# Risk premium, climate premium and pollution premium in Taiwan's labor market

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## Abstract

We study the tradeoff between wage, risk, climate and air pollution in Taiwan using the 1999-2014 Panel Study of Family Dynamics (PSDF) survey data of wage, worker characteristics, and job characteristics, in addition to official data sources of annual job fatality rates, climate, and air quality. By adopting the fixed effect model to relieve the biases caused by the missing time-invariant unobservable variables and risk endogeneity problems, we find positive and significant premiums for risk, climate and pollution disamenities in Taiwan. Workers in Taiwan are compensated for work-related fatal risks, especially for skilled and unskilled workers, but not for managerial workers. Workers are paid more for working in places with higher average temperatures in July or lower averages in January. Workers receive higher wages for working in places with worse air quality.

Keywords: compensating wage differentials, hedonic wage model, risk premium, climate premium, pollution premium

## Introduction

The value of human life has long been a focus of researches in variant disciplines, like philosophy, ethics, and economics. Based on the social norms that human lives are invaluable and irreplaceable, massive media and movies have implicitly transmitted the message that any tradeoffs between life and money should be despised. However, if we observe our daily life, we would find many tradeoffs between money and risk. For instance, everyone who drives a car knows that many people died in traffic accidents every day, and still rely on a car for its convenience. From the view of economics, apparently, the time saved (and the cost saved) weights more than the increased risk from driving for those who choose to drive, and this is one example of risk-money tradeoffs and reveals people's preference over the combination of money and risk, and it has nothing to do with ethics.

Typically, there are two approaches to study the risk-money tradeoff. One is the stated-preference approach. The other is the revealed preference approach. In the stated approach, people are asked how much they are willing to give up for a small risk reduction, like 1/1,000,000. The stated preference approach is subjected to two doubts. One is that people have trouble understanding the small risk reduction. The other is the hypothetical bias since they are not required to pay what they said they would like to pay.

Hedonic wage method is the most widely adopted revealed preference approach and is considered as the most reliable method to study the risk-money tradeoff. It

utilizes information in the labor market. When an individual chooses his job, he chooses his wage and the workplace risk at the same time. So once other personal characteristics (like education, work experience, gender et al.) and job characteristics (like the scale of the firm et al.) are controlled, we can study the relationship of wage and job fatality rate.

Rosen (1974) first come up with the hedonic price model and suggests that the price of a good is the sum of the prices of all the attributes of this good, and consumers' willingness to pay for one attribute is the implicit price of this attribute. Thaler and Rosen (1976) applied this theory to the labor market and developed the hedonic wage model. They applied the hedonic wage model and estimated risk premiums, i.e., the implicit prices of safety, which is the tradeoff between wage and risk when the fatality rate changes by a small amount. Using the risk premium estimated we can calculate the value of a statistical life if the fatality rate decreases from 1 to 0. Afterward, there are a vast of studies on risk premium and VSL using the hedonic wage theory.

However, the standard hedonic wage model has several drawbacks, the risk endogeneity problem and the missing variables are the most important ones.

## Risk endogeneity

The endogeneity problem arises because of two reasons. One is the self-selection bias. Since safety is a normal good, the demand for safety increases as wealth increases, and rich people are less willing to risk their life for high wage income, as Viscusi (1978) points out that, the wealth effect would affect people's job risk choice through the error term, and make the estimation biased. The other comes from the missing unobservable variables. Brown (1980) notice that the important but missing unobservable variables, for example, ability, could make the estimation biased. Garen (1988) also believes that some unobserved personal characteristics like cool-headedness could cause the risk premium to differ in different risk levels and makes the 2SLS/3SLS inconsistent. To solve this problem, he suggests using a weighted 2SLS approach, and he proves this two-step approach (Garen's approach) could give unbiased and consistent estimation results (Garen, 1984).

With the accessibility of panel data, fixed effect model (FE) has been given more credited since it has distinct advantages in dealing with missing time-invariant unobservable variables, thus greatly relieve the endogeneity problem caused by it.

Brown (1980), together with Hintermann et al. (2010) and Kniesner et al. (2012) are, as far as we know, the only three hedonic wage studies using panel data analysis, with a similar method, their conclusions are far different from each. Brown (1980) utilizes the National Longitudinal Survey Young Men's sample from 1966-1973. He believes that one's ability, which is unobservable and cannot be explained by education, has an essential effect on one's wage income. He adopted the FE model to solve the missing variable problem. Brown also adds several worker characters like marital status and health status, and job attributes like whether it is stressful or exhausting to the right side of wage equation and finds evidence of positive risk premium.

