Worker Investment in Safety, Workplace Accidents, and Compensating Wage Differentials

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Abstract

In this paper, we develop a theoretical model of worker investment in safety. Standard theory assumes that the risk of workplace accidents is exogenous to workers. It predicts that riskier jobs are associated with higher wages. In contrast, in our model workers make individual safety investments that reduce the risk of accidents. This results in a *negativ*e association between individual risk and wages. We test the model's predictions using obesity as a proxy for worker disinvestments in human capital and safety. In line with our model predictions, we find a significant positive compensating wage differential (CWD) for nonfatal risk at the occupational level. At the same time, however, there exists an underlying significant negative association between individual accident risk and wages, but only in high risk occupations. The latter relationship may downward bias or mask previous CWD estimates.

Key Words: Worker investment, Safety, Nonfatal risk, Compensating wage differentials, Obesity

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1. Introduction

Since Adam Smith, economists have theorized that workers must be compensated for unpleasant working conditions, of which one of the most important characteristics is workplace safety. Economists are interested in the relationship between on-the-job-risk and wages because it informs us about the way the labor market works (cf. Viscusi 1978; Kniesner et al. 2012). Policymakers care about it because it is used as an estimate of how much people value workplace conditions and their health.

Standard economic theory assumes that firms face a tradeoff between compensating workers for an increased risk of accidents or reducing this risk by investing in workplace safety (and paying lower wages). Thus, firms invest in safety until marginal benefits—a lower wage needed to attract workers in a competitive labor market—equals marginal costs—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 accidents on the job that are unknown to firms, or too costly for firms to exploit. For example, consider that a quarter of fatal occupational injuries are the result of highway accidents.[2] It is clearly possible, even likely, that drivers take action (invest) that are not possible for the firm to undertake to avert accidents. 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.

Compensation policies from industry support the notion that workers can individually invest in safety and are rewarded for such investment. Among the clearest examples of such policies are payments of bonuses for safety. Chappelle (1991) reports that firms offer monetary incentives to make workers more careful. Wilde (2000) notes 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

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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] Census of Fatalities Occupational Injuries (2004).

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.

Several studies and anecdotal evidence suggest that bonuses are associated with reductions in accident rates. In a study that compared different methods of accident reduction, Gregersen et al. (1996) finds that bonuses for safe driving significantly reduce the number and costs of accidents. Nafukho et al. (2004) examine the performance of tractor-trailer truck drivers in a U.S. trucking company and find that bonuses are 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.

In this paper, we develop a model in which workers invest in workplace safety in addition to investments made by firms. The model has important implications for the relationship between safety and wages, and may help explain why there is inconclusive empirical evidence for the existence of compensating wage differentials (CWD), especially for nonfatal risk.[7] 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 accidents (Dorman and Hagstrom 1998). Our model predictions also have implications for estimates of the value of a statistical life (VSL) which are typically derived from CWD estimates.

The second part of the paper tests the model predictions empirically using panel data from the NLSY 1979, which we merged with 3-digit occupational risk data from the BLS. Our rich empirical models include a variety of individual-level covariates, along with hundreds of occupation and industry fixed effects, as well

[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

[7] Wage premiums have been found more consistently for fatal risk, yet some studies do not find evidence of this either (see, e.g., Leigh 1991; Viscusi and Aldy 2003; Kniesner et al. 2012; Doucouliagos et al. 2012).

year and individual fixed effects. The empirical findings are absolutely in line with the model predictions. Most important, we obtain remarkably precise CWD estimates for nonfatal risk that coexist with a similarly strong *negative* association between individual accident risk and wages. As predicted by our model of endogenous worker safety investments, a safety disinvestment wage penalty is only found for high-risk occupations.

2. Previous Literature

Although not in a formal way, several previous CWD studies 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 (Viscusi 1978; Gegax et al. 1991; Shogren and Stamland 2002; Black and Kniesner 2003; Lalive 2003; Leeth and Ruser 2003; Cole et al. 2009, Kniesner et al. 2010; Kochi and Taylor 2012). Other studies have used seat belt use or cigarette smoking as proxies for heterogeneity in risk preferences, but also note that these variables may instead proxy for workers' safety-related productivity (Viscusi and Hersch 2001). An earlier literature also recognizes the importance of worker behavior in affecting the risk of accidents (Oi 1974; Chelius 1974).

