# A Model of Worker Investment in Safety and Its Effects on Accidents and Wages

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**Abstract**

In this paper, we develop a theoretical model of worker investment in safety. Standard theory predicts safer jobs are associated with lower wages. In contrast, our model predicts safer jobs may be associated with *higher* wages to the extent workers invest in skills that reduce the risk of accident and injury. We test the model's predictions using obesity as a proxy for worker investment in safety. In line with our model predictions, we find that obese workers' wages are significantly lower than those of normal-weight workers, but only in high-risk jobs.

## 1. **Introduction**

Since Adam Smith, economists have theorized that workers must be compensated for unpleasant working conditions, where one of the most important characteristics is workplace safety. The relationship between the risk of on-the-job accidents and wages has long been of interest to economists and policymakers. Economists are interested in this relationship because it informs us about the way the labor market works, and policymakers care about it because it is used as an estimate of how much people value life and their health.

Standard economic theory assumes that firms face a tradeoff between compensating workers for increased risk of accident and injury or reducing this risk by investing in safety (and paying lower wages). Firms invest in safety until the benefit – a lower wage needed to attract workers in a competitive market—equals the cost—decreased production and external safety purchases (Thaler and Rosen 1975).[1] The canonical model treats workplace safety as exogenous to the worker. Only firms have the ability to change the workplace environment.

Intuitively, this distinction between workers and firms seems incorrect, as there may be opportunities for workers to affect the risk of accident and injury on the job that are unknown to firms, or too costly for firms to exploit. For example, consider that 24 % of fatal occupational injuries are the result of highway accidents.[2] It is clearly possible, even likely, that drivers take action (invest) to avert accidents that are not possible for the firm to undertake. Indeed, drivers can be induced to take more or less investment in safety through payments such as safety bonuses. In this case, higher wages would be associated with fewer accidents, which is exactly the opposite of what standard theory predicts.

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[1] In this paper, we refer to "risk" and "safety" somewhat interchangeably, although risk and safety are the converse of each other.
[2] Source: Census of Fatalities Occupational Injuries (2004), Bureau of Labor Statistics.

Compensation policies from industry support the notion that workers can invest in safety and are rewarded for such investment. Among the clearest examples of such policies are payments of bonuses for safety, though payments for improved safety may also be part of regular wages. Chappelle (1991) reported that firms offer monetary incentives to make workers more careful. Wilde (2000) noted that firms have been increasingly turning to safety incentive programs as a way to control accident costs. For example, in a survey of 40 long haul trucking firms in Canada, 70% of them have a safety incentive program.[3] USA Waste Management has a bonus pool that rewards employees with excellent safety records.[4] Nationwide Insurance, Charter Communications and General Motors have programs that reward seat belt use. Denark Construction's hourly employees receive a bonus check every quarter if their particular project avoids any serious OSHA citations, individual violations of company safety policies and accidents on that project.[5] There are also many large consulting firms that advise employers on how to motivate employees to improve their safety behavior.

Studies and anecdotal evidence suggest bonuses are associated with reductions in accident rates. In a study that compared different methods of reducing accidents, Gregersen et al. (1996) found that bonuses for safe driving significantly reduced the number of accidents and costs of accidents. Nafukho et al. (2004) examined the performance of tractor-trailer truck drivers in a U.S. trucking company and found that bonuses were associated with a reduction in accidents. Furthermore, some companies report client testimonials of how programs have reduced their accident rates and costs.[6] In sum, there is widespread and growing use of paying employees for improved safety.

[3] http://www.tc.gc.ca/innovation/tdc/summary/13200/13256e.htm
[4] http://www.billsims.com/oshmag2.php
[5] http://ehstoday.com/safety/incentives/ehs_imp_37524/index.html
[6] http://www.safetypays.com/clients2.html

In this paper, we develop a model in which workers invest in workplace safety in addition to firms. The model has important implications for the relationship between safety and wages, and may help explain why there is surprisingly little empirical evidence that a wage premium for risk of accident and injury exists, especially for nonfatal risk.[7] Notably, the model we develop does not rely on the absence of a competitive labor market to explain the absence of a wage premium for risk of injury (Dorman and Hagstrom 1998).

## 2. Previous Literature

Although not in a formal way, several previous studies of compensating differentials refer to heterogeneity in safety-related productivity. To incorporate this notion empirically, these studies typically include an interaction between a personal characteristic and a measure of job risk to assess whether the return to risk differs by the specific characteristic. For example, Viscusi (1978) allows the effect of fatal risk to differ by age, race, health status and education and finds that the wage premium for risk is higher for those with more education. However, the primary motivation for the specification is that education is a proxy for the value the worker attaches to different health outcomes (i.e., preferences for risk). The possibility that such characteristics may be associated with worker actions that affect risk is somewhat of an afterthought. Viscusi states: "The interpretation of this result is unclear, since better educated workers may be safer workers. The premium may then not reflect differences in preferences but differing efficiency in the production of workplace health and safety (Viscusi 1978, p. 381)." Other studies have used seat belt use and/or cigarette smoking as proxies for heterogeneity in risk preferences, but also note that these variables may instead proxy for workers' safety-related

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[7] Wage premiums for risk have been found more consistently for fatal risk, yet some studies do not find evidence of this either (see, e.g., Leigh 1981, 1986, 1987, 1991; Dorsey 1983; and Moore and Viscusi 1988).

productivity (Hersch and Viscusi 1990; Viscusi and Hersch 2001). Hersch and Viscusi (1990) argue: "Worker actions that promote safety reduce accident costs to the firm, such as interrupted production runs and workers' compensation (WC) premiums. Firms should reward workers for the greater productivity in producing safety…" (Hersch and Viscusi 1990, p. 205).

These insights are consistent with an earlier literature that recognized the importance of worker behavior in affecting risk of accident. Oi (1974) noted that risk of injury can be affected by a worker's physical and mental health, his exercise of care on the job, or the matching of job and personal attributes – all factors that can best be controlled by the worker" (Oi 1974, p. 674). In a similar context, Chelius (1974) noted that "one less obvious resource … is the personal behavior resource of acting with care and caution." Chelius (1974) argued that if employers and employees can bargain without cost for prevention of accidents, the least cost producer of safety would prevent the accident regardless of assignment of liability. He illustrated this principle with an example where workers can invest in "careful behavior" at lower cost than the firm. "If the firm is liable, it will induce workers to prevent this type of accident by paying them some part of the difference between the cost of machinery and the careful behavior (Chelius 1974, p. 703-4 )."