Hintermann et al. (2010) adopt the British Household Panel Survey (BHPS) 1991-2003 data as the source of worker characteristics and job characteristics, and the risk data is from UK's health and safety executive (HSE). They apply several different methods to deal with the risk endogeneity problem, like the fixed effect model, 2SLS, and 2SLS with a first difference. They also study the

subsample of blue-collar workers. They find that the compensating wage differentials exist only among blue-collar workers.

Kniesner et al. (2012) modified the hedonic wage model to the first-difference version and the double-differenced version to address the measurement error problem. They also estimated the 2SLS estimation of the double-differenced version of the hedonic wage model to control for latent heterogeneity and endogeneity, resulting in a narrower range of the estimated VSL of $4 million to $10 million.

## The missing variables problem

At the same time when the FE model becomes more attractive, some factors other than worker characteristics and job characteristics are found to influence the wage. For example, Brown (1980) found that workers' perceived job attributes like stress, and labor intensity are unwanted attributes and workers are thus paid higher to keep them in these jobs. Roback (1982) studied the hedonic wage function with the 1973 US Census Bureau data and found that total crime rate, particulate level, population size and growth, and the number of heating degree days, total snowfall, and the number of cloudy days always have a positive influence on wage and are net disamenities. Workers receive a real premium for working in these unpleasant conditions. While the number of clear days is amenable. At the same time, the unemployment rate does not influence wages. Maddiso and Bigano (2003) utilize the 1991-1995 wage data in Italy to calculate the implicit price of environmental attributes with hedonic wage model and hedonic price mode. They find that higher temperature in July and higher precipitation in winter are disamenities. Rehdanz (2006) utilizes the house price and wage in 1993 and the climate data during 1961-1990 in the UK, by applying the hedonic price model and hedonic wage model. He found that average temperature in January is an amenity, and household's willingness to pay for one centigrade increase in January is 207-344 pounds on average; While precipitation is an unwanted attribute, and household is willing to pay 4 to 9 pounds to reduce rainfall by one millimeter.

Some recent researches find similar results. Koirala and Bohara (2014) study the willingness to pay for climate amenity with hedonic wage method and hedonic price method. They found that higher January temperatures are an amenity, and households are willing to pay approximately US$5.90 ($2004) per month for a 1°F increase in the January temperature; While higher July temperatures and precipitation are both disamenities. Chen (2016) found that, in Taiwan, the correlation of wage and average January temperature is negative, meaning that higher average January temperatures are an amenity, and labor supply in areas with this amenity increases, leading to a decrease in wages. At the same time, the average July temperature and pollution are disamenities. Jobs in areas with these disamenities are paid higher.

Huang, X. & Lanz, B. (2018) estimate an equilibrium relationship of wages, house prices and the air pollution with hedonic wage model and hedonic price model with data in 288 Chinese cities in 2011. They adopt a quasi-experimental design to account for the endogeneity of air pollution. They find that a one percent rise of PM10 concentration would lead to a 0.7 percent reduction in house price and a 0.5 percent increase in wage. They find that, on average, people's willingness to pay for a unit reduction of PM 10 concentration is 261CNY (≈ USD 40.5).

## Researches in Taiwan

Hsueh and Wang (1987) utilize the 1984 labor survey in Taiwan and adopt the traditional hedonic wage model. They found that the VSL in Taiwan is between 1200 to 3400 million TWD. Liu, Hammitt and Liu (1997) adopt the Heckman two-stage model to correct for selection bias to study the wage-risk tradeoff in Taiwan during 1982-1986. The VSL they get is 135-589 thousand dollars (1990 dollar). Liu (2011) conducted another OLS regression with labor data of 2002-2006 in Taiwan, and found one percent of risk increase corresponds to a wage increase of 2.6%-4.7%, from which the VSL is calculated to be between 93million to 168 million TWD (2006 )。

From the literature reviewed above, we find that in Taiwan, the risk endogeneity problem is not well considered, and no panel data research has been done yet. What is more, in the previous VSL research in Taiwan, the effect of workplace amenities to wages are not considered.

In this paper, we study the job risk premium in Taiwan under the hedonic wage model with panel data. We are going to deal with the risk endogeneity problem with the fixed model. In addition to the risk premium, we are interested in estimating how climate amenities and pollution affect wages.