Only a few previous studies formally model workplace risk as being endogenous to workers (Rea 1981; Moore and Viscusi 1990; Krueger 1990; Lanoie 1991; 1994). Those studies typically model this in the context of Workers' Compensation (WC) benefits, as they are usually concerned with *ex ante moral hazard*. We provide another model similar to those studies, but with some notable differences. In our model, even a fully insured worker makes investments in safety because they increase worker productivity, thus firm profits, and as a result wages increase. Workers invest in safety for two reasons. As in previous models, such investments increase their 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). In contrast, our model incorporates a direct incentive for both firms and workers to demand such investments. This is because they 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. 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.

3. A Model of Worker Investment in Safety

3.1 Worker's Incentives to Invest in Safety

It is known 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 safety investments increase utility by decreasing the probability of an accident and the associated loss of wages (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 investments in safety, e, which will reduce the

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[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.

probability of an accident.[9] The safety production function is $p(S,e,p^E)$, where S is employer investments in safety and p^E is the endowed risk of injury on a job that is determined by technology. We assume that $\frac{\partial p(S,e,p^E)}{\partial e} < 0$, and $\frac{\partial^2 p(S,e,p^E)}{\partial e^2} > 0$, 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 as follows:

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

The first-order condition is given in equation (A3) (see Appendix B). 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 income in the accident and non-accident state, respectively. Those investments will be higher the more productive workers are in producing safety and the lower are its price q.

If the quantity of worker investments demanded by the firm exceeds the optimal level of investment that the worker would choose on her own, the employer can induce further investments by compensating workers with higher wages. This wage change can be obtained formally by differentiating the expected utility function with respect to wages and worker investments to obtain

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

Equation (2) shows the magnitude of the "safety-investment wage-premium." It is non-negative.

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

3.2 Firm'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: $p(S, e, p^E)$.

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*.

In addition to the firm's incentives to make its own investments as in the standard model, the firm also has an incentive to induce *worker* safety investments because this would increase profits. However, competition for workers would bid away these rents and they would have to be returned to the worker. Therefore, 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]

To complete the firm's problem, we incorporate the 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^*). The latter 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):

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

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

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[10] To see this, consider the employer's profit function given by $\pi = mQ(L) - WL - p(S,e,p^E)AL - cSL$. Using the implicit function theorem, obtain an expression for the wage change needed to keep profits constant when workers invest in safety (i.e., zero profit constraint of competition) $\frac{dW}{de} = -\frac{\partial p(S,e,p^E)}{\partial e} A > 0$. 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.

Note that the employer does not incur the worker's cost (qe) of investment but compensates workers with higher wages for undertaking it. The first-order conditions w.r.t. safety investments by firms (*S*) and workers (*e*) are given by equations (A7) and (A8) in Appendix B, respectively. The optimal level of those investments in safety requires that their marginal benefits equal the marginal costs.

Differentiating equation (3) with respect to labor (*L*), and solving for the wage (*W*) yields a linear association between wages (*W*), the injury risk (*p*), and the firm costs of safety investment, (*cS*):

$$(4) \qquad W = m\frac{\partial Q(L)}{\partial L} - p(S, e, p^E)A - cS \ .$$

Equation (4) illustrates that wages depend on the level of employer and employee investments in safety through their effects on risk, *p*. Our empirical model will be mainly motivated by equations (4) and (2) above. Although firm-level safety investment and risk measures are not included in our dataset, we incorporate firm size dummies, a set of 417 occupational dummies at the 3-digit level, 236 industry dummies at the 2-digit level as well as year fixed effects. These variables should capture the accident risk (*p*) as well as firm investment costs (*cS*) in equation (4) above. Note that one could easily reformulate the firm's problem and aggregate it up to the occupational or industry level.

In addition to their own investments, firms can induce safety investments by workers over and above the optimal level they would choose on their own as derived from equation (A3). As mentioned, this may be necessary and efficient since employers *(a)* cannot make these investments or *(b)* workers can make them more efficiently, i.e. $\frac{\partial p(S,e,p^E)}{\partial S} < \frac{\partial p(S,e,p^E)}{\partial e} < 0$ and $q <= c$. Real world examples may be mining, logging, clerking or driving.

The wage increase required to keep worker utility constant when the worker invests in safety is given by equation (2). An alternative formulation is derived in Appendix B and given by:

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

The left-hand-side of equation (5) represents the reduction in accident costs through the increased safety investment, i.e., its marginal benefit. The right-hand-side of equation (5) represents the marginal cost and 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 (χ).