Only a few previous studies formally incorporate the idea of worker investments in safety (Diamond 1977; Viscusi 1979; Rea 1981; Moore and Viscusi 1990; Krueger 1990; Lanoie 1991; 1994). We provide another model similar to those in these studies, but with some notable differences. In our model, even a fully insured worker makes investments in safety because they increase worker productivity (firm profits) and as a result directly increase wages. Workers invest in safety for two reasons. As in previous models, such investments raise utility by decreasing the probability of the hazardous state, which entails a personal financial loss. Such models, however, tend to focus on investments in safety only through the demand for it by workers (Seabury, Lakdawalla and Reville 2005). By contrast, we incorporate a direct incentive for both firms and workers to demand investments in safety. This is because such investments are valuable to the firm regardless of workers preferences for wages, safety and WC benefits.[8]

In sum, previous studies generally do not formally incorporate or systematically analyze workers' investments in safety and their implications for the determination of wages and risk of accidents. Although the exception, some previous empirical studies implicitly recognize the issue, but usually discuss it in terms of worker heterogeneity in ability or preference for risk and analyze it in an ad-hoc way. The general failure of previous research to incorporate the possibility that workers invest in safety seems unwarranted and is inconsistent with empirical evidence that higher workers' compensation benefits result in more accidents and injuries, some part of which must be due to fewer worker investments in safety (Chelius 1974; Butler 1983; Ruser 1985; 1991; 1993; Moore and Viscusi 1989). Furthermore, there is considerable evidence that workers invest in a variety of productivity-enhancing skills and it is certainly plausible that some of those investments translate into skills that reduce accident risk. Finally, evidence from other contexts suggests consumers invest in safety. For example, increases in automobile insurance are associated with higher accident rates (Chiappori 2000), suggesting insurance reduces consumers' incentives to prevent them. In short, it is somewhat surprising that worker investments in safety have been largely overlooked in the literature; thus, a model allowing for such investments is warranted.

[8] Previous studies only focus on the safety of the worker, and accident costs faced by the firm are typically thought to be WC benefits and lower wage costs. However, firms may face direct costs of accidents. Consider the hedonic methodology used in previous empirical studies. In this approach, firms are sellers and workers are buyers of safety. Our model is different in that firms are not only sellers, but also buy safety produced by workers.

## 3. A Model of Worker Investments in Safety

*3.1 Worker's Incentives to Invest in Safety*

A well known result is that firms have an incentive to invest in safety because it lowers accident and wage costs, as workers are willing to accept lower wages for a lower risk of accidents. However, workers also have an incentive to invest in safety that is independent of the firm's objectives. Worker investments in safety increase utility by decreasing the probability of an accident and the associated loss of wages, as long as the worker is not fully insured (Ehrlich and Becker 1972).

To make this point more formally, we begin by considering the worker's incentives drawing on the model by Ehrlich and Becker (1972). There is a probability $p$ that an accident occurs resulting in the worker's nonfatal injury, $0 \leq p < 1$. Workers can make investment in safety, $e$, which will reduce the probability of an accident.[9] The safety production function is $p(S, e, p)$, where $S$ is employer investments in safety and $p$ is the endowed risk of injury on a job that is determined by technology. We assume that $\frac{\partial p(S,e,p)}{\partial e} < 0$, and $\frac{\partial^2 p(S,e,p)}{\partial e^2} > 0$, i.e., worker investments reduce the probability of an accident and there is decreasing marginal productivity of investment. The price of a unit of investment in safety is $q$. If there is no accident, the worker earns wage $W$ and his utility is $U(W - qe)$, where $U(\cdot)$ is a twice-differentiable, increasing and concave function. If there is an accident, there is a loss $l$, so worker's utility is $U(W - l - qe)$ in that state.

The worker's problem is to choose investments in safety, $e$, to maximize expected utility

$EU$

[9] Differentiating between general investment in safety and firm-specific investment in safety does not alter the results.

$$EU^* \equiv \max_e EU = [1 - p(S,e,p)]U(W - qe) + p(S,e,p)U(W - l - qe) \quad (1)$$

The first-order condition is given in equation (A3) (see Appendix B). Basically, the marginal benefit of worker safety investment—in form of a reduced accident probability—has to equal its marginal costs—in form of its price, q, weighted by the expected marginal utility of the accident and non-accident state, respectively. Investments in safety will be higher the more productive workers are in producing safety and the lower its cost $q$.

*3.2 The Employer's Incentives to Invest in Safety*

Now consider the firm's incentives to invest in safety ($S$). Building on models by Smith (1974) and Oi (1974), we assume the employer produces output $Q$, which is an increasing function of labor $L$, $\frac{\partial Q(L)}{\partial L} > 0$, $\frac{\partial^2 Q(L)}{\partial L^2} < 0$. The price of a unit of output is $m$. An accident can occur with probability $p$, and the safety production function is the same as above: $p(S,e,p)$ .

Accidents cost the firm $A$ dollars per worker, and include costs of training and replacing injured workers, lost production time of the victim and other workers, lost output and interrupted production. The price of a unit of firm investment in safety is $c$.

The firm has an incentive to induce worker investments in safety because they would increase profits. However, competition for workers would bid away these rents and they would have to be returned to workers. The employer would be willing to pay a higher wage for worker investments and would to do so until the wage increase for the last unit of investment equals the decrease in accident costs.[10]

[10] To see this, consider the employer's profit function given by $\pi = mQ(L) - WL - p(S,e,p)AL - cSL$ . Using the implicit function theorem, obtain an expression for the wage change needed to keep profits constant when workers

To complete the firm's problem, we incorporate a constraint that the value of workers' utility resulting from firm choices is equal to the value of workers' utility that they can achieve on their own ($EU^*$), which is obtained from the solution to the worker problem given by equation (1). This captures the idea that workers must be compensated for investing beyond their own optimal investment. The employer's problem is to choose labor ($L$), investments in safety ($S$), and worker investments in safety ($e$) to maximize profits subject to a constraint that workers' utility is equal to $EU^*$ (the alternative):

(2) $$\max_{L,S,e} \pi = mQ(L) - WL - p(S,e,p)AL - cSL$$

$$s.t. \{[EU^* = (1 - p(S,e,p))U_1(W - qe) + p(S,e,p)U_0(W - qe - l)]L\}$$

Note that the employer does not incur the worker's cost $(qe)$ of investment but compensates workers with a higher wage for undertaking the investment. The first-order conditions w.r.t. firm investments in safety ($S$) and worker investments in safety ($e$) are given by

(3) $$\frac{\partial p}{\partial S}A + \chi \frac{\partial p}{\partial S}(U_1 - U_0) = -c$$

(4) $$\frac{\partial p}{\partial e}A + \chi\{\frac{\partial p}{\partial e}(U_1 - U_0) = -r[(1-p)U_1' + pU_0']$$

Equation (3) yields the optimal level of employer investments in safety ($S$). The left-hand-side of the equation is the marginal benefit of investment, which is the sum of the reduction in accident costs and the increase in worker utility resulting from the risk reduction weighted by the

invest in safety (i.e., zero profit constraint of competition) $\frac{dW}{de} = -\frac{\partial p(S,e,p)}{\partial e}A > 0$ This equation shows wages would rise in response to an increase in worker safety investments, where the magnitude of the wage increase would equal the expected reduction in accident costs. Note that worker investments in safety are no different than any other form of human capital investment. Investment raises worker productivity and is rewarded by higher wages. The magnitude of the wage increase would equal the expected reduction in accident costs.

value of changing utility by $\$1\,(\chi)$. The increase in utility resulting from the investment is a benefit to the employer because workers accept lower wages in return.

Equation (4) yields the optimal level of worker investments in safety $(e)$. The left-hand-side is the marginal benefit of such investment, which consists of the decrease in accident costs plus the increase in weighted utility stemming from the reduced injury risk. The right-hand-side is the investment's marginal cost, which is the worker's cost of investment ($r$) weighted by his marginal utility of income.