The labor data and job characteristics data used are from the Panel Survey of Family Dynamics conducted by Academia Sinica during 1999-2014. Job fatality rate comes from the Bureau of Labor Insurance, Ministry of Labor (1999-2014), and the climate data of 1981-2005 and pollution data of 2008-2011 are calculated by Research Center for Environmental Changes, Academia Sinica.

Our paper is organized as follows. Data are described in section 2. Section 3 introduces the hedonic wage theory and the fixed effect model we are going to apply. In section 4 we conducted several estimations with the full sample and the subsample of high skilled workers and low skilled workers, using both OLS and FE model. We also calculated the VSL in section 4. Section 5 concludes.

## Data

Three data sets are needed in our research, i.e., survey data, job fatality rate, and climate amenity data.

The Panel Survey of Family Dynamics (PSFD) is conducted in Taiwan and Three east provinces(cities) in mainland China. The Taiwan part, the sample of this study, conducted by the Research Center for Humanities and Social Science, Academia Sinica since 1999. Data were collected every year except 2013. This survey provides information on job features like the wage, job industries, occupations and so on. Worker's characteristics like education, gender, marital status, health, education of parents, et al. are also covered in the survey data. Like most VSL studies, workers in agricultural, and those who work for them instead of haired by others, together with those who are not currently employed, are excluded from our sample, ending with a total sample of 13,180 valid observations. The definition of variables and data statistics used in this study are shown in Table 1.

The job fatality rate is from the Bureau of Labor Insurance, Ministry of Labor, data span is 1999-2014. Like Hintermann et al. (2010) and Kniesner et al. (2012), we used the moving average of job fatality rate of past three years rather than the current year fatality rate to reduce the fluctuations due to stochastic shocks. The industrial job fatality rates and their trends with time are shown in Graph 1. Overall, the fatality rate in each industry shows a downward trend, especially in the mining sector.

Table 1. Data statistics

| Category | Variables | Definition | Mean | Std. Dev. |
|---|---|---|---|---|
| personal characteristics | health | self-perceived health, from 1- very bad health, to 5- very good health | 3.68 | 0.82 |
| | edu_year | years of education | 12.79 | 3.07 |
| | marriage | 1 if married, 0 otherwise | 0.53 | 0.50 |
| | wexp | years of work experience | 16.63 | 10.84 |
| | medu_year | mother's education years | 5.76 | 3.91 |
| job features | wage | yearly wage | 515,963 | 379,811 |
| | past3_risk | the average job fatality rate of the past three years | 0.045 | 0.048 |
| | female | 1 if female, 0 otherwise | 0.43 | 0.50 |
| | scale1 | 1 if the number of employees lies between 10-49, 0 otherwise | 0.28 | 0.45 |
| | scale2 | 1 if the number of employees lies between 50-499, 0 otherwise | 0.26 | 0.44 |
| | scale3 | 1 if the number of employees is more than 500, 0 otherwise | 0.24 | 0.43 |
| Climate and pollution amenities | _1tp_avg | average January temperature of each county | 16.2 | 1.2 |
| | _7tp_avg | average July temperature of each county | 29.0 | 0.6 |
| | pm10 | average pm10 concentrations of each county | 63.6 | 12.5 |

Data source: PSFD (1999-2014); Bureau of Labor Insurance, Ministry of Labor; Research Center for Environmental Changes, Academia Sinica