As a final remark, note that our simple model does not allow for worker heterogeneity. Obviously, in reality and our data, there is variation of worker investment in safety at the individual level. Our model could generate this type of variation if one introduced heterogeneity and allowed worker safety productivities to differ across individuals. In a competitive labor market with heterogeneity in job risks, one would then need to introduce job search costs, mobility or switching costs to avoid complete worker sorting into different occupations. However, we decided to keep the model tractable.

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

The key insight of the model above is that workers can invest in safety and such investments raise the value of workers to the firm. Employers induce those 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 risk of accidents on wages is *a priori* ambiguous. The standard prediction is that the association between job risk and wages is clearly positive because firms offer CWDs to attract workers to accept risky jobs. This is true if risk is exogenously determined and cannot be influenced by workers. However, when workers invest in risk reduction, the association between wages and (worker-produced) risk is negative; firms pay workers higher wages to induce them to invest in safety.

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

However, in line with our model, we also assume that workers can individually modify this exogenously given occupational accident risk through individual investments in safety. Hence, we hypothesize that there is *(ii)* a *positive* association between measures of worker investments in safety and wages. Since we employ an actual measure of *dis*investment in safety, we expect to find a *negative association* between our measure of safety disinvestment 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 disinvestment in safety and wages is more pronounced in high risk occupations. Put differently, the wage premium for a given level of (exogenous) risk is higher among non-obese workers—i.e., those who invest in safety.

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 training. However, such measures are difficult to obtain. In addition, direct worker safety investment measures would need to be observable by the employer and, ideally, one would need exogenous variation in these measures.

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 (Kenkel 2000). Likewise we can think of becoming obese as some sort of disinvestment in human capital and safety. For example, the largest US employer, the US military, explicitly imposes weight-for-height and Percent Body Fat (PBF) standards for enlistment (Cawley and Maclean 2012). Using our dataset, we also find strong suggestive evidence that becoming obese leads to more injuries: Regressing an indicator of *individual-level* workplace accidents on a rich set of socioeconomic characteristics, and fixed effects for industries, occupations, years, and individuals, we find that becoming obese increases the probability of a workplace accident by 1.5 percentage points. This coefficient estimate is significant at the 6% level and translates into an increase of 21% (results available upon request).

[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.

At least three potential pitfalls should be kept in mind when using obesity as a proxy for individual disinvestment in workplace safety: *(a)* it has been shown that obesity measures that 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, and *(c)* we should keep in mind that obesity is only an indirect proxy measure of worker disinvestment in safety. As noted above, we cannot exploit a direct 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 or non-sorting into training participation.

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 et al. 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 essence, the main necessary condition that needs to hold when using obesity as a proxy for worker disinvestment in safety is that obese workers have a significantly higher risk of having an accident on the job. This can be considered a stylized fact and has been shown by a growing body of literature (Stoohs et al. 1994; Froom et al. 1996; Craig et al. 1998; Engkvist et al. 2000; Corbeil et al. 2001; Xiang et al. 2005; Yoshino et al. 2006; Finkelstein et al. 2007; Ostbye 2007; Lakdawalla et al. 2007; Pollack et al. 2007; Guardado 2008).

4.1 Research Design and Methods

For the empirical analysis, we use a simple linear specification motivated by equations (2) and (4) above:

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

$$(6) \quad \begin{array}{ll} i = 1, \ldots, N & \text{(index of persons; } N = 7{,}006) \\ j = 1, \ldots, J & \text{(index of 3-digit occupations; } J = 417) \\ k = 1, \ldots, K & \text{(index of 2-digit industries; } K = 217) \\ t = 1992, \ldots, 2000 & \text{(index of years)} \end{array}$$

In equation (6), *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 those investments, and worker preferences toward risk.

α_i, π_j and σ_k are person, occupation and industry fixed effects, respectively. These are proxies for accident costs and for the productivity and cost of workers' and firms' safety investments. These factors are further captured by the firm size dummies included in *X*.

OB is a measure of obesity (body mass index >30). Note that *X* additionally includes a continuous measure of BMI. This is to capture non-obesity-related weight effects.[12] *RISK* is the nonfatal injury rate at the 3-digit occupational level per 100 full-time workers (FTW). It varies across the 417 occupations and over time between 1992 and 2000. *OB**RISK* is the interaction term between our safety disinvestment 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 accident risk and wages since firms in higher risk occupations have to offer CWDs to attract workers. The first-difference coefficient on *RISK* yields the CWD for riskier occupations; thus we expect γ to be positive.