The firm will induce worker investments by paying a higher wage. The wage increase required to keep worker utility constant when the worker invests in safety is given by equation (A4) in Appendix B. By substituting equation (A10) into equation (6) and rearranging we obtain an alternative version of the first-order condition for worker investment in safety:

$$(5) \qquad \frac{\partial p}{\partial e} A = -\frac{dW}{de}[(1-p)U_1' + pU_0']\chi,$$

The left-hand-side of equation (5) represents the reduction in accident costs through the increased safety investment, i.e., the marginal benefit of worker investment in safety. The right-hand-side of equation (5) is the wage increase required to compensate workers for their investment weighted by their marginal utility of income and the value of changing utility by \$1 ($\chi$), i.e., the marginal cost of worker investment in safety. Worker investment in safety will be higher the higher are expected accident costs, and they will be lower the larger is the wage increase per unit of investment (i.e., its implicit price), which is an increasing function of the cost of investment and a decreasing function of workers' tolerance for risk.

The first-order condition of equation (2) w.r.t. labor, L, is given by the usual condition that the value of the marginal product of labor equals its marginal cost (see equation (A6) in Appendix B). Solving for the wage ($W$) yields:

(6) $$W = m\frac{\partial Q(L)}{\partial L} - p(S,e,p)A - cS\ ,$$

which shows that wages depend on the level of employer and employee investments in safety through their effects on risk, *p*. Such investments in turn depend on a variety of factors. Equation (3) shows that employer investments in safety will differ depending on their price (*c*), productivity$\left(\frac{\partial p}{\partial S}\right)$, accident costs (*A*), and employees' tradeoff between wages and employer-determined risk. Equation (5) shows that employee investments in safety depend on their price (*q*), productivity$\left(\frac{\partial p}{\partial e}\right)$, accident costs (*A*), and the tradeoff between wages and employee-controlled risk.

*3.3 Summary of Theory and Predictions to be Tested in Empirical Analysis*

In this section, we developed a theoretical model of worker investment in safety. The key insight of this model is that workers can invest in safety and such investments raise the value of workers to the firm. Employers induce workers to make safety investments by paying for them with higher wages. These investments cannot be undertaken by the firm because it does not know about them, or finds it too costly to implement them.

An important prediction of this model is that the net effect of injury risk on wages is *a priori* ambiguous. The standard prediction is that the association between this risk and wages is positive because firms offer a compensating differential to attract workers to a relatively risky job. This will be true only if risk is exogenously determined by technology and cannot be influenced by workers. However, when workers can make the investment in safety, the association between wages and (worker-produced) risk is negative; firms pay workers higher wages to induce them to invest in safety and reduce risk.

The next section tests the model empirically. To derive testable conditions, we assume first that—from the perspective of the individual worker—nonfatal injury risk is exogenously determined by the occupation. Thus, across occupations, we hypothesize to find *(i)* a *positive* correlation between occupational risk and wages since firms in higher risk occupations have to offer compensating wage differentials to attract workers.

However, in line with our model, we also assume, second, that workers can individually modify this exogenously given occupational injury risk through own worker investment in safety. Hence, we hypothesize to detect *(ii)* a *positive* association between measures of worker safety investment in safety and wages. Since we employ an actual measure of disinvestment in safety, we expect to find a *negative association* between our measure of disinvestment in safety and wages

Third, we assume that the marginal benefit of worker investment in safety is higher in high-risk occupations. Thus, we hypothesize that *(iii)* the negative association between our measure of individual (dis)investment in safety and wages is more pronounced in high risk occupations.

## 4. Effect of Worker Investment in Safety on Wages: An Empirical Application

Ideally, to test the theoretical model, we would need a direct measure of worker investment in safety, such as specialized safety equipment or specialized safety training. However, such measures are difficult to obtain. In this paper, we present an application afforded by mounting evidence that obesity increases the risk of accidents.[11] Because obesity is to a significant degree individually modifiable, preventing it to reduce the risk of accidents can be thought of as an investment in self-protection or safety. Likewise we can think of becoming obese as some sort of disinvestment in safety.

At least three potential pitfalls should be kept in mind when using obesity as a proxy for individual investment in (workplace) safety: *(a)* it has been shown that Body Mass Index (BMI) and obesity measures which are generated from self-reported height and weight measures, include substantial measurement error and are not perfectly correlated with the real degree of body fat (cf. Burkhauser and Cawley, 2009), *(b)* there is the possibility that obese workers are systematically more careful on the job since they are well aware of their higher injury risk. This could offset the higher injury risk induced by obesity. *(c)* We should keep in mind that obesity is only an indirect proxy measure of worker investment in safety. As noted above, we cannot exploit a direct unambiguous worker investment measure such as hours of safety training. On the other hand, employing these direct measures would also require certain assumptions, e.g. effectiveness of the safety training.

In essence, the main necessary condition that needs to hold when using obesity as a proxy for worker investment in safety is that obese workers have a significantly higher risk of having an accident or injury on the job. As mentioned, this can be considered a stylized fact and has

[11] See Guardado 2008; Pollack et al. 2007; Lakdawalla et al. 2007; Ostbye 2007; Finkelstein et al. 2007; Yoshino et al. 2006; Xiang et al. 2005; Corbeil 2001; Engkvist et al. 2000; Craig et al. 1998; Froom et al. 1996; Stoohs et al. 1994.

been shown by a growing body of the literature. In addition, there are several (medical) reasons why obese workers would be more prone to accidents. Obesity is associated with sleep apnea, which makes obese persons more likely to fall asleep or become drowsy while working (Browman et al., 1984; Strobel et al., 1996; Froom et al., 1996). Heavy persons are more likely to fall, particularly because of difficulty in controlling balance recovery in the anterior position (Corbeil 2001). Moreover, obese persons have a hard time concentrating at work, which could be a "recipe for disaster, particularly for laborers working around machines" (Shutan 2003, p. 1039). The most suggested mechanisms underlying obese workers' higher risk of accidents are fatigue, sleepiness, physical limitations, ergonomics and poorer health (Pollack 2007).

In line with the existing literature, the theoretical model developed above predicts that obese workers will earn lower wages because of their lower safety-related productivity. While weight control may not always reflect a purposeful investment in safety, on average, it nevertheless is a modifiable attribute that increases workplace safety.

*4.1 Research Design and Methods*

For the empirical analysis, we use a simple linear specification motivated by equation (8)

$$LnW_{ijkt} = \alpha_i + \pi_j + \sigma_k + X_{it}\beta + \delta\, OB_{it} + \gamma RISK_j + \lambda(OB_{it} * RISK_j) + e_{ijkt}$$

$$(7)\quad \begin{array}{ll} i = 1,\ldots,N & \text{(index of persons)} \\ j = 1,\ldots,J & \text{(index of three-digit occupations)} \\ k = 1,\ldots,K & \text{(index of two-digit industries)} \\ t = 1992,\ldots,2000 & \text{(index of years)} \end{array}$$

In equation (7), *X* is a vector of an extensive set of regional, demographic, educational as well as workplace characteristics (see Appendix A). These characteristics are expected to affect wages and should proxy for the price of worker investment in safety, worker productivity in producing safety investments, and worker preferences toward risk. $\alpha_i$, $\pi_j$ and $\sigma_k$ are person, occupation and industry fixed effects, respectively, which will proxy for workers' and firms' cost as well as productivity of safety investments and accident costs. *OB* is a measure of obesity (body mass index >30). Note that we additionally incorporate the continuous plain BMI measure into *X*. This is to capture no-obesity-related weight effects.[12] *RISK* is the nonfatal injury rate in the three-digit occupation per 100 full-time workers (FTW). *OB*RISK* is the interaction term between our worker investment and risk measures and is our main variable of interest.