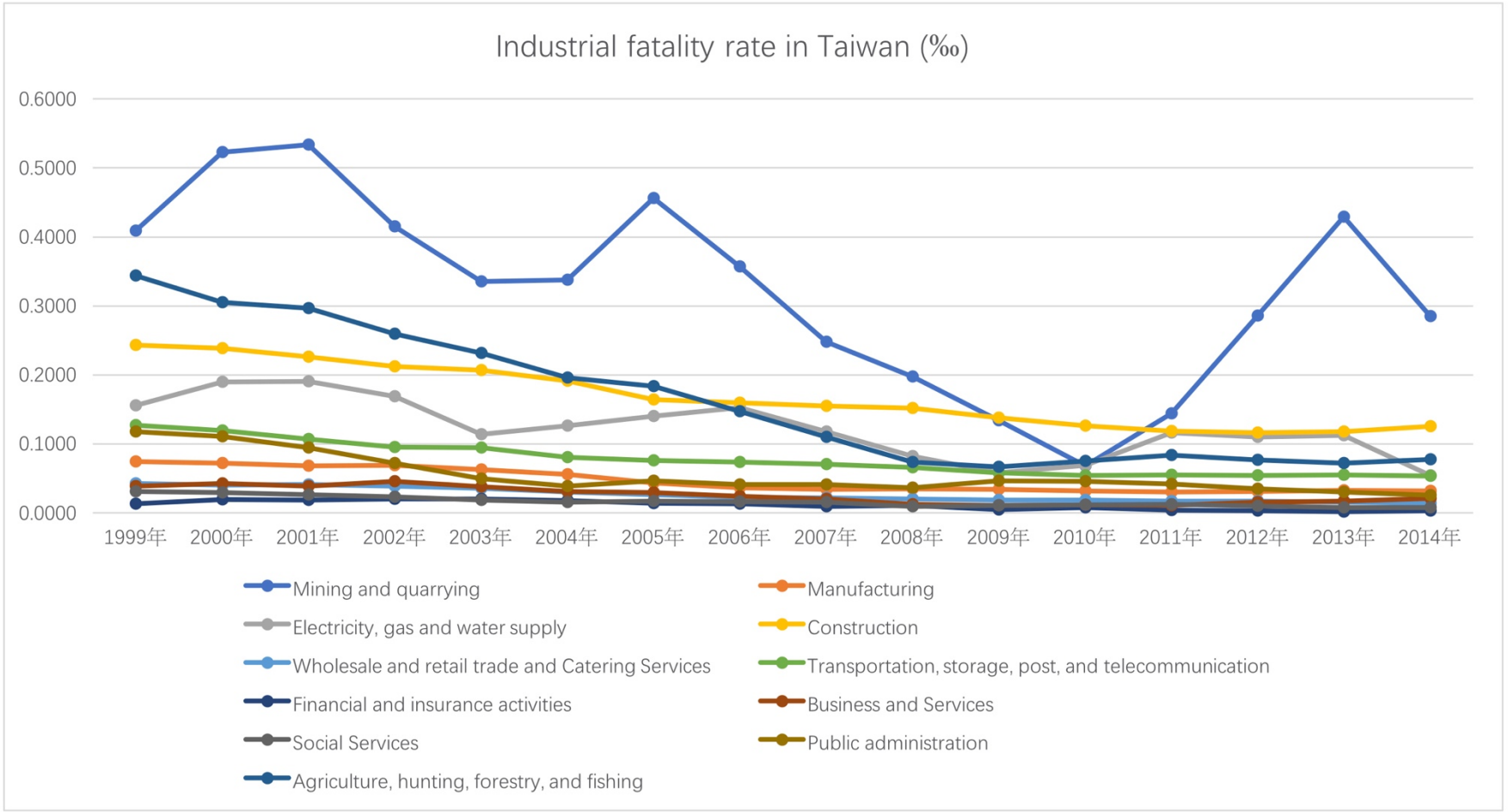


Fig 1. The industrial fatality rate from 1999 to 2014 (‰)

To get the measures of air quality to which the respondents are exposed, we analyze the annually mean PM10 concentrations from 2008 to 2011 from 78 monitoring stations of the Taiwan Environmental Protection Administration. The PM10 concentrations are interpolated from these 78 air quality stations to the locations of township governments in where the respondent resided. The interpolation method is based on Cressman scheme (Cressman G.P., 1959) which is commonly used by meteorological models (e.g., Weather Research and Forecasting Model, http://www.wrf-model.org/index.php ).

## Theory and Econometric Model

Rosen (1974) developed the hedonic price theory. He believed that any product could be completely described by a vector of objectively measured attributes or characteristics. Hedonic prices are defined as the implicit prices of attributes and are revealed to buyers and sellers from observed prices of goods consist of specific amounts of characteristics. Compensating wage differentials theory is the application of the hedonic price model in the labor market, and thus called hedonic wage theory. When a worker decides to take a job, he takes all the attributes of the job, like pace, pressure, and other workplace amenities. Thus, the wage rate of this job embodies the prices of all these attributes. Considering a case that all job attributes except risk are at their equilibrium prices and quantities. For firms, reducing risk is costly. A firm can only cut down the wage at the same time it reduces the risk to maintain the profit constant (zero profit). Besides, as risk decreases, the marginal cost of risk reduction is higher. Thus, the iso-profit curve of a firm should be concave to the origin. Firms are different in their marginal costs of risk reduction, resulting in different iso-profit curves. As

The climate data at the locations of township governments where the respondents reside in are interpolated from a 1km-resolution uniform-grids climate dataset over Taiwan. The climate dataset is provided by the Taiwan Climate Change Projection and Information Platform (TCCIP, http://tccip.ncdr.nat.gov.tw/NCDR /main/usage.aspx) project. The TCCIP uniform grids temperature dataset is constructed using a conventional spatial interpolation technique (Weng and Yang, 2012) and multiple data sources (Central Weather Bureau, Water Resources Agency, Irrigation Associations, Taiwan Power Company). More than 300 monitoring stations are used.

