Compensating Differentials and Moral Hazard in the Labor Market

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Abstract

This paper shows that, in an environment of asymmetric information, the wage premium of an unpleasant job attribute not only includes the compensating differential but also the economic rent that stimulates worker effort. The wage premium is equal to the compensating differential if and only if workers are perfectly monitored. Estimates of a structural model using data from the National Longitudinal Survey of Youth find that both the compensating differential and the efficiency wage premium are important in accounting for the total wage premium. This implies that reduced-form estimates of the compensating differential by hedonic wage regressions are biased upward.

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1 Introduction

The theory of compensating differentials (Rosen 1974, 1986) states that firms and workers exchange wage-job attributes bundles in an implicit market. The market offers higher (lower) wages to compensate workers for bad (good) job attributes. The implicit prices of equalizing the differences of job attributes are compensating differentials. In equilibrium, in a competitive labor market, the marginal worker is indifferent between working on a run-of-the-mill job and an unpleasant one. Much of the empirical literature estimates compensating differentials of job attributes, such as work-related injuries, by hedonic wage regressions. The theory hypothesizes that the market offers a wage premium to compensate workers that put themselves at risk of injury. However, empirically, unobserved productivity heterogeneity creates a biased estimate of the wage premium. Selection bias arises because low-ability workers sort into risky jobs,\(^1\) therefore the estimate is biased downward.\(^2\) Several empirical strategies attempt to correct for selection bias such as adding individual fixed effects (Brown, 1980; Duncan, 1983) and using instrumental variables to account for selection into jobs (Garen, 1988).

The development of the estimation of compensating differentials by hedonic wage regressions has used different econometric techniques to solve the identification issues such as selection bias. The main argument of this paper is that the estimate of compensating differentials will be biased even when the selection issues are appropriately corrected. The bias

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\(^1\)Risky jobs are defined as jobs on which workers have work-related injuries or illnesses.

\(^2\)See Hwang et al. (1992) for a further discussion of selection bias associated with the estimation of hedonic wage regressions.
is due to the misspecification of the econometric model in that the reduced-form estimate is not exactly equal to the compensating differential of work-related injuries in an environment of asymmetric information.

The idea of the argument is that the labor market offers higher wages (compensating differentials) to workers who work on risky jobs because they suffer losses in utility from injuries. Because of asymmetric information between firms and workers, however, firms cannot perfectly monitor worker effort. As a consequence, workers have a higher incentive to shirk on risky jobs relative to jobs with no disamenities. To illustrate this argument, suppose the utility function of workers is \( U = w - e(\delta + D) \), where \( w \) is the wage rate, \( e \) is effort, \( D \) is work-related injury, and \( \delta \) is a parameter.\(^3\) Since \( dU/de = -(\delta + D) < 0 \), the gain in utility from shirking (reducing effort) on risky jobs is higher than on non-risky jobs as \( \delta + D > \delta \). And the costs of being caught shirking are job losses in both cases, so workers have a higher incentive to shirk on risky jobs relatively.\(^4\) Intuitively, although the market offers workers higher wages to attract them to accept risky jobs, workers’ preferences of disliking injuries are unchanged and firms’ monitoring on worker effort is imperfect, so workers are tempted to slack off their duties on risky jobs.

\(^3\)The utility function captures the idea that if workers do not work, namely, \( e = 0 \), they no longer face any work-related injuries.

\(^4\)If we assume a Cobb-Douglas utility function, the prediction is stronger because of the wealth effect. Suppose \( U = w^\alpha(1 - e(\delta + D))^{1-\alpha} \), so \( dU/de = -(w/(1 - e(\delta + D)))^\alpha(1 - \alpha)(\delta + D) < 0 \). A higher wage leads to a stronger incentive to shirk on risky jobs because safety is a normal good.
elicit worker effort (Shapiro and Stiglitz, 1984). The idea of efficiency wage theory is that above market clearing wages provide economic rents to workers, which makes their jobs more valuable. Workers are thus motivated to work diligently because they would lose the rents if they are detected shirking. Overall, in principle the wage premium of risky jobs includes not only the compensating differential but also the efficiency wage premium. The former is to compensate workers for the disutility of facing work-induced injuries and the latter is to provide incentives for them to work hard in unpleasant working conditions. The estimate of the compensating differential in a hedonic wage regression is biased because the econometric model is misspecified in that the reduced-form estimate is not necessarily equal to the compensating differential of work-related injuries under imperfect monitoring. The idea is illustrated in Figure 1.

We develop a structural model that shows that the reduced-form wage premium is the same as the compensational differential if and only if the probability of monitoring workers equals unity. The structural model permits the direct estimation of the parameters of the utility function and of the probability of monitoring workers, so that the worker’s marginal willingness to pay (MWP) to avoid work-related injuries and the efficiency wage premium can be estimated. A generalized Roy model is incorporated in the structural model in which workers consider non-pecuniary components when they make their occupational choices. Such a modeling strategy is particularly useful to fix the selection issues, as low-ability workers sort into the risky sector that is associated with undesirable job attributes. The
structural model also includes a discrete choice model of job demotion because it is useful to map unobservable work/shirk decisions to observable job demotion decisions. As such, the probability of monitoring workers, which is essential to compute the efficiency wage premium, can be identified. To separately identify the compensating differential from the efficiency wage premium, we exploit the idea that there would be no efficiency wages if workers are perfectly monitored. This is achieved by setting the parameter attached to the probability of monitoring workers equal to unity to shut off the efficiency wage premium.

The structural model is estimated using data from the National Longitudinal Survey of Youth 1979 cohort (NLSY79). Armed with the structural parameter estimates, we are capable of decomposing the total wage premium into the compensating differential and the efficiency wage premium. The structural estimate of the total wage premium is 6.6%, which is similar to the reduced-form estimate of 6.2%. The total wage premium is decomposed into a compensating differential that accounts for 2.8% and an efficiency wage premium that accounts for 3.8%. Since the total wage premium is interpreted as the compensating differential in a hedonic wage regression, the results show that the reduced-form estimate of the compensating differential has substantial upward bias.