**Testing hypotheses.** Recall the model predictions and the three derived hypotheses that we intend to test empirically with this model (see Section 3.3):

*(i)* First, across occupations we expect to find a *positive* association between occupational risk and wages since firms in higher risk occupations have to offer compensating wage differentials to attract workers. The plain *RISK* coefficient yields the compensating wage differential for riskier occupations and thus we expect $\gamma$ to be positive.

*(ii)* Second, we assume that workers can individually modify the exogenously given occupational injury risk through own investments in safety. We proxy for worker (dis)investment in safety through *OB*, i.e., becoming obese. Hence, we expect $\delta$ to be negative. Note that this association could also capture other underlying relationships between obesity and wages above and beyond worker safety and wages. One explanation could refer to discrimination. Another to the idea that obesity may be correlated with productivity that is not specific to reducing accident risk.

*(iii)* Third, and this represents the core idea of this paper, we hypothesize that the marginal benefit of worker investment in safety is higher in high-risk occupations. In other

[12] However, the results are robust to including the continuous BMI measure.

words, we would like to test whether the wage premium for job risk differs by obesity. Thus, the main coefficient of interest in equation (7) is the interaction term between obesity (*OB*) and *RISK*. We expect $\lambda$ to be negative.

*4.2 Data*

Data for the empirical analysis come from three sources. The primary source is the 1979 NATIONAL LONGITUDINAL SURVEY OF YOUTH (NLSY). The NLSY is a sample of 12,686 people aged 14-22 years in 1979. The survey was conducted annually until 1994 and biennially thereafter. All the variables, with the exception of nonfatal injury and accident risk, were obtained from the NLSY.

**Dependent variable.** The dependent variable is the natural logarithm of the respondent's real hourly wage at his current/most recent job. We calculate the real hourly wage using the Consumer Price Index (CPI) for all urban consumers where the base period is 1982-1984. As shown in Appendix A, the average logarithm of the hourly wage is about 2 or about $7.50. However, the smallest reported hourly wage was $1.05 and the highest $56.83. This illustrates that our dependent variable exhibits a significant degree of variation.

**Obesity Measure.** One key independent variable is obesity, which we calculate from the body mass index (BMI) using reported weight in each year and the reported height in 1985.[13] We then create a dummy variable for obesity status (BMI>=30). The average BMI is 26.9, but values range from 10.9 to 91.2 (see Appendix A). About 23 % of all respondents are classified as obese. The evidence that high weight increases the risk of injury is mainly found only for those who are obes (BMI>=30), and not just being overweight (30>BMI>=25)

[13] $BMI = K/(M^2)$, where *K* is weight in kilograms and $M^2$ is height in meters squared.

**Nonfatal Risk Measure.** We obtained nonfatal injury rates by 3-digit occupation from the THE SURVEY OF OCCUPATIONAL ILLNESSES AND INJURIES (SOII) of the BUREAU OF LABOR STATISTICS (BLS).[14] The SOII provides information on nonfatal occupational injuries and illnesses resulting in at least one day away from work and on median days away from work due to injury. The SOII is a federal/state program in which reports are collected from private industry employers. State agencies collect and process the survey data and prepare estimates using standardized procedures established by the BLS to ensure uniformity and consistency between states. The data is available for the years 1992 to 2000.[15]

To turn the fatality counts into rates, we divide them by annual 3-digit occupation employment counts provide by the March CPS. In the following, we always report risk rates per 100 full-time workers (FTW). As the Appendix A demonstrates, the variation in this crucial variable for our analysis is large and ranges from 0.006 to 102 nonfatal injuries or accidents per 100 FTW, occupation, and year. This risk measure is skewed to the right, with an average of 1.9, a median of 1.1, a 90$^{th}$ quintile of 4.7 and a 99$^{th}$ quintile of 10.5.

**Other Covariates.** In our preferred specifications, we control for the following personal characteristics in addition to the individual fixed effects. The latter net out all time-invariant individual unobservables, which may confound simple OLS estimates.

A first category of controls refers to *demographics* and includes covariates such as age, gender, race, marital status, or #kids in the household (see Appendix A).

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[14] For 3% of all occupation-year observations, no risk rate measure could be assigned since no count of nonfatal injuries and diseases was available. Another reason for only being able to calculate rates for 97% of all observations were missing CPS employment counts. More specifically, for our time period covered, the CPS still used the 1980 Census Occupation Code, whereas the SOII used the 1980 Census Occupation Code. Despite crosswalks, the concordance is not perfect and not all codes could be matched. However, as a robustness check, we imputed 3-digit *industry*-specific risk measures for the missing values. The results are very robust.

[15] 1995, 1997, and 1999 are not covered.

A second category refers to *education* and includes dummies for high-school degree, some college education, or being a college graduate. We also split the Armed Forces Qualification Test Score (AFQT) into quartiles and include dummy variables for each quartile accordingly.

A third category of controls makes use of *workplace characteristics* and includes four firm size dummies (*<=25, 26-99, 100-499,>500 employees*), an indicator for whether there was a job change, and a dummy indicating whether the person holds a private or public sector job.

Finally, we also include *regional controls for economic conditions* and characteristics that may affect the value of the worker's marginal product, e.g. the local unemployment rate (*<=6%, 6 to 8.9%, > 9%*) as well as the region of residence (*northeast, north central, west and south; urban or rural residence*).

Note that we always consider the survey year in form of year fixed effects. In more sophisticated models, we additionally incorporate a full set of 3-digit occupation fixed effects (417 dummies) as well as a full set of 2-digit industry fixed effects (236 dummies).

**Sample Selection.** We restrict the sample to those who worked for pay, worked at least 40 weeks in the year prior to the survey, usually worked at least 24 hours a week, were not self-employed, were not in the armed forces, reported valid 3-digit occupation and 2-digit industry codes, had non-missing data on key variables, and did not have a real hourly wage less than $1 or greater than $100.[16] We drop observations with extreme values of the real hourly wage as they are likely coding errors. After all restrictions, we have a sample of 26,016 person-year observations on 7,006 persons.

[16] We exclude those in the armed forces as is common in previous literature. After the aforementioned selection restrictions, the following variables have missing data: wage (N=451), occupation (N=120), industry (N=163), weight or height (bmi) (N=710.

## 5. Results

*4.1 Descriptive Evidence*

We begin by showing mean values for obese vs. non-obese employees in Table 1. As can be inferred from this descriptive exercise, on average, obese people work in slightly riskier occupations. However, particularly given the huge standard deviation of *RISK* of 2.6, the differences in average injury risk per 100 FTW are minor (1.9 vs. 2.0). It is also worthwhile to note that, on average, obese workers make less than non-obese workers ($7.74 vs. $6.97).