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

(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 with *OB*, i.e., becoming obese. Hence, we expect δ to be negative. Note that δ could also capture the effect of factors other than those related to worker investments in safety, such as discrimination or non-safety-related productivity.

(iii) Third, and this represents the core idea of this paper, we hypothesize that the marginal benefit of worker investments in safety is higher in high-risk occupations. In other words, we aim to test whether becoming obese—which we see as an observable and individually modifiable disinvestment in human capital and safety—triggers a wage penalty that varies across the exogenously given occupational job risk. A priori, there is no reason to believe that any of the possible alternative explanations under *(ii)* which would explain a negative relationship between obesity and wages—e.g. discrimination—should differ significantly by the riskiness of the job. Thus, the main coefficient of interest in equation (6) is the interaction term between obesity (*OB*) and *RISK*. We expect λ 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 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 (i.e., \$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 accidents is mainly found for those who are obese (BMI>=30), but not for those who are just overweight (30>BMI>=25).

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. 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 are available for the years 1992 to 2000.[15]

To turn the injury counts into rates, we divide them by annual 3-digit occupation employment counts provided by the March CPS. In the following, we always report injury rates per 100 full-time workers (FTW). As 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 90th quintile of 4.7 and a 99th 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 unobservable factors, which may bias simple OLS estimates.

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

14 For 3% of all occupation-year observations, no risk measure could be assigned since no count of nonfatal injuries and diseases was available. Another reason we could calculate rates for just 97% of all observations is that there 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 1990 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 first category of controls refers to *demographics* and includes covariates such as age, gender, race, marital status, and #kids in the household (see Appendix A).

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 (cf. Bender and Mridha, 2011), i.e., 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.

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[16] We exclude those in the armed forces as is common in the 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 the empirical analysis by showing mean differences between obese and 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 difference in average injury risk per 100 FTW is minor (1.9 vs. 2.0). It is also worthwhile to note that, on average, obese workers earn less than non-obese workers ($6.97 vs. $7.74).

[Insert Table 1 about here]

However—and this may be surprising—overall, all relevant covariates seem to be reasonably well balanced. We do not find empirical evidence of 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 or not employees changed their job. 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 (23.6% vs. 24.6%); the normalized difference is only 1.6%.

Table 2 presents wage differences between obese and non-obese workers by nonfatal riskiness of the job (risk quartiles). Differences in wage levels are reported in Panel A, and differences in wage changes are in Panel B. Note there are between 5,000 and 6,500 total observations in each quartile. This shows we have enough observations across the whole risk distribution to obtain statistical precision and that those observations are (surprisingly) well balanced. The descriptive results in Panel A can be summarized as follows:

(I) Wages seem to strictly decrease with the risk level of the job. This is not in line with our hypothesis (i) above and the standard finding of the CWD literature that wages and risk should be positively related. However, one should keep in mind that these are simple descriptive correlations.

(II) Obese workers earn lower wages than non-obese workers in each risk category. This is in line with our hypothesis (ii) above—that worker disinvestment in safety (obesity) would be negatively related with wages. It is also in line with the previous literature on the obesity-wage relationship (Cawley, 2004; Lindeboom et al., 2010; Kan and Lee, 2012; Sabia and Rees, 2012).

(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 hypothesis (iii), which would suggest a stronger wage differential as risk increases.

[Insert Table 2 about here]

In Panel B of Table 2, we compare wage *changes* of workers who become obese to workers who do not by riskiness of the job. We find the following:

(I) Again, consistent with the results in Panel A, wage growth seems to decelerate as job risk rises. However, this relationship is much less pronounced than when comparing wage *levels* as in Panel A. In addition, there are no statistically 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 do not. 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 wage growth differential is slightly *larger* for lower risk than for higher risk categories.

4.2 Evidence from Standard Regression Models

Table 3 presents estimates of the effect of job risk on wages, allowing the effect to differ by obesity status (equation (6)). The first three columns report the findings for a simple OLS regression model that correlates the natural logarithm of the hourly wage with measures of the levels of BMI, obesity (*OB*), nonfatal risk (*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. The model underlying the results in

Column (1) only includes year fixed effects and is roughly, 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 bias the statistical relationship between wages, job risk, and obesity. For example, although we have not found evidence for this in Table 1, it may be plausible for obese workers to self-select into specific occupations and/or industries with 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. Note that the R^2 strongly increased from 0.05 in column (1) to 0.41 and 0.52 in columns (2) and (3). This shows that we employ an unusually rich microdata model that may explain more than 50% of the cross-sectional variation in wage levels.

