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Compensating Wage Differentials for Job Fatality and Injury Risk in Australia*

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This study explores whether compensating wage differentials (CWDs) are still found for Australian workers using data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey, and risk data from Safe Work Australia. Our study finds evidence of CWDs for the risk of workplace fatalities that are smaller in magnitude compared to the estimates previously reported in the 1990s for Australia. We find limited evidence of CWDs for the risk of workplace non-fatal injuries. Using panel data and a risk variable that varies by both the worker's industry and occupation of employment, we find that Australian workers who face the mean level of fatality risk receive a CWD of between 0.13% and 0.44% for a unit increase in risk, depending on the model specification. These estimates correspond to a value of statistical life of $9.7 million and $34.9 million.

I Introduction

The theory of compensating wage differentials (CWDs) postulates that in a competitive market, firms need to compensate workers for undesirable job characteristics such that the total monetary and non-monetary benefits are equalised across jobs. Researchers often use work-induced injuries and fatalities as undesirable job characteristics in the estimation of CWDs because it is assumed that the average worker will find the risk of injury or death always to be an unappealing characteristic of any job. Consequently, a continuously positive relationship between risk and wages is expected. In this sense, estimated CWDs should reflect the marginal worker's willingness to accept a riskier work environment.[1]

Hedonic wage regressions have served as the main econometric tool used by labour economists to gauge the size and significance of CWD payments for work-associated disamenities. Studies that find evidence of CWDs can compute value of statistical life (VSL) and value of statistical injury (VSI) estimates as they can be directly inferred from hedonic wage regressions. Such estimates have been used to inform policymakers of the relative costs and benefits associated with investments in workplace risk reduction (Kenkel, 2003; Viscusi & Aldy, 2003) and even to evaluate the mortality costs associated with war (Wallsten & Kosec, 2005; Bilmes & Stiglitz, 2006).

There are two aims of this study. The first is to assess whether CWDs for workplace fatality risk and injury (non-fatal) risk are evident in Australia using cross-sectional and panel data. The second is to contribute to the international literature by examining the sensitivity of estimates of CWDs to both different measures of risk and specifications of risk. To accomplish this the study makes use of recent waves of the Household, Income Labour Dynamics in Australia (HILDA) Survey to eliminate bias associated with time-invariant

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[1]The marginal worker is the worker who, in equilibrium, is indifferent between a 'safe' job and a 'risky' job at the CWD being offered for the 'risky' job.

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heterogeneity that Kniesner *et al.* (2012) have noted is crucial in reducing the variation of VSL estimates. To demonstrate the importance of this, two sets of CWD estimates are generated. One set treats the HILDA data as a pooled cross-section and the second set treats the data as panel data. In addition, we use both a single (industry or occupation) risk measure and a composite risk measure (varying by industry and occupation) to demonstrate that the magnitude and significance of CWD and corresponding VSL and VSI estimates are highly sensitive to the estimation technique and risk specification used. Finally, the importance of specifying risk as a non-linear variable rather than a linear variable is demonstrated.

The results presented in this paper show that CWD estimates from panel data are lower than those computed using pooled data, implying that previous Australian studies may have overestimated the return to job risk in Australia. We find little evidence of CWDs for non-fatal risk. In terms of model specification, the results indicate that the omission of quadratic risk terms in the previous Australian studies results in a model misspecification and that the bias associated with this misspecification, particularly in the context of pooled estimates, tends to be large. We also find that using the composite measure of fatal risk results in CWDs that are smaller in magnitude than those found using a single fatal risk measure in both pooled and panel specifications, but larger for non-fatal risk. We consider our estimates based on a fixed-effects model and the composite risk measure to be the most accurate estimate of CWDs for workplace fatality risks. There is evidence of significant union effects regardless of the model or risk variable used. In the case where panel data are used with a composite measure of risk, only union members are found to receive compensation for workplace fatalities and injuries.

The remainder of this paper proceeds as follows. Section II outlines the relevant CWD literature. Section III provides a description of the data and econometric methods used to construct the composite risk variable and estimate the models. Section IV presents the results and relevant discussion. Section V concludes.

II Relevant Literature

More than 20 years have passed since Kniesner and Leeth (1991) and Miller *et al.* (1997) explored CWDs for job risk in Australia. Both studies were limited to cross-sectional data and a relatively restricted sample of workers. Kniesner and Leeth (1991) used demographic data for manufacturing workers collected by the Australian Bureau of Statistics (ABS) in conjunction with manufacturing fatal and non-fatal risk data from the Industrial Accidents and Manufacturing Establishments Report published by each state to estimate CWDs for job risk. They determined that Australian manufacturing workers who were exposed to the mean fatality rate received a CWD of approximately 2.5%, but found no significant evidence of CWDs for non-fatal risk. The study by Miller *et al.* (1997) used fatality risk data from Safe Work Australia (the Australian government statutory agency that collects data on Australian workplace health and safety) and worker demographic data from the 1991 Australian Census of Population and Housing for male workers aged between 20 and 64 who were employed in the non-agricultural sector.[2] The estimates from their models implied that a worker who faced the mean industry fatality risk received a CWD of approximately 4.6% on average, compared to a worker in a zero-risk job. Their CWD estimate of 4.6% corresponded to a VSL, expressed in 1991 dollars, of around $19 million for an Australian worker.