**[Insert Table 1 about here]**

However—and this may be surprising—overall, all relevant covariates seem to be reasonably well balanced and we do not find empirical evidence for worker sorting into occupations based on their obesity status. Imbens and Wooldridge (2009) propose to judge the covariate balance based on the scale-free "normalized difference" (see notes to Table 1 for more details). According to their rule of thumb, values below 0.25 suggest a well covariate balance. Column (3) of Table 1 shows that all normalized differences are significantly below 0.25; for most variables, the values are even below 0.1. For example, consider the indicator for whether employees changed their job or not For various reasons, one might suspect that obese workers switch jobs more often. The difference in the job switching rate is, however, minor and even lower for the obese (24.6% vs. 23.6%); the normalized difference is only 1.6.

Table 2 now differentiates by job risk. The first column header of Panel A indicates the nonfatal risk quartiles. In each quartile, i.e. across the whole risk distribution, we have enough observations for obtaining statistical precision and they are also surprisingly balanced; each quartile counts between 5,000 and 6,500 observations. The second column header differentiates by obesity status. The first row indicates the hourly wage. Panel A lets us conclude the following:

(I) The wage seems to strictly *de*crease with the risk level of the job. This is not in line with our hypothesis (i) above and the standard finding of the wage-risk compensation literature. However, one should keep in mind that these are simple descriptive correlations.

(II) Obese workers make less than non-obese workers in each risk category. This is in line with our hypothesis (ii) above. It is also in line with the previous literature on the obesity-wage relationship (Cawley, 2004).

(III) The wage differential between obese and non-obese workers decreases with job risk – both in absolute and relative terms. This purely descriptive finding is also at odds with our hypothesis (iii) above.

**[Insert Table 2 about here]**

In Panel B of Table 2, we now look at *changes* instead of levels and compare workers who become obese to workers who did not—again by risk category. We do not only look at changes in weight, but also at changes in wages as indicated by the row. We find the following:

(I) Again, as above in Panel A, wage growth seems to slow down, the higher the risk category. However, the relationship is far less pronounced than when looking at the variables in levels. In addition, in a statistical sense, there are no differences in wage growth across risk categories.

(II) The wage growth for workers who become obese is not statistically different from the wage growth for workers who keep the same weight. This finding holds across all risk categories.

(III) The wage growth *differential* between weight gainers and weight keepers does not differ statistically across the different risk categories. The mean values for the two worker groups within a risk category are almost identical. However, just looking at simple means, one finds that the differential wage growth is slightly *larger* for lower risk as compared to higher risk categories. Although this is in line with our hypothesis (iii).

*4.2 Evidence from Standard Regression Models*

Table 3 shows the results of different regression models as illustrated by equation (7). The first three columns report the findings for a simple OLS regression model that correlates the natural logarithm of the hourly wage with level measures of the BMI, obesity, nonfatal risk as well as the interaction between *OB* and *RISK*. The three columns only differ by the inclusion of sets of covariates as indicated in the bottom of the table. Column (2) only considers year fixed effects and is, except for correcting for year shocks, the regression analogue to Panel A of Table 2.

Column (2) incorporates a rich set of 417 occupation and 236 industry fixed effects. Essentially, this means that we net out persistent wage differences across industries and occupations. We also net out all other time-invariant occupational and industry factors, observable and unobservable, that may confound the statistical relationship between wages, job risk, and obesity. For example, although we have not found evidence for this in Table 1, it is thinkable that obese workers self-select into specific occupations and/or industries which structurally different wage levels. The descriptive associations in Table 2 may be an artifact of such sorting.

Column (3) of Table 3 additionally controls for a rich array of individual-level controls with respect to demographics, education, and the workplace (see Appendix A). Such individual-level factors may likewise confound the relationship between wages, on the job risk, and obesity. We find the following from the first three columns of Table 3:

(I) Only in the most parsimonious specification, in column (1), we find that higher injury risk is negatively correlated with wages. Again, this is the regression analogue to Panel A of Table 2. We see that workers in occupations with 1 additional injury per 100 FTW make 3.5% less. 1 additional injury per 100 FTW represents an increase of about 50% of the variable mean. However, once we net out persistent differences across occupations and industries in columns (2) and (3), this statistical association vanishes.

(II) Obese workers have a lower wage, independent of their occupational risk. However, the wage penalty decreases from 14% in column (1) to 4% in column (3). Overall, this negative statistical correlation is in line with our hypothesis (ii) above. Note that BMI in levels—independent of obesity status—is positively correlated with wages. This may be due to the fact that sick people are typically underweight and that the health/productivity-BMI relationship is certainly nonlinear.

(III) Once we consider occupation and industry fixed effects, obese workers seem to have a significantly 0.8% *higher* wage when increasing the injury risk by 1 injury per 100 FTW. However, one needs to consider that, in general, obese workers have a 4% *lower* pay. Hence, overall, this still yields a wage penalty for obese workers. However, obese workers still seem to be *relatively* better off in high-risk occupations. This is not in line with our hypothesis (iii).

**[Insert Table 3 about here]**

In columns (4) to (6) of Table 2, we likewise include sets of covariates stepwise. However, in contrast to columns (1) to (3), we now consider individual fixed effects. This is important since now we look at obesity in *changes* rather than levels. In other words, the effects are identified by individuals who experience a weight change, in this case, by those who become obese. This is an important distinction to the simple OLS model since it nets out all time-invariant unobservables that may be correlated with both obesity and wages, and may lead to spurious statistical correlations. We find the following when we employ these more sophisticated specifications.

(I) Workers in high risk occupations make more money, in our preferred specifications 5 to 6% more. This finding is in line with our hypothesis (i). Note that this positive wage differential is identified by workers who switch occupations or whose occupations become riskier over time and thus see a change in their occupational risk. It also illustrates that the zero or even negative finding of the OLS model in columns (1) to (3) is spurious. The existence of a compensating wage differential for higher risk jobs has been demonstrated by numerous studies in the economics literature (cf. Viscusi and Aldy, 2003).

(II) The general statistical association between obesity and wages vanishes. However, interestingly, the positive association between BMI and wages is persistent. Note that the zero finding for obese people does not contradict our hypothesis (ii). This is a finding independent of the job risk and holds for the average obese person. For example, assume that obese people only experience a wage penalty in high risk jobs but not in jobs without risk. Further assume that many obese people work in low risk jobs. Then the non-significant relationship between obesity and wages may be the consequential statistical finding for the average obese person.

(III) Our main variable of interest, the interaction term between obesity and job risk, is highly significant and negative. It suggests that becoming obese reduces wages by about 0.4% -- but only in high risk jobs. By excluding job changers we show in a robustness check below that this is not due to an alternative explanation which would refer to obese workers who switch jobs. The finding that becoming obese leads to a wage penalty only in high risk jobs is absolutely in line with our model and hypothesis *(iii).*

A highly significant wage penalty of 0.4% appears to be small in magnitude; however, it translates into $200 per year for an annual income of $50,000. After a work life of 30 years and assuming a 2% discount rate, this yields a wage penalty of more than $8,000.