shown in graph 2, firm 1 (OC1) is more efficient and safer than firm 2 (OC2) as it can provide the same level of safety at a lower cost. For the consumers, we assume that usually people hate risk, and are willing to endure a higher risk only if they are paid a higher wage. As risk goes higher, higher compensation is needed to make the consumer feel as good as before. This gives us an indifference curve convex to the origin, as shown in graph 2 (Viscusi and Aldy, 2003). Consumer 1 (EU1) is more risk-averse than consumer 2, as consumer 1 needs to be paid more to accept the same level of risk than consumer 2. When market clears, the most risk-averse consumer (consume 1) goes to the safest firm (firm 1). The iso-profit curve of firm 1 and the indifference curve of consumer 1 will be tangent at the point $(w_1, p_1)$. The same process also applies for firm 2 and consumer 2, and their tangent point is $(w_2, p_2)$. Suppose there are numerous consumers and firms when the market clears, then the tangent points of all the iso-profits and indifference curves will make an upward curve $\mathrm{w} = \mathrm{f(p)}$, known as the hedonic wage function, which is the implicit price of risk is sold and bought in the labor market.

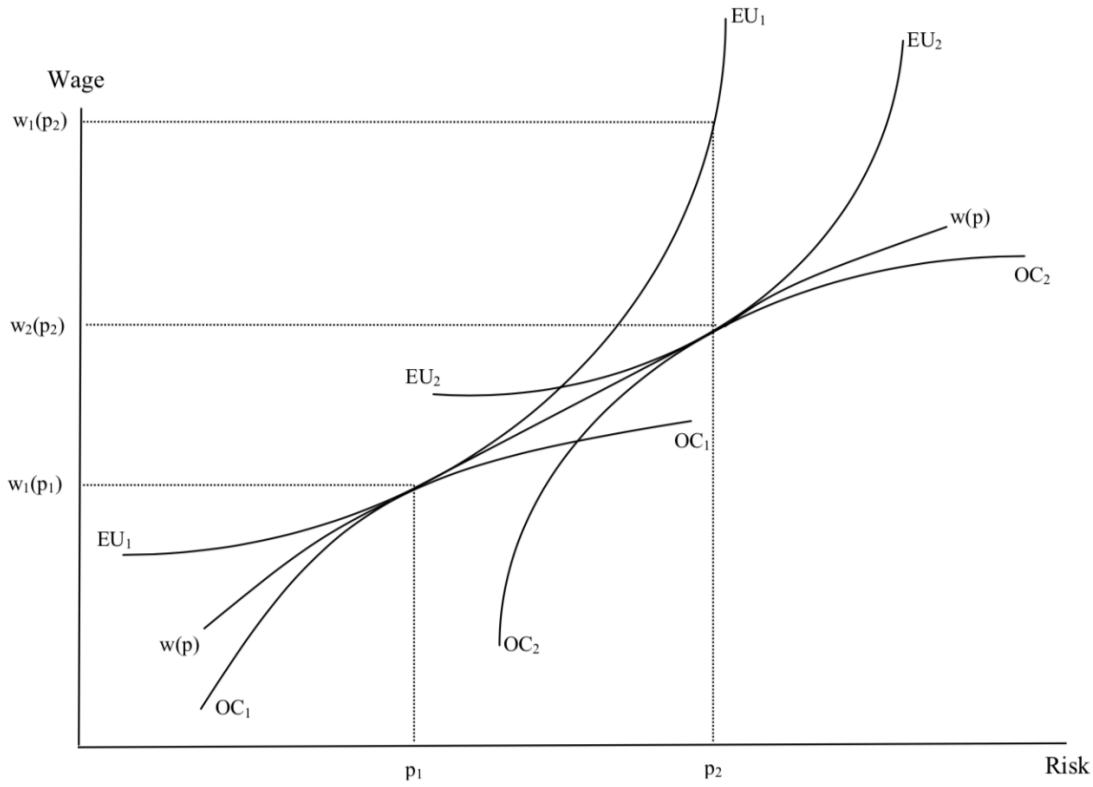


Fig 2. The hedonic wage function (Viscusi and Aldy, 2003)

The standard hedonic wage approach is to estimate the wage equation with risk as our core variable:

$$lnW = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \beta * R + \varepsilon \quad (1)$$