Many CWD studies, including the two previous Australian studies, estimated earnings functions that have included the job risk variable only linearly (Kniesner & Leeth, 1991; Cousineau *et al.*, 1992; Leigh, 1995; Miller *et al.*, 1997; Arabsheibani & Marin, 2000; Madheswaran, 2007; Scotton, 2013). However, if the marginal worker in a high-risk job is less risk adverse than the marginal worker in a relatively low-risk job, the wage–risk profile for workers will be nonlinear. Some studies such as Olson (1981), Leeth and Ruser (2003) and more recently Guardado and Ziebarth (2019) have modelled fatal risk quadratically and found there to be significant concavity in their wage equations, implying that, for most levels of risk, the return to workplace

[2] Miller *et al.* (1997) note concern about the reliability of income reporting for workers in the agricultural sector and chose to exclude these workers from the sample. Upon investigation, the inclusion of agricultural workers reduced the magnitude (but not the significance) of CWDs for fatal risk under the industry risk measure by up to five times and increased the magnitude of the CWD estimate slightly for the occupational measure of risk.

fatal risk increases at a decreasing rate. Notably, Guardado and Ziebarth (2019) have also shown evidence of significant concavity in the earnings equations for non-fatal risk. Allowing for non-linearity of both fatal and non-fatal risk is thus important because ignoring any significant concavity (or convexity) would lead to biased CWD estimates, with the direction of bias depending upon the value of risk at which the CWD is evaluated (Olson, 1981).

The magnitude of CWD estimates for job risk has been shown to be highly dependent upon the classification of risk (either industry or occupation) that has been used (Dorman & Hagstrom, 1998; Viscusi & Aldy, 2003). To reduce the variability of estimates, a few studies such as Martinello and Meng (1992), Viscusi (2004), Kniesner *et al*. (2012) and Scotton (2013) have used a composite risk measure that accounts for both the worker's industry and occupation of employment to improve the precision with which the risk variable reflects the risk faced by workers in the sample. Estimates from studies that have used a composite measure of risk have tended to be lower than estimates from comparable single-risk studies. There has, however, been limited investigation of the impact on the magnitude of CWD estimates when replacing a single measure of risk with a composite measure of fatal risk for the same sample of workers. Notably, Viscusi (2004) presented CWD estimates from a single-industry measure of fatal risk and a composite measure of fatal risk with the same sample of workers. The composite measure of fatal risk returned CWD estimates that were smaller in magnitude than the estimates found when a single-industry fatal risk measure was used. This would suggest that CWDs that are estimated from fatal industry risk alone may include the effect of industry-specific factors that are positively correlated with risk, making the estimates biased upwards. Such bias would be mitigated when the risk measure varies across occupations as well as industries. Thus, if both industry and occupation risk are available, it would be ideal to construct and use a composite measure of risk for CWD estimation.

Many previous studies have investigated the impact of unions on CWDs for workplace risks, but no study has been done for Australia. Studies for other countries have found that unions strengthen the CWDs paid to members (Thaler & Rosen, 1976; Viscusi, 1980; Olson, 1981; Garen, 1988). The explanation for this is based on the greater bargaining power of unionists than of non-union members, and also on the strength of the 'collective voice' of unionists compared to non-union members that enables them to gather greater information about the true risks faced on the job (Freeman & Medoff, 1984). Consequently, CWD payments are higher to union members as they are more informed about the risks faced and can use union power to push for higher wages. There are a handful of studies, such as Marin and Psacharopoulos (1982) and Sandy *et al*. (2001), that have found the CWDs to union members were lower or not significantly different than the CWDs to non-members, perhaps because unions may push for a safer work environment rather than for compensation in the form of higher wages (Marin & Psacharopoulos, 1982).

III Data and Econometric Method

Worker and workplace data have been extracted from the HILDA Survey. Introduced in 2001, the HILDA Survey is answered by more than 17,000 Australians each year and collects a broad range of self-reported worker information such as income, health, education and family dynamics as well as information regarding respondents' working lives, such as years of labour market experience, industry and occupation of employment and the worker's union status. Using HILDA to explore the relationship between unions and CWDs in Australia is difficult because only individual-level data are available and these data only identify whether an individual worker is, or is not, a union member. Furthermore, under the Australia Human Rights Commission Act (1986) it is illegal to discriminate on the basis of trade union membership, and as such union negotiated wages and conditions at a workplace cannot be limited to only union members at the workplace and will flow onto non-union members. Consequently, the union impacts on CWDs for job risk that are found using HILDA data likely represent the lower bound of these impacts. It would be preferable to have enterprise- or workplace-level data about unionisation, but currently such information does not exist in Australia.

The surveys are longitudinal as respondents who complete one wave of the survey are followed up in subsequent periods. There are 20 waves of data available as of 2020, but only data from Waves 10–18 inclusive (2010–18) are used in this study.[3] We collect Consumer Price Index (CPI) data from the Australian Bureau of Statistics (ABS) to deflate the nominal wage series. An Australia-wide value for the CPI has been used and was calculated as the average CPI value for Australia over the four quarters of each year.[4]

The data on fatal and non-fatal risk were taken from Safe Work Australia, which publishes workplace health and safety and worker compensation data each year for Australia. The fatal risk rates were taken from Safe Work Australia's Fatality Statistics reports, which give the rates of death each year from workplace accidents. The reports draw on compensation claims and coroners' reports to determine legitimate worker fatalities. To be deemed a fatality, the worker must have died in Australia or Australian waters as the result of work activity or work exposure. The fatality rates are expressed per 100,000 workers.[5] Non-fatal (injury) data was taken from Safe Work Australia's Compensation Statistics reports. Like the Fatality Statistics reports, they are released annually, but unlike them, they cover the financial year period. Data from reports that cover the beginning of the year in question were used; so, for the year 2010, the financial year starting July 2009 and ending June 2010 was used. To be considered a non-fatal injury, the worker must have an accepted compensation claim which has resulted in an absence from work of at least one working week. Non-fatal risk rates are expressed per 1,000 workers.

There are two features of the Safe Work Australia fatality data which are important to note. Firstly, Safe Work Australia's calculation of the published fatality rates includes fatalities of bystanders. These are fatalities that occur as a direct consequence of another's work actions. Secondly, for some years, the fatality data included 'commuter deaths' in the calculation of the fatality rates. Commuter deaths are worker fatalities that occur as they travel to or from their workplace. The numbers of commuter deaths for each year are not reported by Safe Work Australia. The more recent Safe Work Australia publications (2012 onward) exclude commuter deaths.[6] Unfortunately, commuter deaths and bystander deaths cannot be separated from the yearly workplace risks, but given that wave dummies are included in all the specifications, we expect the impact of these fatalities on our CWD results to be minimal. Commuter injuries are excluded in Safe Work Australia's injury risk rates.