We summarize the findings from the first three columns of Table 3 as follows:

(I) In the most parsimonious specification—column (1)—we find that higher injury risk is negatively correlated with wages. However, once we net out persistent differences across occupations and industries in columns (2) and (3), this statistical association vanishes.

(II) Obese workers earn lower wages independent of their level of occupational risk. However, the wage penalty decreases substantially in magnitude (to 4 percent) as we include more controls (Column 3). Overall, this negative statistical correlation is in line with our hypothesis (ii) above. Note that the BMI level—independent of obesity status—is positively correlated with wages. This may be due, for example, to the possibility that being underweight may be associated with ill health, and wages thus increase with BMI, particulary in the left tail of the BMI distribution. Indeed recent research has shown that the obesity-wage relationship is highly nonlinear (Caliendo and Gehrsitz, 2014).

(III) Once we include occupation and industry fixed effects and other personal characteristics (Column 3), the results suggest that obese workers earn a statistically significant 0.8% *higher* wage in jobs with 1 additional injury per 100 FTW. However, recall that obesity is associated with a 4% *lower* pay; thus, the total effect still yields an obesity penalty. Nonetheless, the result that obese workers appear to be *relatively* better off in high-risk occupations is not in line with our hypothesis (iii).

[Insert Table 3 about here]

The results in Columns 1-3 do not control for heterogeneity in unobserved worker characteristics that may be correlated with the variables of interest, such as risk preferences or safety-related productively. In columns (4) to (6) of Table 3, we similarly include sets of covariates in a stepwise fashion, and in contrast to columns (1) to (3), we now include individual fixed effects. This is important since now we look at *changes* in obesity rather than levels. In other words, the effects are identified by individuals who experience a weight change—i.e., those who become obese. This is an important distinction to the simple OLS model since it nets out all time-invariant unobservable factors that may be correlated with both obesity and wages and that may lead to spurious statistical correlations. We find the following when we employ these more sophisticated specifications:

(I) Workers in high risk occupations earn wage premiums. The results from our preferred specifications in columns (4) to (6) show that high risk jobs raise wages by 0.5% to 0.6% per additional accident per 100 full time workers. Moving from the median risky job (1.1 accidents) to the 90th percentile (4.7 accidents) implies a wage premium of about 2%, and moving to the 99th percentile (10.5 accidents) carries a CWD of about 5%. This finding is in line with our hypothesis (i) that workers in high risk jobs would earn CWDs. Note that this wage premium is identified by workers who either switch occupations or whose occupations become riskier over time and who 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. This finding fills a gap in the economics literature on the existence of a CWD for higher risk jobs, some of which had not found evidence of wage premiums for nonfatal risk (cf. Viscusi and Aldy, 2003).

(II) The first-difference statistical association between obesity and wages vanishes. Note that this finding does not contradict our hypothesis (ii), is independent of job risk and holds for the average obese worker. To illustrate, 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 insignificant relationship between obesity and wages may be the consequential statistical result for the average obese person.

(III) Our main variable of interest—the interaction term between obesity and job risk—is negative and highly significant. We interpret these estimates as the wage effects of worker investments in safety. They show that the return to a given level of occupational risk is higher among workers who make those investments—i.e., becoming non-obese. Specifically, they indicate 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 lifetime wage penalty of more than $8,000. Moreover, it is possible that a more direct measure of worker investment in safety would yield estimates of larger magnitude. Finally, classical measurement error in the obesity or job risk measures could bias our coefficient of interest toward zero.

4.3 Robustness Checks

We performed several analyses to ensure that our results on the wage effects of job risk for obese and non-obese workers were robust. As a first check, we exclude workers who changed their jobs. Recall that the negative coefficient on our main variable of interest *OB*RISK* may either stem from workers who become obese or from obese workers who switch jobs and sort into occupations. We already demonstrated 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. Here we bolster that evidence by ruling out the possibility that our main findings (column (6) of Table 3) are a result of obese workers switching jobs. We find that excluding job switchers yields a surprisingly robust and highly significant negative relationship between becoming obese, job risk, and wages (column (1) of Table 4). Becoming obese results in a wage penalty of about 0.5% in higher risk occupations—specifically, in jobs with one additional injury per 100 FTW.