Here $W$ refers to the wage income, $X_1$ is a vector of worker characteristics like gender, education and so on. $X_2$ is a vector of the job attributes, including the scale of the firm, et al. The core variable here is the job risk, usually represented by the industrial fatality rate. The coefficient $\beta$ is expected to be positive, if the compensating wage differentials (CWD) theory holds, meaning when other factors controlled, workers take jobs with higher risk should be paid higher. But as Viscusi (1978) and Garen (1988) points out, the risk one involves might be endogenous. The wealth effect enables richer people to take safer jobs, and poor workers are more inclined to take risky jobs in order to make more money. The self-selection problem could also arise from other factors which influence people's risk preference other than wealth, like gender, age and, other personal characteristics. Besides, some missing unobserved variables like cool-headedness may cause the heterogeneity of risk premium, making people with cooler heads have higher productivity in a risky situation than in a safe situation. Both the self-selection problems and the omitted unobserved variables imply the endogeneity of workers' risk choices in labor market decisions, which make the OLS estimation biased. To solve the risk endogeneity problem, we adopt the fixed effect model, which is a perfect tool to deal with the missing time-invariant variables and help relieve the risk endogeneity problem.

## Empirical results

Following the standard hedonic wage approach, we first estimate the wage equation (1) with OLS. Then we estimate the wage-risk tradeoff with the fixed effect model

to account for the problems of missing time-invariant variables.

Standard hedonic wage estimation.

In the OLS estimation, we develop three different models by controlling different variables.

In model 1 we control only the primary factors that affect one's wage income, i.e., one's characteristics like education and gender and so on, together with the essential job attributes, like the scale of the firm, with job fatality as our core explanatory variable. The results are shown in table 2.

Table 2. OLS estimation results

| | model 1 | model 2 | model 3 |
|---|---|---|---|
| Ln(wage) | | | |
| lnpast3_risk | 0.0410*** | -0.00206 | 0.00413 |
| | (8.10) | (-0.39) | (0.78) |
| female | -0.288*** | -0.303*** | -0.304*** |
| | (-35.71) | (-38.11) | (-38.91) |
| medu_year | 0.00487*** | 0.00871*** | 0.00637*** |
| | (3.94) | (7.11) | (5.25) |
| health | 0.0358*** | 0.0229*** | 0.0272*** |
| | (7.46) | (4.83) | (5.82) |
| lnedu_year | 0.844*** | 0.880*** | 0.837*** |
| | (46.06) | (48.75) | (46.65) |
| marry | 0.127*** | 0.115*** | 0.117*** |
| | (14.24) | (13.12) | (13.47) |
| lnwexp | 0.153*** | 0.148*** | 0.136*** |
| | (21.51) | (21.12) | (19.60) |
| scale1 | 0.137*** | 0.133*** | 0.123*** |
| | (12.37) | (12.19) | (11.43) |
| scale2 | 0.225*** | 0.217*** | 0.202*** |
| | (19.68) | (19.37) | (18.25) |
| scale3 | 0.350*** | 0.341*** | 0.327*** |
| | (29.32) | (29.09) | (28.27) |
| year | | -0.0237*** | -0.0215*** |
| | | (-22.55) | (-20.64) |
| _1tp_avg | | | -0.0530*** |
| | | | (-16.06) |
| _7tp_avg | | | 0.108*** |
| | | | (16.49) |
| pm10 | | | 0.000558* |
| | | | (1.85) |
| _cons | 10.36*** | 57.77*** | 51.23*** |
| | (182.55) | (27.47) | (24.28) |

t-values in parentheses

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

As we can see from model 1, the coefficients of control variables have the expected signs: workers are paid higher for higher job fatal risk, donating a positive risk premium. Female workers earn less than their male counterparts. One's work experience, health, and education, together with his/her mother's education, which could be seen as one's human capital, have a positive effect on one's wage, meaning there exists a positive human capital premium or skill premium in the labor market in Taiwan. Besides, we can see that workers in big firms receive higher wages than workers in small firms when other factors controlled. In model 2, when time trend is controlled, the coefficient of risk becomes negative and insignificant, meaning the relationship between risk and wage is dwarfed by the descending trend of real wage in Taiwan.