The risk rates are classified by industry and occupation separately. The industry categorisations follow the 2006 Australia and New Zealand Standard Industrial Classification system and are given by major industry (at the one-digit level). There are 19 industry classifications in total. Occupational categories are classified using the one-digit 2006 Australia and New Zealand Standard Classification of Occupational system. There are eight occupational categories.

To be included in the sample, respondents must be working for pay, and have income data available for each wave. Respondents must also have both an occupational and industry classification for each year and must not be studying full-time or be self-employed. Excluding the self-employed is a common practice when estimating CWDs for risk as the fatal risk faced by those who are self-employed is higher than for their counterparts who are not self-employed (Pegula, 2004). Further, self-employed workers are excluded from Safe Work Australia's calculation of industry and occupation injury risk rates. To be consistent with much of the prior research, only workers with a labour force status of full-time are included in the final sample. Workers who report a nominal hourly wage lower than the minimum wage for each period or who report a real hourly wage greater than $400 are also excluded.[7] The

[3] Prior to Wave 9, there was no differentiation between respondents who belonged to a trade union as opposed to an employee association. As firms have no legal obligation to engage in collective bargaining with employee associations, it is less likely that CWD payments for risk will emerge for workers who belong to this group. See Summerfield *et al*. (2019) for more details of the survey.

[4] CPI data sourced from ABS catalogue no. 6401.0.

[5] Safe Work Australia periodically updates the risk rates for previous years. The changes made to both risk rates are small. The rates used in this study were current as of 2018. We are confident that the impact of using more current rates would be minimal and would not alter the significance of the important results presented in this paper.

[6] The exclusion of commuter deaths does not lead to any discernible changes in the pattern or prevalence of fatal risk across industries or occupations.

[7] There were 1924 observations which reported a nominal hourly wage less than the minimum wage, and one instance of a worker reporting a real hourly wage more than $400 per hour. Workers who report a nominal hourly wage less than the minimum wage may have few skills desirable in the market, and thus may accept relatively high-risk jobs irrespective of the CWD paid.

final data set contains 51,256 observations on full-time workers across nine waves (years).

(i) Construction of the Composite Risk Variable

We construct a composite risk measure which varies by both the industry and occupation of each worker using the risk rates taken from the Safe Work Australia reports. The requirements for the risk rates are that each cell must represent the fatal risk rate per 100,000 workers (1,000 for non-fatal risk) and that the sum over all industries in each occupation, or the sum over all occupations in each industry, must match the risk rate for the corresponding occupation or industry.

To make the relevant calculations, it is assumed that the relative risks between different occupations are the same across industries. For example, the ratio of risk rates between clerical workers and labourers is assumed to be fixed for all industries. Thus, the risk rate for occupation k in industry j is estimated as

$$r_{kj} = K \times I_j \times \frac{O_k}{\sum_{k=1}^{K} O_k}, \quad \text{for } k = 1, \ldots, K(8); \text{ and } j = 1, \ldots, J(19) \qquad (1)$$

where r_{kj} is the fatal (non-fatal) risk rate per 100,000 (1,000) workers of occupation k in industry j, I_j is the marginal risk rate per 100,000 (1,000) workers in industry j, and O_k is the marginal risk rate per 100,000 (1,000) workers for occupation k. Multiplying by $K = 8$ ensures that the calculated risk represents rates per 100,000 (1,000) workers.[8] By keeping constant the relative risk between occupations across all industries or keeping constant the relative risk between industries across all occupations (the same outcome is achieved either way), unique risk rates for each industry/occupation combination can be computed.[9]

Figure 1 provides histograms for industry risk rates, occupational risk rates, and our composite risk rates for the entire sample. Apart from industry injury risk, the risk rates are skewed to the right, with higher rates of death and injury less prevalent than lower rates. The median level of fatality risk is 0.6 per 100,000 workers and 1 per 100,000 workers for industry and occupation, respectively. The mean industry fatality risk is 1.6 per 100,000 workers and the mean occupation fatality risk is 1.8 per 100,000 workers. The median and mean level of fatal risk for our combined measure is 1.4 per 100,000 workers and 2.2 per 100,000 workers, respectively. The composite fatality risk measure has a minimum value of zero and a maximum value of 73 per 100,000 workers. The 90th percentile of the industry, occupation and composite fatality risk rates are 3.5 per 100,000 workers, 4.5 per 100,000 workers and 4.5 per 100,000 workers, respectively. For non-fatal (injury) risk, the mean rates are 11.0, 9.8 and 9.9 per 1,000 workers, for industry risk, occupation risk and the composite risk measure, respectively. The composite non-fatal risk has a minimum value of 0.3 per 1,000 workers and a maximum value of 48.6 per 1,000 workers. The 90th percentile values for non-fatal industry risk, occupation risk and the composite risk measure are 17.7 per 1,000 workers, 24.1 per 1,000 workers and 27 per 1,000 workers, respectively.