[Insert Table 4 about here]

In column (2) of Table 4, we re-estimate the models using lagged values of all the independent variables. Note that our main coefficient of interest—*OB*RISK*—shrinks in magnitude but remains statistically significant at conventional levels. The shrinking of the coefficient makes sense since the NLYS does not include the years 1995, 1997, and 1999. This means that, for 1996, 1998 and 2008, a lag is actually a lag of two years, not just one, and the obesity-risk-wage association thus decreases over time.

Finally, in the models underlying column (3), instead of clustering the standard errors at the individual level, we cluster them at the *occupation* level (Bertrand et al. 2004). In these models, both the magnitude and statistical significance of the estimates are highly robust.

4.4 Heterogeneity in Effects

Next we explore whether there is heterogeneity in the main effects of interest. First, we test whether the results differ by gender. To do that, we generate and add an additional triple interaction term between *female* and *OB*RISK* to the model. Other evidence finds that obesity increases the risk of accidents for both males and females (e.g., Guardado 2008). If our obesity measure is capturing safety-related productivity, then we should not expect to find a wage differential by gender. If we did, that might suggest the obesity penalty might be due to other factors, for example, if obese women were discriminated against *more* in risky jobs. Column (4) of Table 4 shows that there is no evidence that our main result differs by gender. This bolsters the idea that the wage penalty we find is due to lower safety-related-productivity.

Next, we test whether the results differ by race by including two additional triple interaction terms between the main variable of interest *OB*RISK* and dummies for *black* and *Hispanic*, respectively. Similar arguments to those we made above with respect to gender apply here as well. The results show that all workers—in this case across race-ethnicity status—earn lower wages in high risk jobs when they are obese. We do not find any evidence that the results differ by race.[17]

In column (5), 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, which suggests 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.

4.4 The Role of Job Requirements

Thus far we have considered accident rates (risk) across occupations and over time. However, certain characteristics of jobs, such as being physically demanding or strenuous, are a plausible channel of transmission underlying the risk-obesity-wage relationship. Strenuousness may lower obese workers' safety-related productivity and thereby increase their risk of workplace accidents.

To investigate this possibility, we generate a variable *JobPhysicallyDemanding*, which takes on values 1 to 3 and varies across occupations. Higher values represent more strenuous jobs. It indicates whether the job requires *(i)* climbing, *(ii)* reaching, or *(iii)* stooping, kneeling, crouching or crawling.[18] We re-estimate our standard models with the addition of this variable in levels along with a triple interaction term. We hypothesize that the wage penalty for obese workers in high risk occupations is particularly pronounced in jobs with these physical requirements since they obviously increase the risk of accidents.

[17] Results are not displayed in Table 4 but are available upon request.

[18] We assigned these job characteristics to the occupations in the NLSY using the *Dictionary of Occupational Titles (DOT), Revised Fourth Edition*, following the work of Lakdawalla and Philipson (2009). This consisted of first matching 1990 US Census occupation codes (used in the NLSY) to the occupations in the DOT, and then assigning DOT scores to the US Census occupation codes. Because DOT occupations can be more narrow and specific than the Census occupations—Census occupations can match to multiple DOT occupations—we averaged the DOT scores within each 1990 US Census code to obtain an average score for each Census code. We were unable to assign job characteristics for 147 individuals.

The results from this exercise are presented in column (6) of Table 4 and are exactly in line with our expectations. The triple interaction term is significant at conventional levels and of the same size in magnitude as the *OB*RISK* coefficient in Table 3, column (6). Note that the *OB*RISK* coefficient in this model is no longer significant. This illustrates nicely that the obesity-wage-penalty is not only specific to high-risk occupations, but also to high-risk occupations that require physically demanding work such as climbing, reaching, or stooping. This is strongly in line with our model and our hypothesis: becoming obese indicates a depreciation of human capital which translates into a decrease in wages, but only in high risk and physically demanding jobs.

6. Summary and Conclusions

The standard economic theory of compensating wage differentials (CWDs) assumes that firms and workers face tradeoffs between risk of accidents 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, that 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 risk of accidents 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 the risk of occupational accidents is exogenously given but that the individual worker can influence the risk through individual investments in safety. We test the following three hypotheses empirically: *(i)* Across occupations, which differ by accident risk over time, the association between risk and wages is positive since employers need to pay CWDs to attract workers. *(ii)* In contrast, individual-level safety investments 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.

