post-injury trend interactions.

The impact of the injury on earnings. The second part of the estimated model accounts for the impact of the injury on earnings, reflecting the patterns in the overall raw data shown in Figures 1 through 4. The changes in earnings observed in the raw data suggest a model that allows post-injury changes in earnings to differ among injury groups and vary in size and direction for each of the four post-injury



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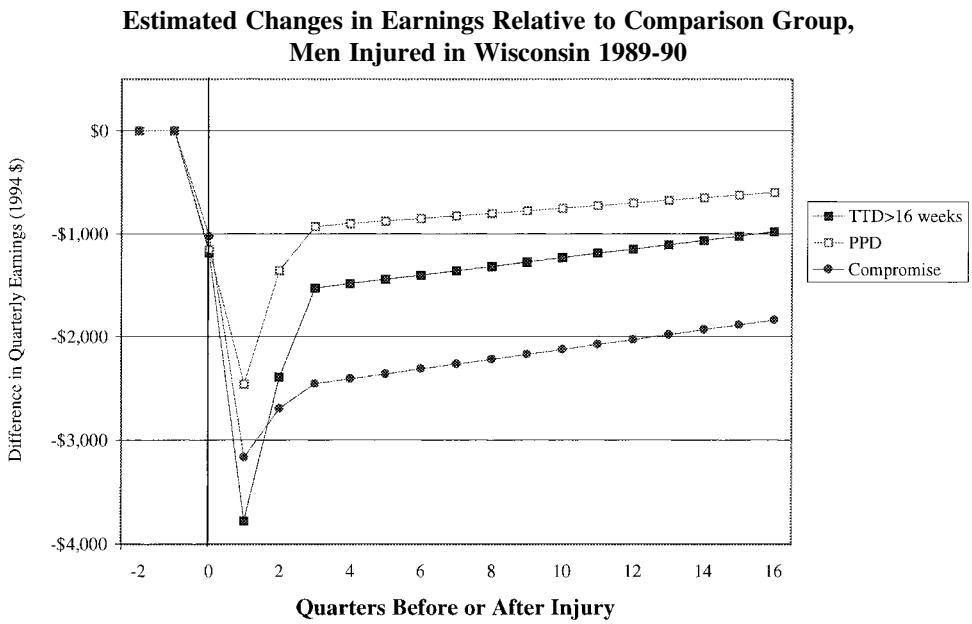

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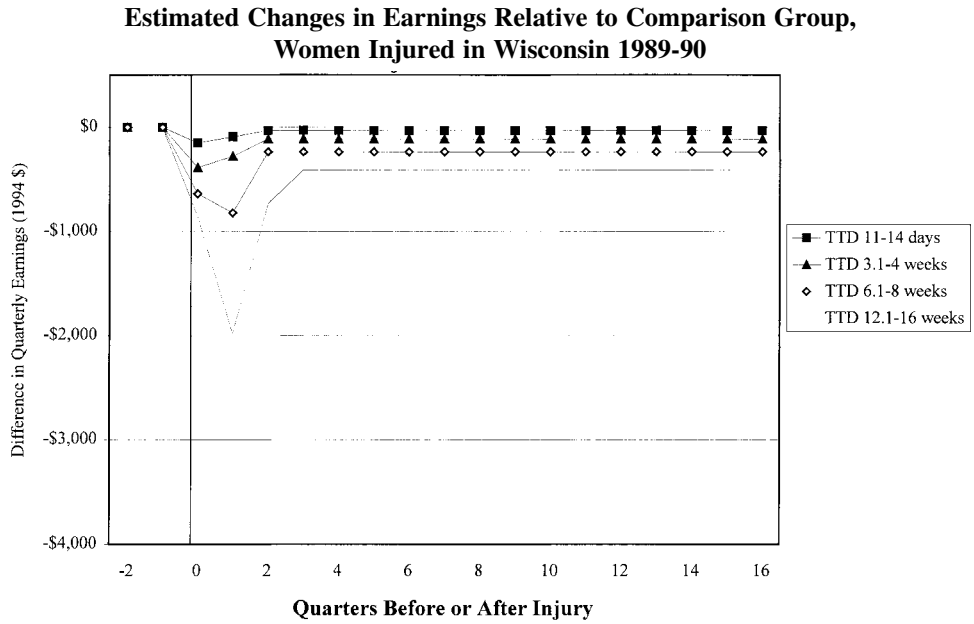

