STRESS AND FATIGUE OF PROFESSIONAL DRIVERS: A CASE IN TAIWAN

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ABSTRACT

To thoroughly investigate the association of driver characteristics and organizational factors with the stress level, sleep quality and burnout level of professional drivers, quantile regression is applied to examine the association over the whole distribution with a special focus on the upper quantiles. The occupational stress level, sleep quality and work-related burnout level are measured using the Effort Reward Imbalance model, the Pittsburgh Sleep Quality Index and the Copenhagen Burnout Inventory, respectively. A total of 1,064 questionnaires were collected from railroad and bus drivers in Taiwan. The results show that most associations evaluated in this study are varied over the whole distribution and either linear or quadratic in shape, which cannot be easily observed using the ordinary least squares method where only average impacts are estimated. Moreover, most results indicate larger covariate effects and wider confidence bands in the upper quantiles. In other words, the covariate effects on drivers in the upper tail could be underestimated if only ordinary least squares were applied. Health problems and carrier types are found to be the most significant covariates explaining drivers' stress level while stress is the most critical covariate for sleep quality and work-related burnout levels. The results suggest the importance of stress reduction programs in professional drivers' health and wellness management.

1. INTRODUCTION

The safety of passengers and other road users is of prime importance in the passenger transport industry. Professional drivers stand in the front line to carry travellers to their destinations. The physical and psychological health of professional drivers is critical to safely operate passenger transportation vehicles. Any impairment may lead to undesirable consequences for drivers, passengers and operators alike such as rising insurance premiums, health care costs, and worker's compensation; increasing incidents of injuries, deaths, costly accidents, and absenteeism; the problems of finding replacement employees while some workers are out; and ultimately jeopardizing profits for the company (Krueger *et al.*, 2007).

Professional drivers are vulnerable to specific health problems. For example, because of the sedentary nature of driving, heavy workload, fatigue and various stressors from the driving environment, such as customers and heavy traffic, bus drivers are more likely to suffer from cardiovascular diseases than are individuals in other occupations (Tse et al., 2007; Tuchsen and Endahl, 1999; Wang and Lin, 2001). Bus and railroad drivers are also exposed to more hazardous substances such as carbon monoxide, sulphur dioxide and nitrogen oxides, which may lead to elevation in cardiovascular disease or lung cancers (Gustavsson *et al.*, 1996; Hesterberg *et al.*, 2006). Furthermore, due to tight timetables and irregular shift schedules, professional drivers report a high level of work-related stress and gastrointestinal complaints (Kompier and Dimartino, 1995; Tse *et al.*, 2006). In addition, the sedentary nature of driving and almost continuous exposure to whole-body vibration while driving have been found to be important components of the origin of musculoskeletal problems such as lower back and neck pain for bus drivers (Bovenzi et al., 2005; Magnusson et al., 1996).

Besides physical health problems, psychological health problems are also a serious concern for professional drivers. For example, bus driving has been recognized as a high-demand but low-control job, which translates into a high-stress job that affects drivers' psychological working conditions, and consequently leads to physical health problems such as cardiovascular diseases (Gustavsson *et al.*, 1996; Rydstedt *et al.*, 1998). Moreover, professional drivers sometimes face traumas at work such as injuries or deaths due to traffic accidents, which could induce post-trauma stress disorder (PTSD). Studies have shown that bus and railroad drivers who have the symptoms of PTSD also have more problems with physical health, work burnout and substance abuse (Chen and Cunradi, 2008; Issever et al., 2002; Vedantham et al., 1999).

The aim of this study is to investigate how driver characteristics (e.g., age, gender) and organizational factors (e.g., safety culture) are associated with the occupational stress and fatigue levels of professional drivers. Occupational stress (or work stress) is defined as the stress originating from the work environment, which includes the daily responsibilities of professional drivers related to driving, traffic environment and organizational policies. Unlike non-professional drivers where driving is a more self-paced task, professional drivers have to cope with various demands such as time schedules and long working hours which make driving a less self-regulated task. Moreover, there are many organizational factors such as a company's culture, safety policies and practices as well as safety climate that have a big impact on how safely a professional driver drives (Oz *et al.*, 2010). Occupational stress, just like other types of stress, is considered to have a significant impact on driving safety either directly or via other variables such as road rage (Hoggan and Dollard, 2007). Consequently, the impact of occupational stress on driving behaviour and safety may be more serious for professional drivers than for non-professional drivers (Cartwright *et al.*, 1996; Oz *et al.*, 2010).