The histogram for composite risk does not correctly illustrate the true degree of variation in the variable, especially within the range between 0 and 1, due to the large scale of the horizontal axis. An examination of the coefficient of variation indicates that the composite risk measure has the largest variation among the three alternative measures of fatality risk. The coefficient of variation for the composite fatality risk measure is 2.83, which is much larger than the 1.63 for industry risk and 1.24 for occupation risk. This is also the case for the injury risk measures. The

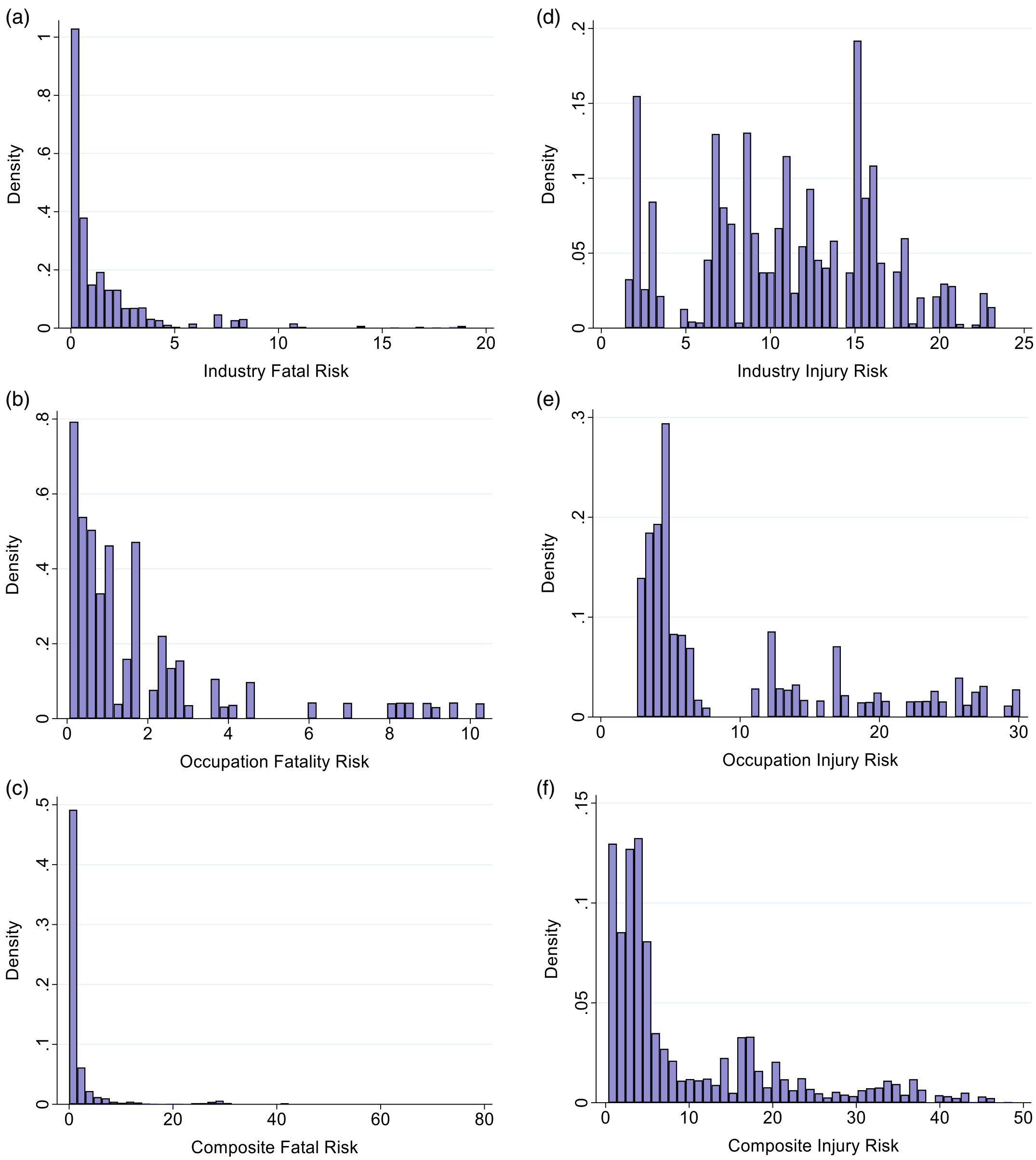
[8] Due to statistical rounding and the omission of minor occupational categories in the Safe Work Australia data, the risk rates calculated using the above method will require an adjustment. In other words, the total accidents across all 19 industries will not equal the total accident count over all eight occupations. This is problematic as all fatalities and injuries recorded in the industry need to be accounted for in the appropriate occupations. To overcome this issue, occupational risk rates have been scaled upward or downward depending on the relative difference between occupation and industry risk totals. That is, each occupational risk rate has been multiplied by a scalar factor $\lambda = \left(\sum_{j=1}^{J} I_j \times K\right) / \left(\sum_{k=1}^{K} O_k \times J\right)$.

[9] The constant relative risk assumption may be viewed as a necessary limitation of the current study, although the assumption sounds reasonable (it is plausible that all managers will experience less risk than labourers, regardless of which industry they work in). Although it is unlikely that the relative risk will be fixed in proportion across all industries, the assumption still allows for risk to vary, to a large degree, between industries and occupations.

FIGURE 1
Histograms of the Alternative Measures of Fatality and Injury Risk. [Color figure can be viewed at wileyonlinelibrary.com]

Industry (a), occupation (b), and composite (c) fatal workplace risk per 100,000 workers.

Industry (d), occupation (e), and composite (f) non-fatal (injury) workplace risk per 1,000 workers.



composite injury risk measure has much larger variation than the other two measures, with its coefficient of variation (1.09) being much larger than those for industry risk (0.48) and occupation risk (0.82). The higher variation in composite risk, which is achieved through the combination of two sets of information, is expected improve the efficiency of our CWD estimates.