*4.3 Other Sensitivity Analyses (results available upon request)*

As a first robustness check, we exclude workers who changed their jobs. Recall that the negative effect of the *OB*RISK* may either stem from workers who become obese or from obese workers who switch jobs and sort into occupations. We have already seen in Table 1 that the covariates between obese and non-obese workers are very well balanced. This supports the view that the negative association is not a result of worker sorting. Now we exclude the possibility that the finding in column (6) of Table 3 may be a result of obese workers switching jobs. Excluding workers who switched jobs yields a surprisingly robust and highly significant negative relationship between becoming obese, job risk, and wages. Becoming obese results in a wage penalty of about 0.5% for higher risk jobs; more specifically, for a risk rate increase of one additional injury per 100 FTW. This did you have a thought here?

In a second robustness check, we would like to test whether the results differ by gender. Consequently, we generate and add an additional triple interaction term between *female* and *OB*RISK* to the model. If our obesity measure is capturing safety-related-productivity, then we should not expect to find a differential. Other evidence finds that obesity increases the risk of accidents for both males and females (e.g., Guardado 2008). Thus, we do not expect to find a differential by gender. If we did, that might suggest the obesity penalty might be due to other factors, if, say, obese women were discriminated against *more* in risky job. We do not find any evidence that the result differ by gender. This bolsters the idea that the wage penalty is due to lower safety-related-productivity.

In a third robustness check, we would like to test whether the results differ by race and add two triple interactions between the dummies *black* and *Hispanic*, respectively, to the model. Similar arguments to those we made above with respect to obesity apply here as well. All workers – in this case across race-ethnicity status—are at higher risk of accidents when they are obese. Again, we do not find any evidence that the results differ by race.

Finally, we interact *age* with *OB*RISK* and add this triple interaction term to the model. Note that all respondents are between 27 and 43 years old. Nevertheless, we find a marginally significant and negative triple interaction suggesting that the high risk job wage penalty increases by 0.4% for every 5 life years (and presumably work experience). Put differently, the return to worker investment in safety increases with age. Interestingly, in our preferred specification, the simple interaction term *OB*RISK* becomes insignificant and the stand age effect translates into a wage gain of X% for every 5 life years.

## 6. Summary and Conclusions

The standard economic theory of compensating wage differentials assumes that firms and workers face tradeoffs between risk of accident or injury and wages. Firms can pay higher wages to compensate workers for accepting this risk, or they can invest in safety to lower the wages they pay. Importantly, this model makes the strong assumption that risk is exogenous to workers, as only firms can reduce risk. We depart from most past research by incorporating worker investments in safety. A key prediction of the new model is that the risk will be positively associated with wages only to the extent it is produced by the firm or determined by technology. However, if risk is produced by workers, then greater risk is associated with lower wages.

To derive testable implications, we assume that occupational injury risk is exogenously given but that the individual worker can influence the individual-specific risk through individual investments in safety. We test the following three hypotheses empirically: *(i)* Across occupations, which differ by injury risk, the association between injury risk and wages is positive since employers need to pay a compensating wage differential to attract workers. *(ii)* Individual-level safety investment measures are positively associated with wages, i.e., at the individual level, risk is *negatively* associated with wages. *(iii)* The positive association between changes in worker investment in safety and wages is more pronounced in high-risk occupations.

Because there are no direct measures of worker investments in safety such as specialized safety equipment or training, we test this model by taking an indirect approach. Previous evidence finds that obesity increases the risk of accidents; thus, because obesity is (partly) a modifiable attribute, weight control can be thought of as an investment in self-protection or safety (Kenkel 2000). If obese workers make fewer or no investments in safety (or have lower safety-related productivity), our model predicts they will earn lower wages in risky jobs.

We test our three hypothesis empirically using NYLS data for 1992-2000 and detailed nonfatal risk measures at the 3-digit occupation level. As a proxy for worker-specific safety (dis)investment, we use obesity. Our empirical results are both in line with our three hypotheses and the previous literature. Most important, we find a highly significant negative relationship between obesity, job risk, and wages. When workers become obese, they face a wage penalty of about 1.5% in a high risk as compared to a median risk occupation ($90^{th}$ vs. $50^{th}$ risk percentile). For every additional injury per 100 FTW and year, the wage penalty for obese workers increases by about 0.5%.

By showing that the covariates between obese and non-obese workers are well balanced and by excluding job changers in a robustness check, we provide strong evidence against the notion that the wage penalty for obese workers in high risk occupations is a result of sorting. We also address concerns that omitted variable bias might produce our findings by incorporating a very rich set of year fixed effects, occupational and industry fixed effects, personal and regional covariates as well as individual fixed effects into our preferred model specification. Ultimately, the empirical effect is identified by workers who are at least observed twice in our panel data, become obese and do not change jobs. Considering a rich array of individual-level worker characteristics that have to be shown to be correlated with wages and obesity as well as persistent wage differences across occupations and industries, we estimate the effect of becoming obese on wages in occupations with varying injury risk. Note that this occupational injury risk is plausibly exogenous from a worker perspective.

However, to be cautious, we do not interpret our findings as strict causal evidence, but as strongly in line with our model predictions and the idea of worker investment in safety. After all, we do not have a direct measure of worker investment in workplace safety, but only a proxy. However, this proxy is highly correlated with accidents, is modifiable by the worker, and thus varies at the individual level. Alternative stories about time-varying unobservables that are correlated with wages, obesity, and occupational risk are imaginable, but we consider the probability of their real life relevance as minor. We suspect that measuring the effects of more direct measures of worker investments in safety might yield larger estimates than those we identify here. We intend to head in this direction of inquiry and encourage other researchers to do the same.

In summary, our empirical evidence suggests that obese workers earn lower wages particularly in high risk occupations. More generally, the results of this study are consistent with models in which workers invest in safety and firms pay higher wages for these investments. Worker investments in safety will generate a negative relationship between wages and overall workplace risk, which is the opposite prediction from the standard compensating differential argument. Failing to account for this possibility may be one explanation for the absence of a consistent finding of compensating wage differentials for risk of injury and other disamenities in the workplace that can be offset by worker action.

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**Table 1: Balancing Properties of Covariates by Obesity Status**