The above findings are driven by the assumption that worker effort and work-induced injuries are interdependent in the utility function. The motivation of this assumption is to capture the fact if workers do not work, they no longer suffer any work-induced injuries.
Although this assumption cannot be tested directly, one can test its implications. In particular, the testable implication is that workers have a higher incentive to shirk on jobs with disamenities, and so the job demotion rate is predicted to be higher in the risky sector. We find that this hypothesis is corroborated by the data.

The results in this paper are related to the recent findings in the literature of compensating differentials with imperfect information. Hwang et al. (1998) and Lang and Majumdar (2004) introduce search frictions into their models, and theoretically show that search frictions lower the value of compensating differentials. The intuition of their results is that with costly job search compensating differentials and the MWP of workers to avoid a job disamenity do not necessarily coincide. This result is empirically confirmed by Bonhomme and Jolivet (2009) who estimate the model of Hwang et al. with European data. This paper complements the recent papers in the literature in that it considers moral hazard, whereas they consider search frictions, in the theory of compensating differentials. The main difference is that in the present model the reduced-form wage premium exceeds the MWP because of efficiency wages; but in their models the reduced-form wage premium falls short of the MWP because of search frictions. Given that search frictions are deadweight losses in society and efficiency wages are valuable to workers, the two models generate different welfare implications for workers.

This paper is also related to the empirical literature of efficiency wages wherein nearly
all of the papers test the efficiency wage theory by testing the hypothesis of the negative relationship between wages and monitoring. The findings are somewhat favorable to the existence of efficiency wages. Leonard (1987) and Neal (1993) find that there is no negative relationship between wages and monitoring. Brunello (1995) finds that the negative relationship is insignificant after controlling for the quality of supervision. Nevertheless, Groshen and Krueger (1990), Kruse (1992), Rebitzer (1995), Ewing and Payne (1999), Moretti and Perloff (2002), and Georgiadis (2008) find that their empirical results support the hypothesis of the tradeoff between wages and monitoring. In a case study, Krueger (1991) investigates the fast-food industry and finds that monitoring influences worker compensation. Prendergast (1999), however, argues that a negative relationship between wages and monitoring does not necessarily imply that workers are motivated to work by earning economic rents. The simulation exercises below show that there exists a nonlinearly negative relationship between economics rents (efficiency wage premia) and monitoring (probability of monitoring workers), which implies the existence of efficiency wages that is not subject to the critique of Prendergast.

The reminder of this paper is organized as follows. Section 2 presents the baseline and the moral hazard models. Section 3 details the estimation and identification strategies. Section 4 presents the data and summary statistics. Section 5 discusses the empirical results. Section 6 provides simulation results from the model, and Section 7 concludes.

5 On the other hand, Cappelli and Chauvin (1991) and Flinn (1997) look at the relationship between wages and discipline dismissals.
2 Model Setup

This section presents the baseline model to show that the reduced-form wage premium of risky jobs is equal to the worker's marginal willingness to pay (MWP) to avoid work-related injuries. Next, a moral hazard model is set up to decompose the reduced-form wage premium into the compensating differential and the efficiency wage premium.

2.1 The Baseline Model

Suppose there are two jobs: $j = 0$ for an ordinary job and $j = 1$ for a risky job. The utility of worker $i$ in job $j$ at time $t$ is given by:

$$U_{ijt} = w_{ijt} - e_{it}(\delta + \theta D_{it})$$  \hspace{1cm} (1)

where $D_{it}$ is worked-related injury with $D_{it} = 1$ if $j = 1$ and $D_{it} = 0$ if $j = 0$. A characteristic/task approach is used here to define a job; a risky job is equivalent to the job on which the worker has worked-related injuries. Alternatively, $D_{it}$ can be interpreted as the worker’s occupational choice. $e_{it}$ is worker effort, $\delta$ and $\theta$ are preference parameters, and wages in each job are given by:

$$w_{ijt} = X_{it}\beta + \gamma_{it}D_{it} + \epsilon_{ijt}$$  \hspace{1cm} (2)

where $X_{it}$ is a vector of worker characteristics, $\gamma_{it}$ is the parameter of wage premium, and $\epsilon_{ijt}$ is unobserved determinants of wages.
**Assumption 1**: $D$ and $e$ are interdependent in the utility function.

Assumption 1 captures the fact that when individuals do not work, i.e. $e = 0$, they no longer face any work-related injuries. This also implies that it is more painful to work diligently where the work environment is unpleasant or dangerous. For instance, firefighters put themselves at higher risk of injury or death if they expend greater efforts to rescue people from fires. Simple differentiation shows that $\frac{d\bar{w}_{ijt}}{dD_{it}} = \gamma_{it} = -\frac{dU_{ijt}}{dD_{it}} = e_{it}\theta$. Hence, the wage premium of risky jobs is $\gamma_{it} = e_{it}\theta$. The essence of the baseline model is that the reduced-form wage premium $\gamma_{it}$ is equal to the MWP of workers to avoid work-related injuries $e_{it}\theta$, which is equivalent to the compensating differential of risky jobs.

### 2.2 The Moral Hazard Model

In an environment in which firms imperfectly observe effort levels of workers, workers have a discrete choice of working or shirking.

**Assumption 2**: Workers provide job-required efforts $e > 0$ if they work; they provide zero effort $e = 0$ if they shirk.