According to Roback (1982), environmental amenities like temperature and pollution, influence people's dwelling choices and thus affect the house price and the labor supply of a specific region. The wage rates, accordingly, are also affected by the climate and pollution of the region. In model 3, we further control the climate and pollution of the dwelling positions of the workers, proxied by the average January temperature, average July temperature, and PM10 concertation, respectively. We find that the coefficient of risk turns out to be positive but still insignificant. While the three coefficients of the climate and pollution factors are significant: places with a warmer winter (higher January temperature) are attractive dwelling sites for workers, thus resulting in more labor supply and thus lower wages. While places with higher July temperature is less attractive for people to live, thus resulting in less labor supply. Workers are paid more to compensate them for working in areas with this unwanted attribute. Pollution is also a disamenity, and workers are paid more for working in higher PM10 concentration regions.

In the models above, we can see that while other factors have a stable effect on wage, the inclusive of an additional variable has strongly affected the coefficient of risk, meaning the risk-money tradeoff relationship is weak and unstable. It is reasonable to doubt that the core variable risk is correlated with some unobserved missing factors, and we need to use a fixed effect model to study the risk premium in Taiwan's labor market better.

## Fixed effect model estimations

In this section, we are going to estimate the hedonic wage function with the fixed effect model, in order to deal with the missing time-invariant variable problems and relieve the risk endogeneity caused by it. The results are shown in Table 3. Column 2 is the whole sample result.

As we can see, the coefficient of risk is positive and insignificant, meaning that for the whole sample, there is strong evidence of positive risk premium, and the elasticity of risk to wage is 0.338. All the other coefficients have the expected signs: there exists a skill premium (health, education, and experience all increase one's wage income) in the labor market of Taiwan. Besides, the climate and pollution premium are also significant: for desirable climate attributes like higher average temperature in January, workers with this workplace amenity receive lower wages. While for unwanted workplace characteristics, like higher temperature and higher PM10 concentration, workers are paid more to compensate them for working in such disamenities.

Table 3. Fixed effect model estimations

| | total sample | skilled and unskilled workers | managerial workers |
|---|---|---|---|
| lnpast3_risk | 0.0338*** | 0.0567*** | 0.0220 |
| | (4.98) | (4.70) | (1.29) |
| Health | 0.0111*** | 0.00824 | -0.0000591 |
| | (2.61) | (1.16) | (-0.01) |
| lnedu_year | 0.157* | 0.136 | -0.000201 |
| | (1.86) | (1.13) | (-0.00) |
| Marry | 0.0493*** | 0.0419** | 0.0734*** |
| | (4.76) | (2.27) | (2.92) |
| Lnwexp | 0.216*** | 0.132*** | 0.236*** |
| | (13.97) | (4.22) | (6.18) |
| scale1 | 0.0781*** | 0.0804*** | 0.0967** |
| | (6.86) | (4.51) | (2.46) |
| scale2 | 0.123*** | 0.175*** | 0.102** |
| | (9.14) | (7.55) | (2.44) |
| scale3 | 0.157*** | 0.216*** | 0.101** |
| | (10.43) | (7.84) | (2.28) |
| Year | -0.0106*** | -0.0135*** | -0.000314 |
| | (-7.17) | (-5.59) | (-0.08) |
| _1tp_avg | -0.0248*** | -0.0565*** | -0.0151 |
| | (-2.59) | (-2.87) | (-0.64) |
| _7tp_avg | 0.0538*** | 0.0256 | 0.0576 |
| | (3.31) | (0.71) | (1.56) |
| pm10 | 0.00283* | -0.00236 | 0.00799* |
| | (1.70) | (-0.80) | (1.72) |
| _cons | 31.99*** | 39.54*** | 11.52 |
| | (10.77) | (8.10) | (1.52) |
| N | 13180 | 4867 | 2504 |

t-values in parentheses

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

Considering the other source of risk endogeneity, the wealth effect, as Viscussi (1978) put it. It is well accepted that safety is a normal good. Rich people are less willing to take risky jobs for money compared to poor people. Thus, there is self-selection in choosing jobs: the one with more wealth or more likely to earn a high salary would go to the safer occupations, and the poor people or those less capable would go to riskier occupations. Since occupational fatality rate is not available, regression with the whole sample and industrial average risk data will obscure the difference in the choices of risk-wage tradeoffs of these two groups of people.

Because of the lack of information on one's wealth, we cannot separate the two groups by their financial situation. Instead, we turn to the occupation information in the survey. We divide the whole sample into two groups: the skilled and unskilled workers (who on average earns less money), and the managerial workers (who are also the richer ones in the sample), according to their occupations. We expect that, for skilled and unskilled workers, the risk elasticity of risk should be larger than for managerial workers. The fixed effect model estimation for the two groups are shown in Table 3, column three and column four.