| Variables | Obese=1 | Obese=0 | Normalized difference |
|---|---|---|---|
| ***Dependent variable*** | | | |
| lnwage | 2.046 | 1.942 | |
| ***Main variables of interest*** | | | |
| nfatinjr2 | 1.870 & | 2.005 | 0.037 |
| emp | 1,001,527 | 1,029,538 | 0.016 |
| bmi | 24.622 & | 34.497 | 1.839 |
| ***Demographic controls*** | | | |
| age | 34.181 & | 34.966 | 0.155 |
| female | 0.444 & | 0.446 | 0.004 |
| hispanic | 0.177 & | 0.220 | 0.075 |
| black | 0.252 & | 0.361 | 0.169 |
| numkidshh | 1.210 & | 1.338 | 0.074 |
| mar | 0.571 & | 0.559 | 0.018 |
| nevmar | 0.223 & | 0.257 | 0.057 |
| ***Educational controls*** | | | |
| lths | 0.095 & | 0.121 | 0.059 |
| hsgrad | 0.429 & | 0.471 | 0.060 |
| somecol | 0.231 & | 0.252 | 0.035 |
| colgrad | 0.245 & | 0.156 | 0.159 |
| afqt2 | 0.256 & | 0.257 | 0.001 |
| afqt3 | 0.212 & | 0.183 | 0.051 |
| afqt4 | 0.181 & | 0.114 | 0.134 |
| ***Workplace controls*** | | | |
| gov | 0.096 & | 0.125 | 0.064 |
| fsize1 | 0.332 & | 0.316 | 0.024 |
| fsize2 | 0.220 & | 0.229 | 0.016 |
| fsize3 | 0.228 & | 0.238 | 0.017 |
| fsize4 | 0.186 & | 0.181 | 0.008 |
| chjob | 0.246 & | 0.236 | 0.016 |
| ***Regional controls*** | | | |
| northe | 0.161 & | 0.148 | 0.027 |
| northc | 0.244 & | 0.233 | 0.018 |
| south | 0.391 & | 0.438 | 0.067 |
| west | 0.192 & | 0.170 | 0.042 |
| msregion | 0.011 & | 0.012 | 0.006 |
| msrura | 0.011 & | 0.012 | 0.007 |
| rural | 0.218 & | 0.256 | 0.064 |
| uerate2 | 0.355 & | 0.321 | 0.052 |
| uerate3 | 0.152 & | 0.151 | 0.003 |

**Source:** NLYS 1992-2000; the last column shows the normalized difference which has been calculated according to Δs= $(\bar{s}_1 - \bar{s}_0)/\sqrt{\sigma_1^2 + \sigma_0^2}$ with $\bar{s}_1$ and $\bar{s}_0$ denoting average covariate values for obese and non-obese workers, respectively. $\sigma$ stands for the variance. As a rule of thumb, normalized differences exceeding 0.25 indicate non-balanced observables that might lead to sensitive results (Imbens and Wooldridge, 2009)

**Table 2: Descriptive Statistic of the Association between Job Risk, Wages, and Obesity Changes Therein**

***Panel A***

| | **risk < p25** | | **p25<risk<p50** | | **p50<risk<p75** | | **risk > p75** | |
|---|---|---|---|---|---|---|---|---|
| | *obese* | *non-obese* | *obese* | *non-obese* | *obese* | *non-obese* | *obese* | *non-obese* |
| hourly wage | 10.07 | 11.57 | 7.91 | 9.09 | 7.34 | 7.79 | 6.83 | 7.15 |
| *std. dev.* | *(6.18)* | *(7.31)* | *(4.19)* | *(5.65)* | *(4.21)* | *(4.39)* | *(3.17)* | *(3.34)* |
| *N* | *1,250* | *5,130* | *1,435* | *5,197* | *948* | *3,990* | *1,622* | *4,868* |

***Panel B***

| | **risk < p25** | | **p25<risk<p50** | | **p50<risk<p75** | | **risk > p75** | |
|---|---|---|---|---|---|---|---|---|
| | *became obese btw. $t_0$ and $t_1$* | *no obesity change btw. $t_0$ and $t_1$* | *became obese btw. $t_0$ and $t_1$* | *no obesity change btw. $t_0$ and $t_1$* | *became obese btw. $t_0$ and $t_1$* | *no obesity change btw. $t_0$ and $t_1$* | *became obese btw. $t_0$ and $t_1$* | *no obesity change btw. $t_0$ and $t_1$* |
| change in hourly wage btw. $t_0$ and $t_1$ | 1.3254 | 1.1033 | 0.4551 | 0.4962 | 0.5981 | 0.3079 | 0.2640 | 0.2395 |
| *std. dev.* | *(4.4804)* | *(4.6101)* | *(1.9834)* | *(3.8376)* | *(4.6356)* | *(3.3619)* | *(2.5701)* | *(2.6635)* |
| *N* | *2,73* | *4,898* | *217* | *4,460* | *267* | *4,365* | *253* | *3,985* |

**Table 3: Relationship Between Wages, Occupational Risk, and Obesity**

| | OLS | | | FE | | |
|---|---|---|---|---|---|---|
| | lnwage | lnwage | lnwage | lnwage | lnwage | lnwage |
| Covariates | (1) | (2) | (3) | (4) | (5) | (6) |
| nonfatalrisk*obese | 0.0118 | 0.0089*** | 0.0074*** | -0.0041** | -0.0046*** | -0.0042** |
| | (0.0073) | (0.0028) | (0.0025) | (0.0019) | (0.0017) | (0.0017) |
| nonfatalrisk | -0.0355*** | -0.0003 | -0.0023 | 0.0022** | 0.0060*** | 0.0056*** |
| | (0.0039) | (0.0019) | (0.0018) | (0.0010) | (0.0015) | (0.0015) |
| obese | -0.1405*** | -0.0739*** | -0.0395*** | 0.0023 | 0.0005 | -0.0015 |
| | (0.0235) | (0.0145) | (0.0129) | (0.0103) | (0.0099) | (0.0098) |
| bmi | 0.0313*** | 0.0145*** | 0.0028 | 0.0099** | 0.0081** | 0.0080** |
| | (0.0059) | (0.0041) | (0.0039) | (0.0040) | (0.0038) | (0.0039) |
| bmi2 | -0.0005*** | -0.0002*** | -0.0001 | -0.0001* | -0.0001 | -0.0001 |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| year FE | X | X | X | X | X | X |
| occupation FE | | X | X | | X | X |
| industry FE | | X | X | | X | X |
| socio-economic covariates | | | X | | | X |
| individual FE | | | | X | X | X |
| Person-year observations | 26,019 | 26,019 | 26,019 | 26,019 | 26,019 | 26,019 |
| # individuals | 7,009 | 7,009 | 7,009 | 7,009 | 7,009 | 7,009 |
| R-squared | 0.0499 | 0.4103 | 0.5203 | 0.1144 | 0.1867 | 0.1934 |