**Assumption 3**: If workers are detected shirking, they will be demoted with wage cuts and suffer utility losses.\(^6\)

\(^6\)Workers are fired for shirking is not considered, because such a harsh punishment is rare in reality and
The utility function of non-shirkers is the same as equation (1); that is:

\[ U_{ijt}^{NS} = w_{ijt} - e_{it}(\delta + \theta D_{it}) \] (3)

The utility function of shirkers is:

\[ U_{ijt}^{S} = (1 - \pi)w_{ijt} + \pi(\tilde{w}_{ijt} - \kappa) \] (4)

where \(w_{ijt}\) denotes wages, \(\tilde{w}_{ijt}\) demoted wages, and \(\tilde{w}_{ijt} < w_{ijt}\). \(\pi \in (0, 1]\) is the probability of monitoring workers, \(e_{it}\) is the job-required effort, and \(\kappa\) is the parameter of utility losses which incorporates unobservable punishments faced by workers. Workers would not be caught shirking with probability \((1 - \pi)\) and thus earn \(w_{it}\); they would be caught shirking with probability \(\pi\), and then receive demoted wages \(\tilde{w}_{it}\) and suffer utility losses \(\kappa\). Workers make a binary choice of providing job-required effort or zero effort follows from a simplifying assumption that the intensity of punishments is independent of how much workers shirk.

Workers choose to work if and only if \(U_{ijt}^{NS} \geq U_{ijt}^{S}\), which implies that:

\[ w_{ijt} \geq \tilde{w}_{ijt} - \kappa + \frac{1}{\pi}\delta e_{it} + \frac{1}{\pi}\theta e_{it} D_{it} \] (5)

The interpretation of equation (5) is as follows: When punishment becomes tougher, incorporating unemployment in the model makes the analysis complicated.
either an increase in utility losses $\kappa$ or a decrease in demoted wages $\tilde{w}_{ijt}$ will lead to lower wages $w_{ijt}$. The reason is that wages and punishment are substitutes for disciplining workers. To induce workers to exert a certain amount of effort, firms can provide rewards through higher wages or tougher punishment. The probability of monitoring workers $\pi$ is inversely related to wages because a higher intensity of monitoring is a kind of tougher punishment to workers. Moreover, the labor market offers higher wages to workers if they have a higher disutility of exerting efforts $\delta$ or of suffering work-related injuries $\theta$.

Similarly, workers choose to shirk if and only if $U_{ijt}^{NS} < U_{ijt}^{S}$. By matching variables between equations (2) and (5), the wage premium of risky jobs becomes:

$$\gamma_{it} = (1/\pi)\theta e_{it}$$

(6)

Suppose firms cannot perfectly monitor workers, i.e. $\pi < 1$, the moral hazard model predicts that the reduced-form wage premium is higher than the compensating differential of risky jobs, namely, $\gamma_{it} > \theta e_{it}$. By taking logarithm on $\gamma_{it}$, we analytically decompose $\gamma_{it}$ into two parts:

$$\log \gamma_{it} = \log(\theta e_{it}) + \log(1/\pi)$$

where $\log(\theta e_{it})$ represents the compensating differential and $\log(1/\pi)$ the efficiency wage premium. The rationale is if workers are perfectly monitored, $\pi = 1$, the efficiency wage premium will vanish as the second term becomes zero, then the result will be the same as
the one in the baseline model. The intuition behind this finding is that the labor market offers compensating differentials to workers because they have a higher disutility of working on risky jobs. Because of this, workers have a higher incentive to shirk from their duties. In order to induce effort exertion, firms offer workers economic rents to make their jobs more valuable. Hence, the wage premium of risky jobs not only includes the compensating differential but also the efficiency wage premium, where the former is to compensate workers for the loss in utility from suffering injuries and the latter is to provide incentives to them to work hard. We summarize our finding by the following proposition:

**Proposition 1**: The reduced-form wage premium is same as the compensational differential if and only if the probability of monitoring workers equals unity.

If imperfect monitoring is prevalent in the data, the above proposition implies that hedonic wage regressions give us biased estimates of the compensating differential of work-related injuries. Moreover, because workers have a higher incentive to slack off their duties on risky jobs, the model generates the following testable prediction:

**Prediction 1**: The job demotion rate is relatively higher on risky jobs.
2.3 Occupational Choices

Proposition 1 implies that if we estimate an econometric model without taking efficiency wages into account, it will give us an upward biased estimate of the compensating differential even though there is no selection bias. To emphasize the idea that the bias arises from the model misspecification, this section endogenizes the occupational choices $D_{it}$ of workers in the framework of a generalized Roy model to fix the selection issue.\footnote{Our methodology of solving the selection issue follows Goddeeris (1988) who modeled the occupational choices of lawyers in the context of compensating differentials. See Gould (2002) for an application of a Roy model in sectoral choices.}

Workers sort into different jobs according to their comparative productivity advantages and individual preferences. The utility of worker $i$ who chooses job $j$ at time $t$ is given by:

$$V_{ijt} = (w_{ijt} - e_{it}(\delta + \theta D_{it}))\varphi_j + Z_{it}\alpha_j + \eta_{ijt}$$ (7)

where $Z_{it}$ is a vector of individual characteristics that exclusively determine occupational preferences, $\varphi_j$ and $\alpha_j$ are parameters, and $\eta_{ijt}$ represents i.i.d. measurement errors. Because wages are only observed in one job for each worker, we substitute the wage offer equation (2) into equation (7). The occupational choice of a worker is determined by the sign of the latent utility $V_{it}^*$ that is denoted by a binary variable $D_{it}$:

$$V_{it}^* = V_{i1t} - V_{i0t} = (X_{it}\beta + \gamma_{it} - e_{it}(\delta + \theta))\varphi + Z_{it}\alpha + (\epsilon_{i1t} - \epsilon_{i0t})\varphi + \eta_{it}$$ (8)
\[ D_{it} = \begin{cases} 1 & \text{if } V^*_it \geq 0 \\ 0 & \text{if } V^*_it < 0 \end{cases} \]

where we normalize \( \varphi_0 = \alpha_0 = \eta_{0it} = 0 \) so that \( \varphi = \varphi_1, \alpha = \alpha_1 \) and \( \eta_{it} = \eta_{1it} \).