This study focuses on two fatigue-related measures: sleep quality and burnout. Professional drivers have jobs usually characterized by long working hours and shift rotations, and may have more concern with sleep and fatigue issues than non-professional drivers. Hui *et al*. (2002) showed a high prevalence of objective snoring and sleep disorder related breathing in a sample group of commercial bus drivers in Hong Kong. More than 60 percent of the sampled subjects had a respiratory disturbance index value greater than or equal to 5 per hour of sleep, indicating significant sleep disordered breathing. Burnout is one type of fatigue type which results from chronic stress, and can be defined as a syndrome of psychological problems experienced as a result of chronic work stress (Milfont *et al.*, 2008). Drivers suffering poor sleep quality or burnout could damage their driving performance and the level of customer service due to deteriorating physical capabilities such as longer reaction time or lower awareness.

The rest of this paper is organized as follows. Section 2 defines the measurements used in this study, including stress level, sleep quality, burnout level and safety culture. Section 3 provides a brief introduction of quantile regression. Section 4 presents the survey results, and Section 5 illustrates the analysis results of quantile regression. Section 6 provides a discussion.

2. MEASUREMENTS

2.1 Occupational stress

Karasek's demand/control and Siegrist's effort/reward imbalance (ERI) models are the two most widely applied occupational stress (or work stress) measures. The demand/control model postulates that psychological strain results from the interaction between job demands and job control, with the combination of low control and high demand producing job strain. The ERI model includes the characteristics of the worker and also conceptualizes and measures work conditions more broadly than the demand/control model (Radi *et al.*, 2007). Therefore, this study applies the ERI model to measure professional driver's work stress.

The ERI model focuses on the reciprocity of exchange at work, where high cost/low gain conditions (i.e., high effort and low reward) are considered particularly stressful. Accordingly, effort at work is reciprocated by socially defined rewards which include money, esteem, and status control in terms of promotion prospects and job security.

The ERI scale adopted in this study consists of 17 items (Tseng and Cheng, 2002). The first six items measure participants' efforts, followed by 11 items measuring participants' rewards. The items are rated on a 5-point scale. Effort-reward imbalance is calculated as the sum of effort scores divided by the sum of reward scores with adjustment of the number of questionnaire items. A score of 1 represents a perfect balance between effort and rewards, with higher scores reflecting disproportionate effort.

2.2 Sleep quality

The Pittsburgh Sleep Quality Index (PSQI) is adopted to measure professional drivers' sleep quality and disturbance retrospectively over a 1-month period from self-reports. The PSQI was originally designed for use in clinical populations as a simple and valid assessment of both sleep quality and disturbance that might affect sleep quality (Backhaus *et al.*, 2002). Since its introduction in 1989 by Buchinsky (1998), the PSQI has gained widespread acceptance as a useful tool to measure sleep quality in different patient groups including with professional drivers (e.g. de Pinho et al., 2006; Sabbagh-Ehrlich et al., 2005).

The PSQI is a self-rating questionnaire producing a global score between 0 and 21, which consists of seven component scores including sleep quality, sleep onset latency, sleep duration, sleep efficiency, sleep disturbances, use of sleeping medication and daytime dysfunction. A participant that scores higher than 5.0 is usually classified as having poor sleep quality.

2.3 Work-related burnout

The Copenhagen Burnout Inventory (CBI) is applied to measure professional drivers' work-related burnout in this study. The CBI is a public domain questionnaire measuring the degree of physical and psychological fatigue experienced in three sub-dimensions of burnout: personal, work-related, and client-related burnout. This study focuses on work-related burnout.

The CBI was developed by Kristensen *et al*. (2005). This scale was designed to overcome the limitations of the Maslach Burnout Inventory (MBI) (Maslach and Jackson, 1986) which has been the most widely used instrument to measure burnout since its introduction. The MBI is limited to people-oriented occupations such as teachers. There are, however, limitations regarding its definition and measurement of burnout, and understandability of the questionnaire items across cultural groups. There are two dimensions measured by this scale which do not pertain to burnout syndrome. Finally the MBI is owned by a commercial company, meaning that researchers have to pay for its use (Halbesleben and Demerouti, 2005). The CBI was designed to overcome the limitations outlined above.

The Copenhagen Burnout Inventory (Chang *et al.*, 2007; Yeh *et al.*, 2007) consists of 19 items. In particular, seven of them measure work-related burnout as the degree of physical and psychological fatigue related to work. The responses are recorded on a 5-point scale with responses ranging from always (score 100) to never (0), or very seriously (100) to very slightly (0). The CBI score for each participant is the average of seven component scores; consequently, a CBI score ranges from 0 to 100.

2.4 Safety culture

Numerous definitions of safety culture exist in the academic literature. One of the earliest and widely accepted definitions was proposed by the Advisory Committee on the Safety of Nuclear Installations (ACSNI, 1993): 'the safety culture of an organization is the product of individual and group values, attitudes perceptions, competencies and patterns of behaviours that determine the commitment to and the style and proficiency of an organization's health and safety management'.