*** p<0.01, ** p<0.05, * p<0.1

Robust standard errors in parentheses

## Appendix A: Summary Statistics

| | | Mean | Std. Dev. | Min | Max | Obs |
|---|---|---|---|---|---|---|
| ***Dependent variable*** | | | | | | |
| lnwage | real hourly gross wage, logarithm | 2.022.604 | .5166431 | 0.0046 | 4.4031 | 26,019 |
| ***Main variables of interest*** | | | | | | |
| nfatinjr2 | nonfatal risk per 100 FTW | 1.9056 | 2.5942 | 0.0058 | 1.021.088 | 26,019 |
| obese | =1 if obese (BMI>30) | 0.2269 | 0.4189 | 0 | 1 | 26,019 |
| bmi | Body Mass Index | 26.8633 | 5.3363 | 10.9475 | 91.2293 | 26,019 |
| ***Demographic controls*** | | | | | | |
| age | age in life years | 34.3591 | 3.6001 | 27 | 43 | 26,019 |
| female | =1 if female | 0.4444 | 0.4969 | 0 | 1 | 26,019 |
| hispanic | =1 if hispanic | 0.1869 | 0.3899 | 0 | 1 | 26,019 |
| black | =1 if black | 0.2766 | 0.4473 | 0 | 1 | 26,019 |
| numkidshh | number of kids in household | 1.2388 | 1.2181 | 0 | 8 | 26,019 |
| mar | =1 if married | 0.5683 | 0.4953 | 0 | 1 | 26,019 |
| nevmar | =1 if never married | 0.2306 | 0.4213 | 0 | 1 | 26,019 |
| ***Educational controls*** | | | | | | |
| lths | =1 if educ was less than high school | 0.1010 | 0.3013 | 0 | 1 | 26,019 |
| hsgrad | =1 if high school graduate | 0.4383 | 0.4962 | 0 | 1 | 26,019 |
| somecol | =1 if some college | 0.2356 | 0.4244 | 0 | 1 | 26,019 |
| colgrad | =1 if college degree | 0.2249 | 0.4176 | 0 | 1 | 26,019 |
| afqt2 | =1 if 2nd quartile of AFQT Test | 0.2562 | 0.4365 | 0 | 1 | 26,019 |
| afqt3 | =1 if 3rd quartile of AFQTTest | 0.2057 | 0.4042 | 0 | 1 | 26,019 |
| afqt4 | =1 if 4th quartile of AFQT Test | 0.1656 | 0.3717 | 0 | 1 | 26,019 |
| ***Workplace controls*** | | | | | | |
| gov | =1 if public sector job | 0.1028 | 0.3037 | 0 | 1 | 26,019 |
| fsize1 | =1 if firm < 26 employees | 0.3286 | 0.4697 | 0 | 1 | 26,019 |
| fsize2 | =1 if firm >25 & < 100 employees | 0.2219 | 0.4156 | 0 | 1 | 26,019 |
| fsize3 | =1 if firm >99 & < 500 employees | 0.2304 | 0.4211 | 0 | 1 | 26,019 |
| fsize4 | =1 if firm >499 employees | 0.1848 | 0.3882 | 0 | 1 | 26,019 |
| chjob | =1 if changed job | 0.2434 | 0.4292 | 0 | 1 | 26,019 |
| ***Regional controls*** | | | | | | |
| northe | =1 if region Northeast | 0.1583 | 0.365 | 0 | 1 | 26,019 |
| northc | =1 if region North Central | 0.2412 | 0.4278 | 0 | 1 | 26,019 |
| south | =1 if region South | 0.4019 | 0.4903 | 0 | 1 | 26,019 |
| west | =1 if region West | 0.1873 | 0.3901 | 0 | 1 | 26,019 |
| rural | =1 if rural region | 0.2267 | 0.4187 | 0 | 1 | 26,019 |
| uerate2 | =1 if local (collapsed) unemployment rate is in 2nd of 3 categories by NLSY | 0.3473 | 0.4761 | 0 | 1 | 26,019 |
| uerate3 | =1 if local (collapsed) unemployment rate is in 3rd of 3 categories by NLSY | 0.1519 | 0.3589 | 0 | 1 | 26,019 |

## Appendix B: A Model of Worker Investment in Safety

In our model of workers' investments in safety (Section 3), worker expected utility is given by

(A1) $$EU = [1 - p(S,e,p)]U(W - qe) + p(S,e,p)U(W - l - qe)$$

The basic worker problem is to choose investments in safety, $e$, to maximize expected utility $EU$

(A2) $$EU^* \equiv \max_e EU = [1 - p(S,e,p)]U(W - qe) + p(S,e,p)U(W - l - qe)$$

The first-order conditions to this problem are given by

(A3) $$-\frac{\partial p(e)}{\partial e}(U_1 - U_0) = q[(1-p)U_1' + pU_0']$$

If the quantity of worker investments demanded by the firm exceeds the optimal level of investment that the worker would choose, the employer can induce further investments by compensating workers with higher wages. For example, a fully insured worker would not invest, but the employer may find additional investment profitable. Thus, the question becomes what wage increase is necessary to induce the worker to invest beyond the quantities implied by equation (A3)? This wage change can be obtained by differentiating the expected utility function with respect to wages and worker investments to obtain

(A4) $$\frac{dW}{de} = \frac{\frac{\partial p}{\partial e}(U_1 - U_0) + q[(1-p)U_1' + pU_0']}{(1-p)U_1' + pU_0'} \geq 0$$

Equation (A4) indicates the magnitude of the wage change required to keep worker utility constant for a given change in worker investment in safety. If the employer demands the same quantity of worker investments as the worker would choose on his own, equation (A3) implies no change in the wage since this would make the numerator in equation (A4) equal to zero. To obtain further investments, equation (A4) shows the magnitude of the wage premium, which is positive because it follows from equation (A3) that $q[(1-p)U_1'+pU_0']$ exceeds $\frac{\partial p}{\partial e}(U_1-U_0)$.

The employer would have to pay to obtain additional investment.

If the worker was fully insured, $U_1 = U_0$ , he would have no personal incentive to invest: the first term on the right-hand-side of equation (A4) would be zero and the wage increase "charged" by the worker to invest would be given by $dW/de=q$. This shows that for fully insured workers, the wage increase required to invest in safety would equal the cost of investment $q$. This captures the idea that workers must be compensated for investing beyond their own optimal investment.

The employer's problem is to choose labor ($L$), investments in safety ($S$), and worker investments in safety ($e$) to maximize profits subject to a constraint that workers' utility is equal to $EU^*$ (the alternative):

(A5) $$\max_{L,S,e} \pi = mQ(L) - WL - p(S,e,p)AL - cSL$$

$$s.t.\ \{[EU^* = (1-p(S,e,p))U_1(W-qe) + p(S,e,p)U_0(W-qe-l)]L\}$$

The first-order conditions to this problem are given by:

(A6) $$m\frac{\partial Q(L)}{\partial L} = W + p(S,e^g,e^s,p^E)A + cS$$

(A7) $$-\frac{\partial p}{\partial S}A - \chi\frac{\partial p}{\partial S}(U_1-U_0) = c$$

(A8) $$-\frac{\partial p}{\partial e}A = \chi\{\frac{\partial p}{\partial e}(U_1-U_0) + r[(1-p)U_1'+pU_0']\}$$

(A9) $$EU^* = (1-p)U_1(W-qe^g-re^s) - pU_0(W-qe^g-re^s-l)]$$

Equation (A6) states that the value of the marginal product of labor must equal its marginal cost, which is the sum of the wage, expected accident cost and cost of firm investment in safety. Equation (A7) yields the optimal level of employer investments in safety (*S*) and equation (A8) yields the optimal level of worker investments in safety $(e)$.

Recall the firm will induce worker investments by paying a higher wage. The wage increase required to keep worker utility constant when the worker invests in safety was given by equation (A4). Multiplying both sides of that equation by the marginal utility of income $[(1-p)U_1'+pU_0']$ yields

(A10) $$\frac{dW}{de}[(1-p)U_1'+pU_0'] = \frac{\partial p}{\partial e}(U_1-U_0) + r[(1-p)U_1'+pU_0']$$

Substituting equation (A10) into equation (6) gives another version of the first-order conditions for worker investment in safety:

(A11) $$-\frac{\partial p}{\partial e}A = \frac{dW}{de}[(1-p)U_1'+pU_0']\chi,$$

The right-hand-side of equation (A11) represents marginal benefits and the right-hand side marginal costs of worker investment in safety.