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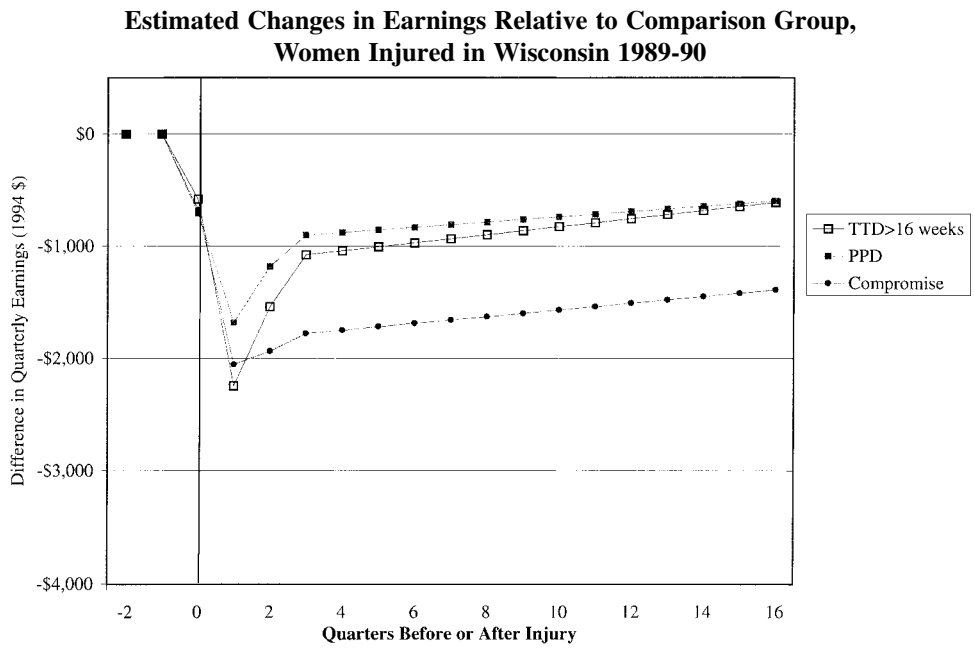

FIGURE 8.

quarters. For workers in some groups, earnings begin to rise in the second quarter after injury and level off after that. For other groups, earnings may continue to fall in the second quarter and rise in the third and fourth quarters. After the fourth post-injury quarter, each group appears to have a stable linear trend in earnings relative to the comparison group.

To capture these changes, we include interactions between post-injury periods and injury groups in our regression. These interactions allow for changes in each of the four post-injury quarters and a trend relative to the comparison group after then. For the PPD and compromise groups, we also allow these relative changes that vary according to the size of the PPD rating (which is between 0 and 100).[5]

[5] We tried different specifications including more period dummies before the linear trend and allowing for both a linear and squared trend component. None appreciably improved the fit.

Finally, about 30% of workers in our sample had more than one injury during the study period (that is, by the end of 1993). The model we use also accounts for the effects of injuries subsequent to the initial one. We tested to see if including information for a third injury changed our estimates of the impact of the first injury. It did not. Also, we did not interact the second injury term with the benefit groups because our results showed that the second injury played almost no role in determining income losses from the first injury and additional interaction terms would have further complicated our estimation.

Given our model accounting for both non-injury and injury related factors, we use two methods to estimate earnings. The first generates linear regression estimates based on first differences. The second method uses a repeated-measures model that allows for first-order autocorrelation of the errors (AR(1)), allowing for correlation of each period's error term with that of the period before it. The second method generates large and significant estimates of the degree of first order autocorrelation ($\rho = 0.75$ for men and $\rho = 0.78$ for women, $P < 0.001$). Both methods have their limitations. The first-differences estimator tends to aggravate bias from measurement error, and the AR(1) estimator is biased in short panels. However, estimates of post-injury changes in earnings (results available from the authors) are very similar for both methods and, indeed, for fixed-effects estimates. This suggests that these biases on measures of the impact of injuries and illnesses are small, although it is possible that they are large and equal. The estimated impacts of workplace injuries and illnesses on earnings are displayed in Figures 5 through 8.

We also tested the null hypothesis that the average trend in pre-injury earnings is equal in the comparison group and the treatment groups, controlling for observed covariates. The null hypothesis cannot be rejected. In the first-differences specification for men, the time trend for the comparison group is \$8 per quarter less than that for other injured workers ($P > 0.31$). For women, the equivalent estimate is \$2 per quarter more ($P > 0.82$).