We test our three hypotheses empirically using NLSY data from 1992 to 2000 and detailed BLS nonfatal risk measures at the annual 3-digit occupation level. As a proxy for worker-specific safety disinvestment, we use obesity. Previous evidence finds that obesity increases the risk of accidents; thus, because obesity is an individually modifiable attribute, weight control can be thought of as an investment in self-protection or safety (Kenkel 2000). Indeed, we find in a rich fixed effects specification that becoming obese increases the individual-level risk of a workplace accident by about 20%.

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%. Put differently, the wage premium for risk is lower among workers who become obese.

It is worthwhile to stress that we obtain a remarkably precisely estimated *positive* relationship between occupational risk and individual wages – this is the standard CWD finding. Importantly, we obtain it with precision for nonfatal risk in a rich model that, in addition to controlling for an extensive set of relevant factors, includes individual, occupational and industry fixed effects. In our empirical model, moving from an occupation with the median risk to jobs in the 90^{th} risk percentile goes along with a CWD of 2%. As mentioned above, we disentangle from this positive risk-wage relationship another precisely estimated *negative* association between a measure of individual accident risk and wages. The latter additionally varies by overall workplace risk, in line with our model, and has the same size as the standard CWD estimate. In an extension to our model, we show that the transmission channel is related to job requirements since becoming obese only leads to a wage penalty in strenuous high risk jobs.

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, hundreds of occupational and industry fixed effects, personal and regional covariates as well as individual fixed effects. 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.

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 such investment, 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 perhaps imaginable, but we consider the probability of their real-life relevance as minor. For example, a priori, there is no reason to believe that discrimination of obese workers should significantly differ by occupational job risk. 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 physically demanding 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 those investments. Worker investments in safety will generate a negative relationship between wages and overall workplace risk, which is the opposite prediction from the standard CWD argument. Failing to account for this possibility may be one explanation for varying and imprecisely estimated CWDs findings. To the extent that these results carry over to fatal risk, they also suggest that current VSL estimates may be severely biased.

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Table 1: Balancing Properties of Covariates by Obesity Status

Variables	Obese=0	Obese=1	Normalized difference
Dependent variable			
lnwage	2.046	1.942	
Main variables of interest			
nonfatalrisk	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
rural	0.218	0.256	0.064
uerate2	0.355	0.321	0.052
uerate3	0.152	0.151	0.003

Source: NLYS and SOII 1992-2000; the last column shows the normalized difference which was calculated as $\Delta s = (\bar{s}_1 - \bar{s}_0)/\sqrt{\sigma_1^2 + \sigma_0^2}$, where $\bar{s}_1$ and $\bar{s}_0$ are the average covariate values for obese and non-obese workers, respectively, and σ is 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: Differences in Wages between Obese and Non-Obese Workers by Job Risk Status

Panel A

	risk < p25		**p25<risk<p50**		**p50<risk<p75**		**risk > p75**	
	Obese	*non-obese*	*obese*	*non-obese*	*obese*	*non-obese*	*obese*	*non-obese*
Real 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 real 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	*273*	*4,898*	*217*	*4,460*	*267*	*4,365*	*253*	*3,985*

Source: NLYS and SOII 1992-2000; the column headers indicate the nonfatal risk quartiles of the respondent's job. Panel A simply displays the real hourly wage by obesity status. Panel B differentiates between respondents who become obese vs. those who did not change their obesity status between t_0 and t_1. Analogously, the row in Panel B indicates the change in real hourly wages between t_0 and t_1.

Table 3: Estimates of the Effect of Job Risk on Wages by Obesity Status

	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)
Bmi^2	-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

Source: NLYS and SOII 1992-2000; *** p<0.01, ** p<0.05, * p<0.1 Robust standard errors, clustered at the individual level, are in parentheses. The first three columns estimate an OLS version of equation (6), i.e. no individual fixed effects. Those three models only differ by the sets of covariates included, as indicated. The last three columns estimate Fixed Effects models that include individual fixed effects. The three FE models also only differ by the sets of covariates included. Obese is a dummy variable equal to 1 if the person's body mass index (BMI) exceeds 30. By contrast, BMI is a continuous measure of BMI. Nonfatalrisk indicates the number of workplace accidents at the yearly 3-digit occupation level per 100 full time employees.