The interpretation of equation (8) is that workers consider their comparative productivity advantages, \((\epsilon_{1it} - \epsilon_{0it})\), when making their occupational choices. In particular, \((\epsilon_{1it} - \epsilon_{0it})\) is correlated with \(\epsilon_{ijt}\) in equation (2) in that workers sort into the sector in which they obtain the highest utility.

### 3 Estimation and Identification

This section describes the estimation procedures, starting with the reduced-form wage premium \(\gamma_{it}\), which is obtained by simultaneously estimating equations (2) and (8). \(\gamma_{it}\) is consistently estimated because the endogeneity and selection issues are taken into account. Next, the full structural model is estimated whereby the reduced-form wage premium is decomposed into the compensating differential and efficiency wage premium.

### 3.1 The Structural Econometric Model

We rewrite equation (5) in a latent utility framework as follows:

\[ U^*_{ijt} = U_{ijt}^{NS} - U_{ijt}^S = w_{ijt} - \tilde{w}_{ijt} + \kappa - (1/\pi)\delta e_{it} - (1/\pi)\theta e_{it}D_{it} + u_{ijt} \quad (9) \]
Suppose $u_{ijt}$ represents i.i.d measurement errors such that $u_{ijt} \sim N(0, 1)$. The probabilities of working and of shirking, respectively, are:

$$Pr(Work_{ijt}) = \Phi(w_{ijt} - \tilde{w}_{ijt} + \kappa - (1/\pi)\delta e_{it} - (1/\pi)\theta e_{it} D_{it})$$

$$Pr(Shirk_{ijt}) = 1 - Pr(Work_{ijt}) \quad (10)$$

The implication of equation (10) is that when workers are in the risky sector, i.e. $D_{it} = 1$, the probability of working (shirking) is relatively lower (higher) under imperfect monitoring, i.e. $\pi < 1$. To motivate worker effort, firms could provide a higher intensity of monitoring through $\pi$, or a harsher punishment through $\kappa$ and $\tilde{w}_{ijt}$, or higher wages $w_{ijt}$.

An econometric issue of estimating this model is that we do not observe both $\tilde{w}_{ijt}$ and $w_{ijt}$ for each individual. Assuming that the potential demoted wages are proportional to observed wages such that $\tilde{w}_{ijt} = \varphi w_{ijt}$, where $0 < \varphi < 1$ is the parameter of wage reduction. If we observe a worker who is not demoted, then $\varphi w_{ijt}$ is used as a proxy of his or her potential demoted wage. Otherwise, if a worker is demoted, $\tilde{w}_{ijt}/\varphi$ is used as a proxy of the worker’s potential non-demoted wage. This formulation allows one to estimate the proportion of wage reduction $\varphi$, which has interesting economic policy implications. Given our interest in estimating structural parameters $\theta$ and $\pi$, we substitute equations (6) into (2) and (8), respectively. The wage equation becomes:
\[ w_{ijt} = X_{it}\beta + (1/\pi)\theta e_{it}D_{it} + \epsilon_{ijt} \]  \hspace{1cm} (11)

where \( \epsilon_{ijt} = \xi_i + \nu_{ijt} \). The individual random intercept \( \xi_i \sim N(0, \sigma^2_\xi) \), and the error term \( \nu_{ijt} \) depends on jobs and is distributed as \( N(0, \sigma^2_j) \). Wages depend on structural parameters \( \theta \) and \( \pi \). In particular, wages are higher if workers suffer from greater losses from work-related injuries or firms monitor workers less frequently. Assume \( \eta_{it} \sim N(0, 1) \), the probabilities of taking risky job or a non-risky job are:

\[
Pr(RiskyJob_{it}) = \Phi\left((X_{it}\beta + (1/\pi)\theta e_{it} - e_{it}(\delta + \theta))\varphi + Z_{it}\alpha\right)
\]

\[
Pr(NonRiskyJob_{it}) = 1 - Pr(RiskyJob_{it}) \hspace{1cm} (12)
\]

Our estimation strategy is to map unobservable work/shirk decisions to observable job demotion decisions as depicted in Figure 2. The idea here is that a worker will be demoted when he or she chooses to shirk and is detected shirking which occurs with probability \( \pi \). A worker will not be demoted if he or she works, or the worker shirks and is not detected shirking which occurs with probability \( (1 - \pi) \). This strategy permits the derivation of the probabilities of job demotion and of no job demotion, respectively, as follows:

\[
Pr(JobDemotion_{ijt}) = \pi Pr(Shirk_{ijt})
\]

\[
Pr(NoJobDemotion_{ijt}) = Pr(Work_{ijt}) + (1 - \pi)Pr(Shirk_{ijt}) \hspace{1cm} (13)
\]
The modified wage equation (11), the occupation choice equation (12), and the job demotion equation (13) are estimated jointly by maximum likelihood. The likelihood function is derived as follows:\(^8\)

\[ L = \prod_{i=1}^{N} \prod_{t=1}^{T_i} f(RiskyJob_{it}, wages_{ijt}, JobDemotion_{ijt})^{D_{it}JD_{ijt}} \]
\[ \times f(RiskyJob_{it}, wages_{ijt}, NoJobDemotion_{ijt})^{D_{it}(1-JD_{ijt})} \]
\[ \times f(NonRiskyJob_{it}, wages_{ijt}, JobDemotion_{ijt})^{(1-D_{it})JD_{ijt}} \]
\[ \times f(NonRiskyJob_{it}, wages_{ijt}, NoJobDemotion_{ijt})^{(1-D_{it})(1-JD_{ijt})} \]

### 3.2 Identification

To separately identify the occupational choice equation from the wage equation in a generalized Roy model, we need at least one variable in \(Z_{it}\) that exclusively affects the occupational choice but is not related to the unobserved components of wages, e.g. unobserved ability.\(^9\)

We use physical weight and regional dummy of living in the West as instruments that exclusively determine preferences for jobs but are not related to unobserved ability. The weight is a proxy of the body size of a worker, which affects his or her job opportunities and comparative advantages. Worker weight is assumed to be independent of predetermined ability,

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\(^8\)The detail of the likelihood function is provided in the appendix, and the logarithm of wages are used in estimations.