The value of losses

Next, we calculated losses, that is, actual earnings minus expected earnings absent injury for all people in the sample. We estimated for injured workers their expected post-injury income if they had been in the comparison group. We then added losses imputed to each individual for a 9 day injury, based on workers' preinjury average weekly wage.[6] For injuries with less than 11 days of lost time, we multiplied by the number of days lost. We use the results from our first-differences estimates. The AR(1) and first differences estimates produced very similar expected losses, and we chose this method because it eliminates the linear component of the impact of unmeasured unchanging differences (like intelligence and motivation) between people in the sample.[7]

The injury has an impact only in the quarter of the accident and in future quarters. Our estimates of losses therefore began with losses equal to zero in the preinjury quarter. Losses are calculated from our estimates for subsequent observed quarters and predicted outside the observed period.

RESULTS

Losses in the Observed Period

We calculated expected losses over the period during which average quarterly losses remain significantly different from zero. Table II shows estimates of the average present discounted value of after-tax losses for men and women during the observed period. Throughout, we express these in 1994 dollars and discounted at 3%.

Several facts are notable. First, men who received more than 12 weeks of temporary disability benefits but did not receive PPD or compromise payments have higher average

TABLE II. After-tax Average Losses During the Observed Period by Benefit Category, Workers Injured in Wisconsin, 1989–1990

	After-tax loss estimates	
	Men (dollars)	**Women (dollars)**
TTD benefits only		
4–7 days	263	189
8–10 days	377	252
11–14 days	567	464
2.1–3 weeks	844	478
3.1–4 weeks	1,293	819
4.1–6 weeks	1,516	1,037
6.1–8 weeks	4,632	3,409
8.1–12 weeks	6,183	5,472
12.1–16 weeks	11,067	8,654
16.1+ weeks	17,434	11,365
PPD benefits	10,431	9,702
Compromise benefits	28,597	20,970
All claims except permanent total and death	4,156	3,616

Note: Does not include lost fringe benefits

[6] Because we estimated losses in comparison to workers who experienced injuries where they lost 8–10 calendar days from work, our method does not account for losses in the initial 8–10 days off work. To account for these losses, we added to the estimated losses each injured worker's average preinjury daily wage multiplied by 9 days, the average duration of temporary disability benefits in the comparison group.

[7] We use the first-differences model to generate losses after two additional preliminary step. We first remove outliers, eliminating men with a residual greater \$30,000 in quarterly earnings and women with a residual greater than \$20,000.

losses than those who received PPD payments. This also is the case for women who had more than 16 weeks of temporary disability but lacked PPD or compromise benefits. Second, overall average losses of women are almost as large as those of men, despite the fact that women's earnings average only two-thirds those of men and that women's losses are smaller than men's within every benefit group. This reflects the smaller proportion of women who have injuries and illnesses with 4 weeks of temporary disability or less (46.6% vs. 49.9% for men) and the larger proportion of women in the two groups with the greatest total losses: those with more than 16 weeks of temporary disability and those with compromise benefits (which together comprise 10.8% of women and 7.4% of men).

Projected Losses

Where average losses at the end of the observed period differ significantly from zero, we projected losses into the future. (The insignificant losses generally are positive, so projecting them would generally produce higher projected losses). To avoid substantially understating the losses, for most groups with continuing losses we projected losses 10 years past the observed period or to age 75, whichever comes first. Our projection assumes that losses continue to decline (or increase) for two years past the observed period at the same rate as we estimated for the end of the observed period; afterward, we assume that losses remain fixed until the end of the projection period.

A 10-year projection provides conservative estimates of losses for people whose average age at injury is about 37 years. Losses may continue indefinitely for many workers who, four years after their injuries, continue to experience substantial losses. However, we were uncertain about how average earnings would change after the observed period. Although we were willing to project earnings 10 years past the observed period, we were uncomfortable with longer projections. Thus, we present relatively short projections on the understanding that these probably present the lower-bound estimates of actual lifetime losses. On the other hand, earnings of workers with permanent total disability and fatal injuries and illnesses declined virtually to zero, so we were comfortable that we could project their earnings and therefore their losses 30 years past the observed period or to age 75 (whichever comes first).