Table 4: Robustness Checks and Heterogeneity in Effects

	Robustness Checks			Heterogeneity in Effects		
	no job changers	lagged independent variables	cluster at occupational level	female	age	physically demanding job
Covariates	(1)	(2)	(3)	(4)	(5)	(6)
Nonfatalrisk*obese*[column header]				0.0016	-0.0007*	-0.0039*
				(0.0040)	(0.0004)	(0.0023)
[column header]				0.0000	-0.0034	0.1686***
				(0.0000)	(0.0067)	(0.0259)
Nonfatalrisk*obese	-0.0046***	-0.0026*	-0.0042***	-0.0044**	0.0195	0.0038
	(0.0018)	(0.0014)	(0.0016)	(0.0018)	(0.0143)	(0.0054)
Nonfatalrisk	0.0053***	0.0014	0.0056***	0.0057***	0.0058***	0.0081***
	(0.0016)	(0.0010)	(0.0015)	(0.0015)	(0.0015)	(0.0023)
Obese	-0.0004	0.0381**	-0.0015	-0.0020	0.0020	-0.0036
	(0.0105)	(0.0169)	(0.0098)	-0.0044**	(0.0098)	(0.0105)
Year FE	X	X	X	X	X	X
Occupation FE	X	X	X	X	X	X
Industry FE	X	X	X	X	X	X
Socio-economic covariates	X	X	X	X	X	X
Individual FE	X	X	X	X	X	X
Person-year observations	19,685	6,883	26,019	26,019	26,019	25,140
# individuals	6,217	4,206	7,009	7,009	7,009	6,862
R-squared	0.1968	0.2110	0.1867	0.1934	0.1867	0.1861

Source: NLYS and SOII 1992-2000; *** p<0.01, ** p<0.05, * p<0.1 Robust standard errors, clustered at the individual level except for column (3), are in parentheses. Obese is a dummy variable equal to 1 if the person's BMI exceeds 30. Nonfatalrisk indicates the number of workplace accidents at the yearly 3-digit occupation level per 100 full time employees. Column (1) excludes job changers. Column (2) uses all independent variables in the leftmost column as lagged independent variables. Column (3) clusters at the occupational level, instead of the individual level. Columns (4) to (6) add additional triple interaction terms between *Nonfatalrisk*obese* and the variable as indicated in the column header, along with the column header variable in levels. For example, in column (4) we add the triple interaction term *Nonfatalrisk*obese*female* to the model. The plain *female* covariate is included in all the models. The variable *PhysicallyDemandingJob* is generated using the DOT (see footnote 18). It varies across occupations, takes on values from 0 to 3 and indicates whether a job requires *(i)* climbing, *(ii)* reaching, or *(iii)* stooping, kneeling, crouching or crawling.

Appendix A: Summary Statistics

		Mean	Std. Dev.	Min	Max	Obs.
Dependent variable		(1)	(2)	(3)	(4)	(5)
lnwage	real hourly gross wage, logarithm	2.0226	0.5166431	0.0046	4.4031	26,019
Main variables of interest						
nonfatalrisk	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 AFQT Test	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 2^{nd} of 3 categories by NLSY	0.3473	0.4761	0	1	26,019
uerate3	=1 if local (collapsed) unemployment rate is in 3^{rd} of 3 categories by NLSY	0.1519	0.3589	0	1	26,019

Source: NLYS and SOII 1992-2000; the leftmost column indicates the variable and the following column defines it. Columns 1-5 display the mean, standard deviation, minimum and maximum variable values, and the number of observations, respectively.

Appendix B: A Model of Worker Investment in Safety

The Maximization Problem of the Worker

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

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

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

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

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 Maximization Problem of the Firm

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

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

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

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

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

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

Equation (A7) 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 value of changing utility by $1 (χ). The increase in utility resulting from the investment is a benefit to the employer because workers accept lower wages in return.

Equation (A8) 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 (q) weighted by his marginal utility of income.

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. Solving for the wage (*W*) yields:

(A9) $$W = m\frac{\partial Q(L)}{\partial L} - p(S, e, p^E)A - cS \quad ,$$

Equation 9 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 (A7) shows that optimal 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 (A8) yields the optimal level of employee investments in safety (*S*); they 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.

Recall the firm will induce worker investments in safety 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) $$\frac{dW}{de}[(1-p)U_1'+pU_0'] = \frac{\partial p}{\partial e}(U_1 - U_0) + q[(1-p)U_1'+pU_0']$$

Substituting equation (A10) into equation (A8) 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.