\(^9\)Refer to French and Taber (2011) for further details on identification of the Roy model.
because workers can change their weights at will. As a supporting evidence, the correlation coefficient between weight and AFQT is -0.006.

Another instrument is a dummy variable that equals unity if the worker lives in the western part of the US and is zero otherwise. Agricultural, forestry, and fishing industries, which involve a high frequency of worker injuries are concentrated in the West because of the favorable weather. It is well known that the education level and observed cognitive ability are lower for people living in the South. We do not, however, have evidence to show that people living in the West are unusually weak in their individual productivity. For example, the mean score of AFQT of these people is slightly higher than the national average (41.8 vs. 41.2).

As shown in equation (6), the compensating differential and the efficiency wage premium can be separately identified in the total wage premium by exploiting the idea that there would be no efficiency wages if workers are perfectly monitored, which could be achieved by setting the probability of monitoring workers equals unity. Equations (11) to (13) shed some light on identifying structural parameters. Variations in job demotions and wages are key to identifying the probability of monitoring workers, \( \pi \). Efficiency wage theory suggests that wages are important because of the tradeoff between wages and monitoring. Variations in effort help to identify the utility parameter of exerting effort \( \delta \), and variations in risky jobs can identify the parameter of the MWP of workers \( \theta \).
4 Data

The data used in the paper come from the National Longitudinal Survey of Youth, 1979 (NLSY79). The NLSY79 is a nationally representative sample of 12,686 young men and women who were 14-22 years old when they were first surveyed in 1979. The survey was conducted annually between 1979 and 1994 and then switched to a biannual schedule. Because observations of effort are only available in the 1998 and 2000 waves of survey, these two survey years are used in the estimation. The procedure starts with 12,686 individuals and excludes 3,965 individuals that were not interviewed in the 1998 and 2000 surveys. Further 2,008 individuals are excluded because complete observations on key variables are unavailable for each of them. Both male and female workers are included. Workers in the agricultural, forestry, and fishing industries are not excluded, because there is evidence of efficiency wages in such industries (Moretti and Perloff, 2002). The final database in the estimation have 6,713 individuals and 11,427 total observations. The summary statistics are reported in Table 1, and the descriptions of the major variables are given below:

*RiskyJob*. A worker is said to have a risky job if he or she had work-related injuries or illnesses since the last interview; otherwise the job is non-risky. Table 1 shows that around 7% of the working population is in the risky sector.

*Effort*. Job-required effort is a continuous variable that is measured by the following survey question:
My job(s) require(s) lots of physical effort. Would you say this is true 1) All or most of the time; 2) Most of the time; 3) Some of the time; 4) None or almost none of the time?\textsuperscript{10}

\textit{JobDemotion.} Workers are asked if they experienced a job demotion since their most recent interview, and then asked if the following reason(s) were applicable to the change in position:

1) Reorganization of department, division or section within company.
2) Change in company ownership.
3) Company growth.
4) Company laying off others.
5) Personal request.
6) Automatic adjustment.
7) Personal job performance.
8) Other reasons.

The first six options are irrelevant to being punished for shirking duties. Only "personal job performance" and "other reasons" are included in accounting for the number of job demotions. "Other reasons" could capture something related to punishments for shirking. For \textsuperscript{10}Given that risky jobs are physically-intensive, physical effort is a good proxy of effort in estimating the wage premium of risky jobs.
example, a financial trader makes use of insider information for his or her own benefit, which violates the standards of professional conduct. This is a kind of shirking behavior from a firm’s point of view. Given this precise definition of shirking-related job demotions, the job demotion rate in the data is around 0.2%.

**Wages.** Wages are hourly rates in cents and have been CPI adjusted for 1998. Real wage values are recorded below $3.00 as $3.00 and values above $200.00 as $200.00. If a worker has multiple jobs, his or her main job is defined as the one with the longest work hours per week and the longest total work weeks conditioned on wages of the job are observed.

**Weight.** The physical weight of each worker in pounds.

**West.** West is a dummy variable that equals unity if the worker lives in the West and is zero otherwise. As defined by the US Census Bureau, the western US includes 13 states: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.
5 Empirical Results

5.1 Reduced-Form Estimates

To illustrate the endogeneity and selection issues of estimating the premium of risky jobs/work-related injuries, this section focuses on the reduced-form estimates and so does not decompose the estimates into different behavioral components. The OLS estimate of equation (2) is as follows:

\[
\log(Wage) = 5.84 - 0.034\text{RiskyJob} + 0.24\text{Male} + 0.005\text{AFQT} + 0.06\text{Educ} + 0.02\text{Tenure}
\]

The estimate of the risky-job coefficient is -0.034 with an estimated standard error of 0.02, which is in line with the results in the literature; that is a wrong sign of risky job premium could result from a downward unobserved ability bias. To control for individually unobserved heterogeneity, we have the following individual fixed-effects (FE) estimation:

\[
\Delta \log(Wage) = 6.15 + 0.023\Delta\text{RiskyJob} + 0.07\Delta\text{Educ} + 0.01\Delta\text{Tenure}
\]