Although losses at the end of the observed period are statistically significant, we did not project losses for the group with 6.1–8 weeks of temporary disability. We treated this group as a transition group between those with at most six weeks of temporary disability (for which we calculated losses only for the first two post-injury quarters because the calculated average quarterly losses after those quarters do not significantly differ form zero at $P = 0.15$) and those with longer temporary disability, PPD, or compromise benefits (for which we project losses past the observed period). Since we were uncertain about when injured workers begin to incur long-term losses, we chose to present losses for the 6.1–8 week group as losses during the observed period only. None of our findings would change qualitatively if we projected losses for this group.

In projecting losses, we also took into account the fact that employment rates of uninjured workers vary by age over the period over which we project earnings, affecting the size of projected losses relative to losses during the observed period. For example, after the age at which somebody would have retired even absent injury, their injury-related losses should be zero. Morbidity, mortality, labor-force participation rates, and unemployment rates—all affect expected earnings and vary by age.

To take this variation into account, we used the administrative data to estimate how the probability of employment (that is, a positive reported wage) in each quarter varies by age. As noted above, we assumed that workers were not employed in any quarter for which no employer reported earnings for them. We estimated separate logistic regressions for men and women (results available from the authors). To account for within-person correlations, we used the White–Huber adjustment for the standard errors. This allowed us to adjust projected losses for increasing participation (for younger people) and declining participation (for older people). For each quarter in the projection period, we multiplied projected losses by the ratio of the expected probability of employment at that age to the expected probability of employment at the end of the observed period.

Table III presents the after-tax projected losses, which add losses during the observed period and losses projected 10 years after the observed period, discounting by 3% annually. As just discussed, we did not project losses for groups with less than 8 weeks of temporary disability benefits, and we projected losses for permanent total disability and death claims for 30 years or until the age of 75, whichever is sooner. The first and third columns show the average present value of losses per injury for men and women in Wisconsin who had at least 4 days' lost time because of workplace injuries and illnesses during 1989–1990. The other two columns show total annualized after-tax losses for each of these groups. As is the case for losses calculated only during the observed period, the projected losses indicate that women, whose earnings average only two-thirds those of men, have relatively larger losses. When we project losses, women's losses per injury average almost as much as men's despite the fact that projected losses are lower in all but two benefit categories (8.1–12 weeks of temporary disability and the PPD category).[8] On average, men injured in Wisconsin with at least seven days' lost time

[8] The difference in mean losses for these groups is not statistically from zero at $P < 0.40$.

TABLE III. After-Tax Average Losses and Annualized Total Losses by Benefit Category, Workers Injured in Wisconsin, 1989–1990, 10-Year Projections (Standard Errors in Parentheses)

	Men		Women	
	Losses per injury (dollars)	Total losses (dollars)	Losses per injury (dollars)	Total losses (dollars)
TTD benefits only				
4–7 days	263 (11)	2,227,961	189 (10)	654,570
8–10 days	377 (58)	2,147,895	252 (59)	599,760
11–14 days	567 (59)	2,358,342	464 (57)	837,675
2.1–3 weeks	844 (56)	3,929,101	478 (57)	977,988
3.1–4 weeks	1,293 (81)	3,391,108	819 (74)	984,984
4.1–6 weeks	1,516 (68)	5,158,443	1,037 (67)	1,653,669
6.1–8 weeks	4,632 (573)	10,313,920	3,409 (598)	3,524,906
8.1–12 weeks	7,876 (1,772)	15,137,672	9,771 (1,780)	10,767,642
12.1–16 weeks	20,021 (2,754)	15,803,243	15,305 (2,310)	8,438,157
16.1+ weeks	25,313 (2,746)	27,405,541	16,078 (2,103)	14,491,637
PPD benefits	14,022 (1,059)	89,264,052	15,565 (1,247)	39,151,163
Compromise benefits	47,406 (2,627)	71,140,604	38,488 (2,283)	32,740,459
Permanent total and death	276,639 (20,282)	18,258,174	164,528 (49,607)	1,206,539
All claims	6,203 (212)	266,536,055	5,964 (283)	116,029,149

Note: Does not include lost fringe benefits. For groups with more than 8 weeks of TTD, PPD, or compromise benefits, losses are projected for 10 years or until age 75, whichever is sooner. Permanent total and death cases are projected 30 years or until age 75, whichever is sooner

lose about 4.8 months' earnings, while women lose about 7.2 months' earnings.