(ii) Econometric Model

The following model is estimated to determine the existence of CWDs for job risk:

$$w_{it} = \beta_1 Risk_{it} + \beta_2 Risk_{it}^2 + \beta_3 (Risk_{it} \times U_{it}) + \beta_4 (Risk_{it}^2 \times U_{it}) + X_{it}'\beta_5 + \alpha_i + \mu_{it} \quad (2)$$

where w_{it} is the log of the respondent's hourly wage and X_{it} is a vector of worker and workplace characteristics that includes work experience, work experience squared, occupation tenure, job tenure, six dummies for workplace size, a dummy for public sector, two dummies for employment contract type, a dummy for worker union status, four dummies for education, a dummy for marital status, two dummies for country of birth, two dummies for dependent children, eight dummies for waves, and 12 dummies for location. The location dummy controls are useful in capturing any differences in worker compensation benefits between states and territories.[10] The wave dummies, which control for time effects, are expected to alleviate the impact of Safe Work Australia's exclusion of commuter deaths from the fatality reports from 2012 onwards. The unobservable individual-specific heterogeneity, represented by α_i, is treated as a part of the random error (pooled estimation) or individual-specific intercepts (fixed-effects estimation). The term μ_{it} is the idiosyncratic error term.

The term $Risk_{it}$ is job fatality or injury risk, which varies by the worker's industry (industry risk), occupation (occupation risk) or industry–occupation (composite risk), depending on the model under consideration. Each fatality risk variable is measured per 100,000 workers, while each injury risk variable is measured per 1,000 workers. The CWDs are identified by the variation in the corresponding risk variable. For the fixed-effects models, the contribution of the variation in risk across industry or occupation towards the identification of risk premium is relatively small because of strong multicollinearity between industry or occupation risk and the time-invariant heterogeneity terms. The main source of identifying variation is instead changes in risk over time where the ratios between industries or between occupations are not fixed. The remaining part of identifying variation comes from workers who switch industry or occupation during the sample period. Out of 51,256 worker–wave observations, there were 6,407 industry changes (12.5%) and 7,036 occupation changes (13.7%). The risk variables are centred at their sample mean values to allow for more direct and meaningful interpretations of model coefficients. Interaction terms between risk, risk squared, and the dummy variable for worker union membership, U_{it}, are included to capture union influence in the size of CWDs for workplace risk.

IV Results and Discussion

(i) Single-Risk Pooled Estimates

Table 1 displays our CWD estimates for fatal and non-fatal risk using pooled data. Model (i) is the most basic model including only industry fatality risk along with occupational dummies and the worker and workplace demographic information contained in the vector $\boldsymbol{X}$.[11] We consider this model to be the most like that used by Kniesner and Leeth (1991) and Miller *et al.* (1997); however, we do not find a significant CWD for industry-specific fatal workplace risk.We deviate from both previous Australian studies in model (ii) by including the square of the industry fatal risk term to capture nonlinearity in the risk–earnings profile which other studies have been significant (Olson, 1981; Martinello & Meng, 1992; Guardado & Ziebarth, 2019). The quadratic risk term has the expected negative sign and is highly significant, indicating concavity in the log-wage–risk relationship. The wage–risk profile peaks at an industry risk rate of 7.27 per

[10] Although workers' compensation benefits have been found to reduce the CWD for workplace fatalities (Kniesner & Leeth, 1991), we exclude them from our model. Because worker compensation benefits for fatalities are for the most part fixed, the fixed-effects model should net out their impact. However, similarly to Kniesner *et al.* (2012), we use location dummy variables to control for differences in workers' compensation benefits between states and territories in Australia.

[11] Industry-specific fatal risk is used for the basic models because it is less likely to contain measurement error compared to the occupational risk measure for our worker-reported data (Bound *et al.*, 2001).

TABLE 1
Ordinary Least-squares Estimates of CWDs for Industry and Occupation Risk with the Inclusion of a Range of Controls

	Fatal risk			Non-fatal risk		
Pooled models	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Industry Risk	0.0058 (0.0052)	0.0353*** (0.0092)	0.0244** (0.0110)	0.0009 (0.0025)	0.0013 (0.0024)	0.0014 (0.0031)
Industry Risk Sq.	x	−0.0031*** (0.0007)	−0.0022*** (0.0007)	x	0.0008** (0.0004)	0.0011** (0.0005)
Occupation Risk	x	x	0.0249* (0.0135)	x	x	−0.0055* (0.0030)
Occupation Risk Sq.	x	x	−0.0057*** (0.0022)	x	x	−0.0001 (0.0002)
Union × Ind. Risk	x	x	0.0392*** (0.0110)	x	x	0.0072** (0.0032)
Union × Occ. Risk	x	x	−0.0044 (0.0111)	x	x	0.0079** (0.0031)
Union × Ind. Risk Sq.	x	x	−0.0048*** (0.0013)	x	x	−0.0011*** (0.0004)
Union × Occ. Risk Sq.	x	x	0.0019 (0.0017)	x	x	−0.0003 (0.0002)
Occupation Controls	Y	Y	N	Y	Y	N
Industry VSL ($ million)	N/A	267.1	182.2	–	–	–
Union industry VSL ($ million)	–	–	503.3	–	–	–
Industry VSI ($ thousand)	–	–	–	N/A	95.7	108.1
Union industry VSI ($ thousand)	–	–	–	–	–	680.5
$\overline{R}^2$	0.37	0.38	0.34	0.37	0.37	0.34

Note: The above results are from the specified model with dependent variable being the natural logarithm of real hourly wages. Controls are added into each model as indicated by the table. Cells with an x indicate the corresponding control is not included, whereas Y indicates the control is included. Sq. indicates the square of risk. The sample size for all specifications is 51,256. The standard errors reported in parentheses are robust standard errors that are clustered at the industry–occupation level. ***p < 0.01, **p < 0.05, and *p < 0.1. Fatal industry risk and fatal occupational risk are measured per 100,000 workers. Industry VSL and Industry VSI are the VSL and VSI values for non-union members for models (iii) and (vi), respectively. Full estimation results are available upon request.