As it is shown in Table 3, the coefficient of risk for skilled and unskilled workers is positive and significant, and bigger than the total sample, while for managerial workers, the coefficient is small and insignificant. It is evident that there is self-selection when people are choosing jobs: workers in managerial positions choose safer jobs that fatal risk is so small that it almost has no compensation at all. While for skilled and unskilled workers, the higher compensation for job risk makes it more attractive for them to take risky jobs.

While the climate and pollution have a different effect on the two groups: managerial workers receive a positive pollution premium, meaning they care more about pollution than the temperature. Higher average temperatures in January means less house heating cost and water heating cost in winter, and our results show that it matters more for skilled and unskilled workers than for managerial workers. The average temperatures in July do not have a significant effect on either group. Our guess of this is because of the location and shape of Taiwan. Since Taiwan is a tropical island, the weather is always warm all the year around accept winter months (around January). Besides, the shape of Taiwan island is narrow in longitude but has a relatively long stretch in latitude, which means a large temperature gap from north to south, especially in winter days. The cost of heating in winter months might be a much heavier burden for the skilled and unskilled workers, which are also low-income workers, than for workers in managerial positions.

## The willingness to pay for a micro risk reduction ($WTP\mu r$) and VSL

According to Camera (2010), we would like to use the term $WTP\mu r$ (the willingness to pay for a micro risk reduction) instead of the term VSL (the value of a statistical life) because of the massive misunderstanding of the VSL. The micro risk reduction refers to a reduction magnitude of 1/1000,000. The $WTP\mu r$ is calculated as below:

$$WTP\mu r = \beta \times \frac{\Delta past3\_risk}{\frac{\overline{past3\_risk}}{1000}} \times wage$$

Where $\beta$ is the estimated coefficient of *lnpast3_risk* in our regression, $\overline{past3\_risk}$ is the average of *past3_risk*. The WTPμr for the whole sample is 390 (2014 TWD), and the corresponding VSL is 390 million (2014 TWD). Our VSL value is larger than the previous studies in Taiwan: In the 1980s, the VSLs of Taiwan are estimated to be within 4 million and 34 million (Liu, Hammitt and Liu, 1997). A recent study in Taiwan (Liu, 2011) found a VSL of between 100 million 187 million (2014 TWD).

Compared with the previous study, our study is different in three ways which may account for the VSLs gap: The first (also the most important) difference is that our research is based on the panel data analysis. By adopting the fixed effect model, we have better control of the missing time-invariant variables and substantially relieve the risk endogeneity problem. Besides, we also control the climate and pollution factors, which turn out to

have significant influences on the labor supply and thus affect the wage. As far as we know, our paper is the first paper discussing the climate and pollution premium under the hedonic wage theory. What is more, we use different survey data resource. While most studies in Taiwan use the Manpower Utilization Survey as the data source of labor characteristics and job characteristics, our labor data comes from the Panel Survey of the Family Dynamics (PSFD). PSDF is conducted by the research center or humanities and social science, Academia Sinica.

Similarly, we can also calculate people's willingness to pay for a unit decrease of PM 10 concentration as below:

$WTP_{PM10} = 0.00283 * wage = 1460.2$ (2014 TWD)

which is about 48 USD, closed to the result of Huang et al. (2018), 40.5 USD.

## Conclusion

We study the risk premium together with climate and pollution premiums in Taiwan's labor market with panel analysis. By solving the missing time-invariant unobserved variables and risk endogeneity problem with fixed effect model, we find that the workers in Taiwan are compensated for work-related fatal risk, especially for skilled and unskilled workers, but for managerial workers, the tradeoff between risk and wage is small and insignificant.

We also study people's willingness to pay for a better climate and less pollution with the hedonic wage model. We find that lower temperature in July and higher temperature in January are preferred; Besides, lower pollution is also a workplace amenity. The climate premium and pollution premium between the two groups are different: the skilled and unskilled workers care more about the January temperature, and they are paid less for working in an environment with higher average January temperature. While managerial workers care more about the pollution level, they are paid higher for working in regions with higher PM10 concentration.

The VSL we get in our research is 390 million TWD, which is larger than previous hedonic wage studies in Taiwan. The reason we presume is the missing variable problems shared by most of the cross-sectional analysis in this field. Many factors like capability and risk preference are vital to one's job choice but are hard to observe or be peroxided. Our research with panel data analysis has a particular advantage of dealing with time-invariant factors, and effectively reduce the estimation bias in the cross-sectional analysis.

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