Overall, we found that less than one fifth of workers injured in Wisconsin experience more than three-quarters of the losses. These are workers with temporary disability longer than 16 weeks, PPD benefits, compromise settlements, permanent total disability, and fatal injuries and illnesses. On the other side of the coin are about 60% of injured workers with lost time lasting longer than three days but no more than four weeks. These workers incur about 8% of losses among men and 5% among women.

Although after-tax losses measure the costs to workers of workplace injuries and illnesses, pretax losses are a better measure of the social costs related to lost earnings. Pretax losses are about 40% higher than the after-tax losses, and have a similar distribution among benefit groups (Table IV).[9] We estimated that pretax losses of men and women total $532,363,276.

We did a sensitivity analysis, changing the discount rate and the projection period. Changing the discount rate to 2 or 4% changed a group's average after-tax projected losses by at most 6%. Extending the projection to 30 years past the observed period increases overall projected pretax losses by 26% and projected losses per injury by $1,931 for men and $2,943 for women, or 22 and 37%, respectively (Table V).

[9] Of course, after-tax losses do not measure the full costs of injuries for several other reasons. They exclude medical costs, nonpecuniary costs, lost fringe benefits, and employer/insurer legal and administrative costs. We also have not calculated losses related to injuries lasting a week or less.

TABLE IV. Pretax Average Losses and Annualized Total Losses by Benefit Category, Workers Injured in Wisconsin, 1989–1990, 10-Year Projections (Standard Errors in Parentheses)

	Men		Women	
	Losses per injury (dollars)	Total losses (dollars)	Losses per injury (dollars)	Total losses (dollars)
TTD benefits only				
4–7 days	366 (12)	3,100,508	264 (11)	914,320
8–10 days	621 (82)	3,538,044	426 (85)	1,013,880
11–14 days	908 (83)	3,776,675	715 (82)	1,290,813
2.1–3 weeks	1,288 (79)	5,996,069	729 (78)	1,491,534
3.1–4 weeks	1,928 (116)	5,056,501	1,215 (106)	1,461,240
4.1–6 weeks	2,302 (98)	7,832,939	1,561 (99)	2,489,275
6.1–8 weeks	7,683 (819)	17,107,480	5,185 (867)	5,361,290
8.1–12 weeks	12,016 (2,339)	23,094,752	13,353 (2,291)	14,715,006
12.1–16 weeks	27,585 (3,587)	21,773,760	20,166 (2,999)	11,118,188
16.1+ weeks	34,653 (3,529)	37,517,648	21,801 (2,717)	19,649,968
PPD benefits	20,328 (1,397)	129,408,048	21,179 (1,646)	53,272,245
Compromise benefits	62,908 (3,384)	94,403,939	49,659 (2,930)	42,243,256
Permanent total and death	351,500 (25,771)	23,199,000	209,577 (55,219)	1,536,898
All claims	8,747 (299)	375,805,363	8,048 (368)	156,557,913

Note: Does not include lost fringe benefits. For groups with more than 8 weeks of TTD, PPD, or compromise benefits, losses are projected for 10 years or until age 75, whichever is sooner. Permanent total and death cases are projected 30 years or until age 75, whichever is sooner.

Workers' Compensation Replacement of Losses

We measured the replacement of lost earnings as the ratio of workers' compensation benefits net of attorney fees to after-tax losses.[10] We compared benefits to after-tax losses because workers' compensation benefits are exempt from state and federal income taxes. Thus, after-tax losses minus workers' compensation benefits measure net lost earnings. Ideally, we should include in losses the value of lost fringe benefits. Practically, we lack a good measure of lost fringe benefits so we do not include them, thus understating losses and overstating replacement rates. We do not measure the replacement rate for permanent total disability and death claims, because these often are paid out over an extended period, so our measures of benefits could be substantially understated.

Overall, excluding the permanent total disability and death claims, our estimates indicate that Wisconsin replaces 89% of after-tax earnings lost during the observed period for injured men and 84% for women. Using projected after-tax losses, we find replacement rates of 64% for men and 50% for women. As we show in Table VI, these averages conceal some striking differences among groups of workers categorized by their benefit status. This table shows that workers' compensation in Wisconsin provides substantial income replacement for workers with less than six weeks of temporary disability benefits and replaces about half of the

[10] Attorney fees average about 10% of compromise settlements, but less than 1% of income benefits in other categories.