100,000 workers, implying that more than 95.6% of workers receive a positive CWD.[12] Furthermore, including the quadratic term results in a large increase in the coefficient of industry risk variable as the CWD increases from zero to 3.53%.[13] The reason for this significant difference between the two estimates is that the distribution of risk is highly skewed to the right. The above estimate of the peak of the wage–risk profile (7.27) means that the CWD is negative for more than 4% of workers. The negative CWD for these workers would have suppressed the size of the risk coefficient in the linear model (i), while the relatively lower average level of risk at which the quadratic risk function is evaluated would have a steeper slope. Given the high statistical significance of the quadratic risk term and the likely bias resulting from its omission, we routinely include it in the remaining models.

Model (iii) in Table 1 shows strong evidence that unions strengthen CWDs for workers, as the CWD for union members increases by an additional 3.92% for a unit increase in industry fatality risk from the mean level. The distinction of CWDs between union and non-union groups is important to note, given that approximately one-quarter of Australian workers in our sample belong to a union. These estimates imply that

[12] The derivative of log wage with respect to risk is $\beta_1 + 2\beta_2 Risk$, where *Risk* is demeaned risk. The wage–risk profile peaks when this equals zero, or given the estimates, when risk is (0.0353/0.0062) + 1.575121 ≈ 7.27.

[13] Calculated as $\beta_1 + 2\beta_2 Risk$. Because risk is measured as deviations from the mean value, the average CWD at the sample mean level of risk is simply β_1.

TABLE 2
Fixed-effects Estimates of CWDs for Industry and Occupation Risk with the Inclusion of a Range of Controls

	Fatal risk			Non-fatal risk		
Panel models	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Ind. Risk	0.0048***	0.0047***	0.0026*	0.0006	0.0005	0.0004
	(0.0015)	(0.0016)	(0.0015)	(0.0004)	(0.0004)	(0.0004)
Ind. Risk Sq.	−0.0004**	−0.0004**	−0.0002	0.0000	0.0000	0.0000
	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
Occ. Risk	x	0.0002	0.0001	x	−0.0015***	−0.0018***
		(0.0017)	(0.0017)		(0.0005)	(0.0005)
Occ. Risk Sq.	x	0.0001	0.0001	x	0.0001***	0.0001***
		(0.0002)	(0.0003)		(0.0000)	(0.0000)
Union × Ind. Risk	x	x	0.0150***	x	x	0.0009
			(0.0030)			(0.0008)
Union × Occ. Risk	x	x	−0.0005	x	x	0.0013
			(0.0027)			(0.0008)
Union × Ind. Risk Sq.	x	x	−0.0015***	x	x	−0.0001
			(0.0003)			(0.0001)
Union × Occ. Risk Sq.	x	x	0.0001	x	x	−0.0001
			(0.0005)			(0.0001)
Industry VSL ($ million)	36.1	35.3	19.5	–	–	–
Union industry VSL ($ million)	–	–	139.6	–	–	–
Industry VSI ($ thousand)	–	–	–	N/A	N/A	N/A
Union industry VSI ($ thousand)	–	–	–	–	–	N/A
$\overline{R}^2$	0.22	0.22	0.22	0.22	0.22	0.22

Note: The above results are from the specified model with dependent variable being the natural logarithm of real hourly wages. Controls are added into each model as indicated by the table. Cells with an x indicate the corresponding control is not included. Sq. indicates the square of risk. The sample size for all specifications is 51,256. The standard errors reported in parentheses are robust standard errors that are clustered at the industry–occupation level. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. Fatal industry risk and fatal occupational risk are measured per 100,000 workers. Industry VSL and Industry VSI are the VSL and VSI values for non-union members for models (iii) and (vi), respectively. Full estimation results are available upon request.

the large CWD value of 6.36% is only received by a relatively small proportion of workers, while a large majority of the Australian workforce receive a much smaller CWD of 2.44% for a unit increase in fatal risk. The implied VSL for a non-union member is $182.2 million, whereas the implied VSL for union members is much larger at $503.3 million.[14]

[14] The VSL figures are computed as $(\partial \ln w/\partial Risk) \times 100{,}000 \times \overline{h} \times \overline{w}$, where $\overline{w}$ is the average real hourly wage and $\overline{h}$ is the average number of hours worked over the course of the year, and 100,000 represents the fact that fatal risk is expressed per 100,000 workers. For VSI calculations, 100,000 is replaced by 1,000. For the sample, the average annual earnings for union and non-union members are approximately $79.1 thousand and $74.7 thousand, respectively. When the model requires no distinction between union and non-union, the annual earnings used is the entire sample mean, which is approximately $75.7 thousand.

There is no evidence of CWDs for non-fatal risk when the pooled models are estimated, except for unionised workers. The coefficient for industry risk that is centred at the sample mean risk level is insignificantly different from zero in all the three models. The coefficient for the quadratic term is significant in models (v) and (vi), but their magnitudes are very small, meaning that the wage–risk profile is almost flat. However, the results from model (vi) show that there exist significant CWDs for injury risk for union members, indicating the existence of significant union influence in the CWDs for injury risk.

(ii) Single-Risk Panel Estimates

We next utilise the longitudinal dimension of our data and re-estimate CWDs using a fixed-effects model (the use of a random effects is strongly rejected by the Hausman test) to control for time-invariant heterogeneity. We exclude models that include occupational or industry

TABLE 3
Pooled Estimates of CWDs for Composite Risk with the Inclusion of a Range of Controls

	Fatal risk			Non-fatal risk		
Pooled models	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Risk	0.0005 (0.0020)	0.0089 (0.0056)	0.0052 (0.0051)	0.0021 (0.0028)	0.0042 (0.0035)	0.0017 (0.0032)
Risk Sq.	x	−0.0002* (0.0001)	−0.0001 (0.0001)	x	−0.0001 (0.0001)	−0.0000 (0.0001)
Union × Risk	x	x	0.0223*** (0.0062)	x	x	0.0131*** (0.0022)
Union × Risk Sq.	x	x	−0.0007*** (0.0002)	x	x	−0.0004*** (0.0001)
VSL ($ million)	N/A	N/A	N/A	–	–	–
Union VSL ($ million)	–	–	218.2	–	–	–
VSI ($ thousand)	–	–	–	N/A	N/A	N/A
Union VSI ($ thousand)	–	–	–	–	–	1175.5
$\overline{R}^2$	0.37	0.37	0.38	0.38	0.37	0.38

Note: The above results are from the specified model with dependent variable being the natural logarithm of real hourly wages. Controls are added into each model as indicated by the table. Cells with an x indicate the corresponding control is not included. Sq. indicates the square of risk. The sample size for all specifications is 51,256. The standard errors reported in parentheses are robust standard errors that are clustered at the industry–occupation level. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. Fatal industry risk and fatal occupational risk are measured per 100,000 workers. VSL and VSI are the figures for non-union members in models (iii) and (vi), respectively. Full estimation results are available upon request.