The FE estimate of the risky-job coefficient is 0.023 with an estimated standard error of 0.02, which implies that \textit{ceteris paribus}, the market offers an increase of 2.3\% in wage rates to those working on risky jobs. This result indicates that unobserved worker heterogeneity creates a biased estimate of the premium of risky jobs.
FE estimation, however, cannot fully solve the selection issue. To demonstrate the idea, equation (2) is rewritten as follows:

\[ w_{ijt} = X_{it} \beta + \gamma D_{it} + (\epsilon_{i1t} - \epsilon_{i0t})D_{it} + \epsilon_{i0t} \]

The FE approach does not work whenever \((\epsilon_{i1t} - \epsilon_{i0t}) \neq 0\). The idea is that the unobserved productivity differs across jobs for the same individual. To consistently estimate the wage premium of risky jobs, sample selection estimation is used in which the wage equation (2) and the occupational choice equations (12) are estimated simultaneously by maximum likelihood. The sample selection estimate of the risky-job coefficient is 0.062, which far exceeds the FE estimate because 1) the FE estimate is biased whenever \((\epsilon_{i1t} - \epsilon_{i0t}) \neq 0\) and 2) the sample selection approach estimates the local average treatment effect of risky jobs in that certain instruments identify returns to taking risky jobs for a subgroup of workers with relatively high returns.

### 5.2 Structural Estimates

After the endogeneity and sorting issues were resolved the wage premium of risky jobs was estimated to be 6.2%. The empirical literature interprets the reduced-form wage premium as the compensating differential in a hedonic wage regression. Nevertheless, as was argued in the model-setup section, the reduced-form wage premium is the same as the compensating differential if and only if firms perfectly monitor worker effort. Otherwise, the reduced-form
wage premium not only includes the compensating differential but also the efficiency wage premium. In order to decompose the wage premium into these two components, the parameters of the utility function and of the monitoring technology are estimated in a structural model. In particular, the modified wage equation (11), the occupation choice equation (12), and the job demotion equation (13) are estimated simultaneously by maximum likelihood.\footnote{We use the Nelder-Mead algorithm to find the vector of parameters that maximizes the likelihood function. The standard errors are computed as the outer-product of the gradient.}

The estimates in the occupational choice equations are reported in Table 2. The instrumental variables exclusively determining the occupational preferences of workers are \textit{Weight} and \textit{West}. Large-sized workers are more likely to take risky jobs. As expected, workers living in the western part of the US have a higher probability of taking risky jobs because agricultural and forestry industries are concentrated there. The coefficient estimates of these two variables are statistically significant at 1%. As shown in Table 3, we find that the coefficient estimates of variables of the wage equation are statistically significant, except that the standard deviation of individual random effect is statistically insignificant.

The estimates of structural parameters of the job demotion equations and the results are reported in Table 4. Consistent with the theory, $\delta$ and $\theta$ are estimated to be positive, which implies that workers suffer utility losses from exerting efforts and from facing work-related injuries. The probability of monitoring workers, $\pi$, is estimated to be 0.42. The estimated parameter for wage reduction, $\tau$, is 0.73; or the average percentage of wage reduction is 27%.
if workers are caught shirking. A positive utility loss, $\kappa$, suggests that there is unobserved punishment faced by workers in job demotions.

Armed with the structural parameters, we perform the below decompositions:

1) The total wage premium of risky jobs is computed by equation (6), i.e. $\gamma = (1/\pi)\theta \bar{e}$, where $\bar{e}$ is the mean level of effort.

2) The compensating differential is computed by setting $\pi = 1$ to remove efficiency wages.

3) The difference between 1) and 2) is the efficiency wage premium.

The results of the decompositions are shown in Table 5. The structural estimate of total wage premium is estimated to be 6.6%, which is similar to the reduced-form estimate of 6.2%. The total wage premium is decomposed into a compensating differential that accounts for 2.8% and an efficiency wage premium that accounts for 3.8%. The efficiency wage premium contribute to more than half of the total wage premium. Since the total wage premium is interpreted as the compensating differential in a reduced-form model, the results show that the reduced-form estimate of the compensating differential has a substantial upward bias. The reduced-form estimate is biased upward because the hedonic wage regression does not incorporate the moral hazard environment wherein firms provide economic rents to workers.
to induce greater effort. In other words, the bias is attributable to the misspecification of the econometric model.

6 Simulations

6.1 Model Fit

This section presents the simulation results generated from the model to evaluate whether it is capable of fitting different aspects of the data. The results are reported in Table 6. The model predicts that around 6.65% of the working population is in the risky sector, which is similar to 6.71% in the data. The data show that the unconditional job demotion rate is 0.18% and the model generates a similar number, i.e. 0.19%. In particular, in the data the job demotion rate on risky jobs is around double the job demotion rate on non-risky jobs. This fact confirms prediction 1 and is explained as follows. Workers in the risky sector suffer greater losses in utility from working stimulates their incentives to shirk. Assume that the monitoring technology is the same across sectors, the job demotion rate is predicted to be relatively higher in the risky sector.\(^\text{12}\) Quantitatively, the model predicts that the job demotion rate on risky jobs is 0.30% and on non-risky jobs is 0.19%. These numbers are similar to 0.39% and 0.17%, respectively, in the data.