TABLE V. Pretax Average Losses and Annualized Total Losses by Benefit Category, Workers Injured in Wisconsin, 1989–1990, 30-Year Projections (Standard Errors in Parentheses)

	Men		Women	
	Losses per injury (dollars)	Total losses (dollars)	Losses per injury (dollars)	Total losses (dollars)
TTD benefits only				
4–7 days	366 (12)	3,100,508	264 (11)	914,320
8–10 days	621 (82)	3,538,044	426 (85)	1,013,880
11–14 days	908 (83)	3,776,675	715 (82)	1,290,813
2.1–3 weeks	1,288 (79)	5,996,069	729 (78)	1,491,534
3.1–4 weeks	1,928 (116)	5,056,501	1,215 (106)	1,461,240
4.1–6 weeks	2,302 (98)	7,832,939	1,561 (99)	2,489,275
6.1–8 weeks	7,683 (819)	17,107,480	5,185 (867)	5,361,290
8.1–12 weeks	13,584 (3874)	26,108448	19,844 (3986)	21,868,088
12.1–16 weeks	39,214 (5905)	30,952,917	28,681 (5048)	15,812,791
16.1+ weeks	44,531 (5740)	48,212,229	29,528 (4,818)	26,614,571
PPD benefits	24,450 (2315)	155,648,700	28,788 (2,790)	72,411,416
Compromise benefits	84,865 (5440)	127,354,077	72,365 (4,924)	61,558,493
Permanent total and death	351,500 (25,771)	23,199,000	209,577 (55,219)	1,536,898
All claims	10,658 (669)	457,883,587	10,991 (578)	213,824,609

Note: Does not include lost fringe benefits. For groups with more than 8 weeks of TTD, PPD, or compromise benefits, as well as permanent total and death cases, losses are projected for 30 years or until age 75, whichever is sooner.

after-tax losses for those with PPD and compromise payments. The PPD and compromise cases have substantial continuing losses, and payments in these cases cover between 54 and 83% of projected losses.

By contrast, injured workers with more than eight weeks of temporary total disability who do not collect PPD or compromise payments receive benefits that are a smaller proportion of their losses. For them, benefits replace between 37 and 56% of losses during the observed period and between 19 and 37% of projected losses.

Finally, we should note that the replacement rates we present do not measure the full replacement of lost earnings, as workers may receive other benefits, like social security disability benefits, payments from private and state disability systems, and welfare benefits. On the other hand, a payment in lieu of future medical benefits may be included in compromise benefits, so that our calculated replacement rate may be overstated for this group.

DISCUSSION AND CONCLUSIONS

In this study, we have estimated lost earnings and compared them with benefits for workers injured in Wisconsin in 1989 and 1990. Our estimates are conservative for several reasons. First, several studies suggested that a substantial number of workers with occupational injuries and illnesses never enter the workers' compensation system [Biddle et al., 1998; Morse et al., 1998]. We do not know the

TABLE VI. Average Replacement of Losses by Benefit Category, Workers Injured in Wisconsin, 1989–1990

	Benefits as a percent of			
	After-tax losses in the observed period		After-tax losses projected 10 years	
	Men (%)	Women (%)	Men (%)	Women (%)
TTD benefits only				
4–7 days	44	48	43	48
8–10 days	102	106	102	106
11–14 days	94	79	94	79
2.1–3 weeks	89	108	89	108
3.1–4 weeks	82	89	82	89
4.1–6 weeks	99	97	99	97
6.1–8 weeks	45	42	45	42
8.1–12 weeks	52	40	37	20
12.1–16 weeks	40	37	20	19
16.1+ weeks	56	54	35	34
PPD benefits	124	113	83	63
Compromise benefits	116	87	63	54
All claims	89	84	64	50

Note: Loss estimates do not include lost fringe benefits, and benefits are net of attorney fees. Average losses used to calculate percentages in this table come from Tables III and IV.