TABLE 4
Fixed-effects Estimates of CWDs for Composite Risk with the Inclusion of a Range of Controls

	Fatal risk			Non-fatal risk		
Panel models	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Risk	−0.0001 (0.0003)	0.0013* (0.0007)	0.0005 (0.0007)	0.0001 (0.0002)	−0.0005 (0.0004)	−0.0008** (0.0004)
Risk Sq.	x	−0.0000** (0.0000)	−0.0000 (0.0000)	x	0.0000* (0.0000)	0.0000** (0.0000)
Union × Risk	x	x	0.0039*** (0.0014)	x	x	0.0017*** (0.0006)
Union × Risk Sq.	x	x	−0.0001** (0.0000)	x	x	−0.0000* (0.0000)
VSL ($ million)	N/A	9.7	N/A	–	–	–
Union VSL ($ million)	–	–	34.9	–	–	–
VSI ($ thousand)	–	–	–	N/A	N/A	N/A
Union VSI ($ thousand)	–	–	–	–	–	65.3
$\overline{R}^2$	0.22	0.22	0.22	0.22	0.22	0.22

Note: The above results are from the specified model with dependent variable being the natural logarithm of real hourly wages. Controls are added into each model as indicated by the table. Cells with an x indicate the corresponding control is not included. Sq. indicates the square of risk. The sample size for all specifications is 51,256. The standard errors reported in parentheses are robust standard errors that are clustered at the industry–occupation level. ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. Fatal industry risk and fatal occupational risk are measured per 100,000 workers. VSL and VSI are the figures for non-union members in models (iii) and (vi), respectively. Full estimation results are available upon request.

dummies because of the strong multicollinearity with the occupational and industry fixed effects. Our fixed-effects estimation results are presented in Table 2.

The results from model (i) indicate that the CWD for a unit increase in fatal risk is approximately 0.48%. The CWD corresponds to a VSL of $36.1 million for an Australian worker. Including the occupational risk rate has almost no impact on the CWD estimates for industry fatality risk, with the estimated CWD marginally reduced from 0.48% to 0.47%. This result suggests that once time-invariant heterogeneity is controlled for, the strategy used to control for worker occupation matters little. Consistent with pooled estimates, the largest CWD estimate is found after allowing for the impact of unions. We find that unions increase the compensation that workers receive by 1.5%, which results in a CWD for union members of 1.76% on average. Workers who are not union members receive a much lower level of compensation for increases in industry fatality risk, at only 0.26% on average. Our estimates correspond to a VSL of approximately $19.5 million for non-union members and $139.6 million for union members.

As was the case for the pooled models, our results show no evidence of CWDs for non-fatal risk in any of the fixed effects models. These results are robust to the inclusion of occupation risk in model (v) and the inclusion of the union–risk interaction terms in model (vi). It may be the case that compulsory workers' compensation in Australia adequately compensates workers in the event of workplace injuries, thus eliminating the need for ex-ante compensation in the form of injury risk CWDs (Purse, 2004).

(iii) Composite Risk Pooled and Panel Estimates

We extend the Australian literature and contribute to the international literature on CWDs by estimating our models using a risk measure that varies by both worker industry and occupation. While the panel results indicate that the inclusion of occupational risk matters little, we support the use of a composite risk measure because it will reflect with greater accuracy the fatality and non-fatality risk faced by each worker (and thus increase the accuracy of CWDs and corresponding VSL and VSI estimates) compared to models that use a single risk measure. Table 3 presents pooled estimates using our composite measure of fatal and non-fatal risk. Just like Table 1, the pooled models contain occupational dummy controls to control for any occupational differentials.

Models (i) and (ii) of Table 3 show that failing to consider the nonlinear relationship between the composite measure of fatal risk and earnings is a model misspecification as the linear risk term is statistically insignificant while the square of risk is statistically significant. We continue to find that unions members earn more than non-union members for increases in workplace fatal risk. Specifically, union members receive a 2.2% increase in earnings for a unit increase in fatal risk compared to non-union members. The corresponding VSL for union members is $218.2 million, which is substantially lower than the estimate computed with separate risk variables. Like the results in Table 1, there is little evidence of CWDs for non-fatal risk when the composite non-fatal risk measure is used. The only significant CWD is found when accounting for union impacts, which results in a CWD of 1.48% for a unit increase in non-fatal risk. The corresponding VSI for a union is approximately $1.18 million.

Finally, we investigate the impact of using a composite measure of risk in fixed-effects models. We view the estimates presented in Table 4 as the most informative as the composite measure of risk and fixed effects should produce estimates which contain the least amount of bias. The estimates in models (i) and (ii) of Table 4 show that failing to account for the nonlinear relationship between fatal risk and earnings is a model misspecification consistent with our earlier findings. Once the nonlinearity is accounted for, the CWD and corresponding VSL for fatal risk are 0.13% and $9.7 million respectively. Including union interaction terms increases the size of the estimated CWD for union members by 0.39% but results in no significant CWD for non-union members.