\(^{12}\)The explanation is not dependent upon the assumption of constant monitoring probability across sectors. In the risky sector, if monitoring is allowed to be lower based on the fact that monitoring is more difficult in dangerous environment, a higher job demotion rate is explained by a higher probability of shirking. In empirical implementation, because observations of job demotion in each sector are small, monitoring probability for each sector is difficult to be separately estimated.
6.2 Validation of Efficiency Wages

The empirical literature examines the existence of efficiency wages by testing whether there exists a negative relationship between wages and monitoring. For example, most papers estimate the following regression:

$$\log(\text{Wage}_i) = X'_i \beta + \alpha \text{Monitoring}_i + \epsilon_i$$

where $X_i$ is a vector of human capital variables of worker $i$, $\epsilon$ is an error term, and $\alpha$ is expected to be negative. Prendergast (1999) argues that the existence of a negative relationship between wages and monitoring does not imply that workers are motivated to work by earning economic rents. Rather, we need to see if there is a tradeoff between economic rents and monitoring. The idea is that if workers earn rents from their jobs they then have a greater incentive to work hard. As a result, firms could lower the intensity of monitoring to achieve the same level of effort exerted by workers. The different levels of probability of monitoring workers are simulated and the corresponding efficiency wage premia are computed in Figure 3. When the probability of monitoring workers equals unity, the efficiency wage premium is zero. There also exists a negative relationship between economics rents (efficiency wage premia) and monitoring (probability of monitoring workers) which is consistent with efficiency wage theory. The relationship is nonlinear, which indicates that the assumption of linearity that tests efficiency wage theory may not be appropriate.
7 Concluding Remarks

The results in this paper highlight the point that one needs to be cautious on interpreting reduced-form estimates in hedonic wage regressions, whenever the assumption(s) of the underlying theory do not hold. In particular, the structural model shows that, in an environment of asymmetric information, the wage premium of a job disamenity not only includes the compensating differential but also the economic rent that stimulates worker effort; where the two components are estimated to be important in contributing to the total wage premium but are different in nature. This suggests that reduced-form estimates of the compensating differential by hedonic regressions have substantial upward bias.

Even though workers may not be concerned with the respective components of their wage premium, there is first order importance from the perspective of policy implications for firms. For example, when there is a demand for creating risky jobs, from our empirical results, firms need to figure out a policy of resource allocation between improving work safety and enhancing monitoring technology to minimize the cost of job creation. In addition, the welfare implications drawn from the results in this paper are different from the ones in the literature. The recent papers on search models find that with search frictions the reduced-form wage premium of a job disamenity falls short of the MWP of workers (Hwang et al., 1998; Lang and Majumdar, 2004; Bonhomme and Jolivet, 2009); in contrast, this paper shows that the welfare implications are not that pessimistic: workers could obtain an extra amount of efficiency wages under imperfect monitoring. For future research, estimating a
model of compensating differentials with search frictions and moral hazard are interesting
to be investigated.

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Appendix - Derivation of the Likelihood Function

Let \( A_{it} = (X_{it}\beta + \xi_i + e_{it}(1/\pi)\theta - e_{it}(\delta + \theta))\varphi \)

\[
L = \prod_{i=1}^{N_i} \prod_{t=1}^{T_i} \left[ \int \Phi \left( \frac{A_{it} + Z_{it}\alpha + \varphi[-1 + \rho\sigma_0/\sigma_1](\log(w_{ijt}) - X_{it}\beta - \xi_i - (\theta/\pi)e_{it})}{\sqrt{1 + \varphi^2(1 - \rho^2)\sigma_0^2}} \right) \frac{1}{\sigma_\xi} \phi\left( \frac{-\xi_i}{\sigma_\xi} \right) d\xi_i \times \frac{1}{w_{ijt}\sigma_1} \int \phi \left( \frac{\log(w_{ijt}) - X_{it}\beta - \xi_i - (\theta/\pi)e_{it}}{\sigma_1} \right) \frac{1}{\sigma_\xi} \phi\left( \frac{-\xi_i}{\sigma_\xi} \right) d\xi_i \times \pi \left( 1 - \Phi \left( \frac{\log(w_{ijt})}{\tau} - \log(w_{ijt}) + \kappa - (1/\pi)\delta e_{it} - (1/\pi)\theta e_{it} \right) \right) \right]^{D_{it}J_{D_{ijt}}} \times \left[ \left( 1 - \int \Phi \left( \frac{A_{it} + Z_{it}\alpha + \varphi[-1 + \rho\sigma_1/\sigma_0](\log(w_{ijt}) - X_{it}\beta - \xi_i))}{\sqrt{1 + \varphi^2(1 - \rho^2)\sigma_1^2}} \right) \frac{1}{\sigma_\xi} \phi\left( \frac{-\xi_i}{\sigma_\xi} \right) d\xi_i \times \frac{1}{w_{ijt}\sigma_0} \int \phi \left( \frac{\log(w_{ijt}) - X_{it}\beta - \xi_i}{\sigma_0} \right) \frac{1}{\sigma_\xi} \phi\left( \frac{-\xi_i}{\sigma_\xi} \right) d\xi_i \times \pi \left( 1 - \Phi \left( \frac{\log(w_{ijt})}{\tau} - \log(w_{ijt}) + \kappa - (1/\pi)\delta e_{it} \right) \right) \right]^{(1-D_{it})J_{D_{ijt}}} \times \left[ \left( 1 - \int \Phi \left( \frac{A_{it} + Z_{it}\alpha + \varphi[-1 + \rho\sigma_1/\sigma_0](\log(w_{ijt}) - X_{it}\beta - \xi_i))}{\sqrt{1 + \varphi^2(1 - \rho^2)\sigma_1^2}} \right) \frac{1}{\sigma_\xi} \phi\left( \frac{-\xi_i}{\sigma_\xi} \right) d\xi_i \times \frac{1}{w_{ijt}\sigma_0} \int \phi \left( \frac{\log(w_{ijt}) - X_{it}\beta - \xi_i}{\sigma_0} \right) \frac{1}{\sigma_\xi} \phi\left( \frac{-\xi_i}{\sigma_\xi} \right) d\xi_i \times \left( \Phi \left( \log(w_{ijt}) - \tau \log(w_{ijt}) + \kappa - (1/\pi)\delta e_{it} \right) \right) \right]^{(1-D_{it})(1-J_{D_{ijt}})} + (1 - \pi) \left( 1 - \Phi \left( \frac{\log(w_{ijt}) - \tau \log(w_{ijt}) + \kappa - (1/\pi)\delta e_{it}}{33} \right) \right) \right]^{(1-D_{it})(1-J_{D_{ijt}})}
\]
Figure 1: Summary of the Idea
Figure 2: Job Demotion Decisions