magnitude of the undercount for all injuries and illnesses, but, for example, the National Traumatic Occupational Fatality System [National Institute for Occupational Safety and Health, 1993] provides estimates for fatal injuries in 1989 and 1990. That source identifies 203 fatal occupational injuries that occurred in Wisconsin in 1989 and 1990. Workers' compensation data for the same period identify only 115 claims involving death benefits—an undercount of 43%. If compensated and uncompensated deaths involved the same losses, taking into account this discrepancy alone would add about 3% to the estimated losses. Second, for most groups, we projected long-term losses only 10 years past the observed period. Projecting losses 30 years ahead would increase the overall estimated losses by 17% for men and 28% for women. Finally, our estimates exclude other injury costs, like medical costs, nonpecuniary costs, lost fringe benefits, employer/insurer legal and administrative costs, and other employer costs attributable to workplace injuries and illnesses. Third, we assumed that losses of workers with TTD benefits lasting less than 11 days do not extend past the period of TTD benefit payment. Fourth, we assumed that the very large number of workers who receive workers' compensation medical benefits but not TTD benefits had no lost earnings. We did not know whether losses from these injuries are substantial, and we certainly could not rule out this possibility.

Using conservative estimates, we have shown that workplace injuries and illnesses often lead to substantial lost earnings. For men in Wisconsin who lost at least 4 days' work during 1989 or 1990, the projected after-tax lost earnings average $6,203. For women, the projected losses average $5,964 (Table III). Pretax losses are $8,747 and $8,048, respectively (Table IV). Within these overall averages, the groups with temporary disability longer than eight weeks, the PPD group, and the compromise group have the largest average losses.

Our data show that a substantial number of people in the longer temporary disability groups suffer losses that continue well after their benefits have ceased. These losses may have been incurred because of labor-market effects that persist after recovery from injury. For example, workers who stay off work for several months may lose their preinjury jobs and their investments in skill and seniority at those jobs. Earnings and employment after return could be affected, even if they fully recover from the effects of the injury. Such impacts have been noted in our 1996 study of return to work in Wisconsin [Galizzi and Boden, 1996]. This study, which accounts for the endogeneity of injury severity, finds that workers with longer durations off work experience higher rates of unemployment after they return to work.

Another possibility is that workers with longer-term disabilities may have weaker labor-market attachment.

However, our model attempts to take this into account by controlling for the frequency of preinjury job changes and instability of earnings. Finally, some of the long-term losses may be attributable to employers' unwillingness to hire people with the stigma of past workers' compensation injuries and illnesses. Employers may believe that long spells of work absence mark someone as unreliable or otherwise unacceptable for employment, thus limiting employment opportunities and reducing future earnings for this group.

We also have measured the replacement of lost earnings by workers' compensation income benefits. Overall, Wisconsin replaces 64% of after-tax projected losses of injured men and 50% of losses incurred by women. The pretax percentages are 47 and 38%, respectively. The average pretax replacement rate for PPD and compromise claims is 53%, lower than the 81% replacement (85% for uncontested PPD claims and 58% for contested PPD claims) reported by Berkowitz and Burton [1987] in their study of workers who received these types of benefits and were injured in Wisconsin in 1968. Probably the main reason for this is that we projected losses and they did not. Our estimated pretax replacement rate for PPD and compromise claims, considering losses only during the 4 observed years after injury, is 83%. Their estimate covered two more years of losses than did ours. Still, the replacement rates are remarkably similar, considering that the injuries occurred over 20 years apart.

To calculate lost earnings, Leigh et al. [1987] assumed replacement of 50% of pretax earnings for permanent partial disabilities and 60% for temporary disabilities; our estimated average pretax replacement is 53 and 29% respectively. Applying their assumptions to our data would lead to estimates of losses that are 15% lower than our estimates. While replacement rates based on losses estimated at the individual level may differ for other states [Reville, 1999], our estimates of overall losses are not very different from those of Leigh and his coauthors.

To conclude, we found that work-related injuries and illnesses can have lasting effects on the earnings of workers and that these losses can be substantial. For injuries occurring in Wisconsin in 1989 or 1990, our conservative estimate of annual pretax losses totalled $532,363,276. We also found that, compared with men, injured women suffer larger effects on their earnings than we would expect given the gender disparity in preinjury earnings.

These results leave us with important unresolved questions: Why do we find such high losses for groups of injured workers who do not receive PPD benefits? Why do women have higher proportionate losses than do men? To what extent are we observing injury-related losses that are caused by the disabling effect of the injury? To what extent are these losses caused by labor-market impacts of time lost from work, injury-related job loss, or stigma attached to workers with long-term injuries and illnesses? What is the magnitude of losses related to unreported injuries and illnesses and to injuries without workers' compensation income benefit payments? Answers to these questions await further study.

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