There is little evidence of CWDs for injury risk using fixed effects and a composite measure of risk as we find no evidence of non-fatal CWDs when injury risk is modelled linearly or quadratically. Only union members are found to have a significant and correctly signed CWD for non-fatal risk. The results from model (vi) indicate that union members receive a CWD of 0.09% for a unit increase in injury risk from the mean level which corresponds to a VSI of $65,300. This result is driven by the inclusion of the interaction term between union and non-fatal risk without which the estimated VSI would be negative.

(iv) Discussion

Overall, this study finds strong evidence of CWDs for fatality risk but less compelling evidence of CWDs for non-fatal risk. For workplace fatality risk, we find that including the square of the fatal risk variable increases the CWD estimate for most pooled and panel models. The negative sign on the squared fatal risk term across all fatal risk models indicates concavity in the wage–risk profile for Australian workers, and the large degree of statistical significance of the squared term indicates that its absence from the model is a misspecification. Considering our results, we find the bias associated with this misspecification, particularly in the context of cross-sectional estimates, to be large.

When the fixed-effects models are estimated, the CWD for a unit increase in fatal risk is consistently smaller than corresponding pooled estimates, which highlights importance of controlling for unobserved heterogeneity as noted by Kniesner *et al*. (2012). In contrast to the panel study by Guardado and Ziebarth (2019), the fixed-effects models do not return statistically significant CWDs for non-fatal risk at all but for unionised workers.

Consistent with overseas literature such as Thaler and Rosen (1976), Viscusi (1980), Olson (1981), and Garen (1988), there is evidence that unions command higher CWDs for both fatal and non-fatal risk across most models and specifications, adding Australia to the list of countries where positive union effects are found. In our most preferred models, we find that unions provide additional earnings of 0.39% for a unit increase in fatal risk and 0.17% for a unit increase in non-fatal risk. We view the distinction between CWDs for union members and non-members as important, given that a small percentage of the Australian workforce indicate that they are union members. The larger union effects for fatal risk may be because compulsory workers' compensation is less adequate in compensating workers for fatalities than it is in compensating workers for injuries and thus requiring the power of unions to command an appropriate level of compensation for the risk faced.

Using a composite measure of fatal risk results in smaller CWD estimates for both the pooled and panel specifications. The magnitude of the fatal risk CWD results in Tables 3 and 4 are like those found in comparable overseas studies (Viscusi, 2004; Scotton, 2013). In the pooled specification, the CWD and corresponding VSL is reduced by more than half when the composite risk measure is used. The estimated fatal risk CWDs are smallest when the composite measure of risk is used in conjunction with the panel specification. We view the results generated from these models as an indication that it is beneficial to construct and use a composite measure of risk to assess workplace risk CWDs when both industry and occupational risk data are available. The estimates imply a VSL of between $9.8 million and $34.9 million for Australian workers. These values are significantly larger than the VSL of $5.1 million reported by the Australian government (Office of Best Practice and Regulation (OBPR), 2021) suggesting that policy-makers may be underestimating the true benefits of workplace risk reductions. The composite measure of injury risk leads us to find a statistically significant CWD and corresponding VSI of 0.09% and $65,300 when using panel data, although this is attributable to union members only.

While our results indicate that there are still significant CWDs for fatal workplace risk in Australia, we do note the following limitations of our study. Firstly, we do not include both fatal and non-fatal risk together in the same model. Ideally, our models would contain controls for both fatal and non-fatal risks because the latter as well as the former type of risk would affect the CWD while the two types of risk are correlated.[15] Hence, the exclusion of injury risk from the model will mean that the fatal risk coefficients could contain a degree of bias. However, the strong collinearity between fatal and non-fatal risk deterred us from including both in the same model. Secondly, the possible endogeneity of risk is not considered in this study either. It is plausible that a worker's preference for job risk declines as their earnings increase (Garen, 1988). In such a case, employing an instrumental variable method for the estimation of the models, after assuming a behavioural model for job choices, would be more appropriate, although our panel models do control for heterogeneity and hence associated endogeneity to some degree. Formally modelling the joint endogeneity between preference for workplace risk and wages for Australia is beyond the scope of this study and we leave this for future research.

[15] The correlations between fatal and non-fatal risk for industry, occupation and the composite measure are 0.55, 0.73 and 0.61, respectively.

V Conclusion

This paper extends the Australian literature on CWDs by estimating pooled and panel models for both fatal and non-fatal risk and contributes to the international literature by demonstrating the sensitivity of workplace risk CWDs to different model specifications, including the use a composite measure of risk which varies by worker industry and occupation.

We find that pooled estimates of CWDs that are produced using a single-dimensional industry measure of risk are not as sensitive to the range of occupational controls included as they are to quadratic risk terms. The most likely reason for this is that the linear risk models are a misspecification of the earnings–risk trade-offs, and when the concavity is ignored, the estimated CWDs derived from singular slope coefficients are misleading. The use of panel data results in sizeable reductions in fatal risk CWDs as fixed effects alleviate biases associated with unobserved heterogeneity. These reductions are robust to the specification of the earnings model. The composite measure results in larger non-fatal risk CWDs for unionised workers than corresponding single-risk estimates.

There is strong evidence that unions in Australia are successful in commanding compensation for members who face fatal and non-fatal risk in the workplace. Specifically, fixed effects estimates using a composite measure of risk results in a CWD of 0.44% for a unit (1/100,000) increase in fatal risk which pertains only to union members. For Australian workers who belong to a union, this estimate implies a VSL of $34.9 million. Ignoring union coverage results in a VSL of $9.7 million. These estimates are both well above the Australian government VSL estimate of $5.1 million (OBPR, 2021), suggesting that more work should be done to narrow the range of VSL estimates. This should be a priority for policymakers if such estimates are used to evaluate the costs and benefits of workplace safety legislation. The average VSI of an Australian worker is $65,300, which is within in the range of VSI estimates produced by the Australian government (OBPR, 2021), although our estimate pertains to union members only.

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