Figure 3: Efficiency Wage Premium and Probability of Monitoring
Table 1: Summary Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>13.3</td>
<td>2.42</td>
<td>0.0</td>
<td>20</td>
</tr>
<tr>
<td>Male</td>
<td>0.52</td>
<td>0.50</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>AFQT</td>
<td>41.2</td>
<td>28.7</td>
<td>1.0</td>
<td>99</td>
</tr>
<tr>
<td>Tenure</td>
<td>6.22</td>
<td>5.58</td>
<td>0.25</td>
<td>30.5</td>
</tr>
<tr>
<td>log(Wages)</td>
<td>7.17</td>
<td>0.59</td>
<td>5.7</td>
<td>9.9</td>
</tr>
<tr>
<td>Effort</td>
<td>2.29</td>
<td>1.13</td>
<td>1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>RiskyJob</td>
<td>0.07</td>
<td>0.25</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>JobDemotion</td>
<td>0.002</td>
<td>0.04</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Weight</td>
<td>179</td>
<td>41.5</td>
<td>75</td>
<td>600</td>
</tr>
<tr>
<td>West</td>
<td>0.19</td>
<td>0.39</td>
<td>0.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

1 Number of Observations = 11,427
2 Number of Individuals = 6,713

Table 2: Estimates in the Occupational Choice Equation

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(Wage)</td>
<td>-0.289**</td>
<td>0.098</td>
</tr>
<tr>
<td>Weight/100</td>
<td>0.267**</td>
<td>0.084</td>
</tr>
<tr>
<td>West</td>
<td>0.143**</td>
<td>0.042</td>
</tr>
<tr>
<td>$\rho$</td>
<td>-0.210**</td>
<td>0.083</td>
</tr>
</tbody>
</table>

Note: Dependent variable: RiskyJob. $\rho$ is the correlation coefficient between the error term in the wage equation and the error term in the occupational equation. Independent variables in the wage equation are included in the occupational choice equation. Results are obtained from jointly estimating the modified wage equation (11), the occupation choice equation (12), and the job demotion equation (13) by maximum likelihood.

** Statistically significant at 1%
## Table 3: Estimates in the Wage Equation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>5.422**</td>
<td>0.164</td>
</tr>
<tr>
<td>AFQT</td>
<td>0.005**</td>
<td>0.000</td>
</tr>
<tr>
<td>Age</td>
<td>0.045**</td>
<td>0.004</td>
</tr>
<tr>
<td>AgeSq/100</td>
<td>-0.125**</td>
<td>0.007</td>
</tr>
<tr>
<td>Education</td>
<td>0.069**</td>
<td>0.004</td>
</tr>
<tr>
<td>Male</td>
<td>0.227**</td>
<td>0.015</td>
</tr>
<tr>
<td>Tenure</td>
<td>0.019**</td>
<td>0.001</td>
</tr>
<tr>
<td>$\sigma_1$</td>
<td>0.459**</td>
<td>0.007</td>
</tr>
<tr>
<td>$\sigma_0$</td>
<td>0.496**</td>
<td>0.071</td>
</tr>
<tr>
<td>$\sigma_\xi$</td>
<td>0.115</td>
<td>0.728</td>
</tr>
</tbody>
</table>

Note: Dependent variable: log(Wage). $\sigma_j$ is the standard deviation of the error term, where $j = 0$ stands for an ordinary job and $j = 1$ for a risky job. $\sigma_\xi$ is the standard deviation of individual random effect. Results are obtained from jointly estimating the modified wage equation (11), the occupation choice equation (12), and the job demotion equation (13) by maximum likelihood.

** Statistically significant at 1%

## Table 4: Estimates in the Job Demotion Equation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Estimate</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta$</td>
<td>Parameter of effort</td>
<td>0.050**</td>
<td>0.010</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Parameter of risky jobs</td>
<td>0.012**</td>
<td>0.002</td>
</tr>
<tr>
<td>$\pi$</td>
<td>Probability of monitoring</td>
<td>0.421**</td>
<td>0.146</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Parameter of wage reduction</td>
<td>0.730**</td>
<td>0.042</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>Loss in utility from punishment</td>
<td>0.739**</td>
<td>0.295</td>
</tr>
</tbody>
</table>

Note: Dependent variable: JobDemotion. Results are obtained from jointly estimating the modified wage equation (11), the occupation choice equation (12), and the job demotion equation (13) by maximum likelihood.

** Statistically significant at 1%
Table 5: Decompositions of Total Wage Premium

<table>
<thead>
<tr>
<th></th>
<th>Reduced-form estimate</th>
<th>Structural estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Wage Premium</td>
<td>6.2%</td>
<td>6.6%</td>
</tr>
<tr>
<td>Compensating Differential</td>
<td>6.2%</td>
<td>2.8%</td>
</tr>
<tr>
<td>Efficiency Wage Premium</td>
<td>-</td>
<td>3.8%</td>
</tr>
</tbody>
</table>

Note: Reduced-form estimate is obtained from jointly estimating the wage equation (2) and the occupation choice equation (12) by maximum likelihood. Structural estimate is obtained from jointly estimating the modified wage equation (11), the occupation choice equation (12), and the job demotion equation (13) by maximum likelihood.

Table 6: Model Fit

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of Risky Jobs</td>
<td>6.71%</td>
<td>6.65%</td>
</tr>
<tr>
<td>Unconditional JD Rate</td>
<td>0.18%</td>
<td>0.19%</td>
</tr>
<tr>
<td>JD Rate on Risky Jobs</td>
<td>0.39%</td>
<td>0.30%</td>
</tr>
<tr>
<td>JD Rate on Non-Risky Jobs</td>
<td>0.17%</td>
<td>0.19%</td>
</tr>
</tbody>
</table>

Note: JD denotes job demotion