There have been attempts within the aviation industry to construct a general and less activity-specific safety culture (climate) survey, so as to make precise comparisons across various types of organizations and activities possible. This study adopts the scale developed by the Global Aviation Network (GAIN, 2001), a scale also adopted by Bjørnskau and Logva (2009) to compare the safety culture between different transport modes including helicopter, airplane, rail and bus.

The scale consists of 25 safety-related questionnaire items covering five presumably safety-relevant issues: management's attitude and focus on safety, the attitude and focus on safety among employees, culture of reporting and reactions to reported errors and incidents, safety training and education, and general questions about safety within the organization. The participants answer all questions using a rating scale from 1 (disagree completely) to 5 (agree completely). The safety culture index is computed as the sum of the scores of the 25 questions. Therefore, the maximum index value is 125 while the minimum is 0. The Global Aviation Network suggests that a score lower than 59 indicates a poor safety culture while a score between 59 and 92, and above 92 indicate bureaucratic and good safety culture, respectively.

3. METHODOLOGY: QUANTILE REGRESSION

Unlike linear regression, where the coefficients reflect the average value of the response variable, quantile regression models the relation between a set of predictor variables and the specific percentiles (or quantiles) of the response variables. That is, ordinary least-squares regression models the relationship between one or more covariates X and the conditional mean of a response variable Y given $X = x$. In contrast, quantile regression models the relationship between X and the conditional quantiles of Y given $X = x$. Moreover, the estimated coefficient vector of quantile regression is not sensitive to outlier observations on the dependent variable (Koenker and Hallock, 2001). Therefore, quantile regression provides a more comprehensive picture and robust measure of the effect of the predictors on the response variable and is especially useful in applications where upper quantiles of pollution levels are critical from a public health perspective (Chen, 2005). Specifically, in this study, those at high levels (i.e., upper quantiles) of stress and fatigue may have heterogeneous conditional distributions and should be paid special attention.

The quantile regression model was introduced by Koenker and Bassett (1978). For a random variable Y with a cumulative distribution function $F(y) = \text{Prob}(Y \le y)$, the τ th quantile of Y is defined as the inverse function $Q(\tau) = \inf\{y : F(y) \ge \tau\}$ where $0 < \tau < 1$. In particular, the median is $Q(1/2)$.

For a random sample $\{y_1, y_2, \ldots, y_n\}$ of Y, the general τ th sample quantile $\xi(\tau)$, which is the analogue of $Q(\tau)$, can be formulated as the solution of the optimization problem

$$\min_{\xi \in \mathbf{R}} \sum_{i=1}^{n} \rho_\tau (y_i - \xi),$$

where $\rho_\tau(z) = z(\tau - I(z < 0))$, $0 < \tau < 1$. Here $I(\cdot)$ denotes an indicator function.
The linear conditional quantile function, $Q(\tau | X = x) = x'\beta(\tau)$, can be estimated by solving

$$\hat{\beta}(\tau) = \underset{\beta \in \mathbf{R}^p}{\text{argmin}} \sum_{i=1}^{n} \rho_\tau (y_i - x_i'\beta)$$

for any quantile $\tau \in (0,1)$. The quantity $\hat{\beta}(\tau)$ is called the τ th regression quantile. The case $\tau = 1/2$, which minimizes the sum of absolute residuals, corresponds to median regression.

The most important feature of this framework is that the regressors' marginal effect, β_θ, may vary over different quantiles. For a given set of regressors X_i, this study estimates a set of coefficients $\{\beta_\theta, \theta = 0.1, 0.11, 0.12, \ldots, 0.9\}$, pertaining to the eighty-one quantiles.

4. SURVEY

Data were collected using a questionnaire survey. The questionnaire comprises six parts: 1) driver characteristics including age, gender, BMI, year of service, driving hours, working hours and rotation and shift systems; 2) health conditions and problems experienced; 3) the Effort Reward Imbalance (ERI) scale; 4) the Pittsburgh Sleep Quality Index (PSQI) scale; 5) the Copenhagen Burnout Inventory (CBI); and 6) the GAIN safety culture scale.

The survey was conducted from October to November 2009. Driver lists were first acquired by the Institute of Transportation, Ministry of Transportation and Communications, Taiwan. The research team then randomly selected drivers to sample based on the driver lists received, according to the number of drivers employed by the operator. The sampled drivers cover those employed by the major railroad and bus carriers in Taiwan. The questionnaires were mailed out with self-addressed envelopes enclosed. In total, 1,221 questionnaires were distributed and 1,064 questionnaires returned; the response rate was 87.1%.

4.1 Driver characteristics

As shown in Table 1, most drivers employed by railroad and bus companies are male. Moreover, the drivers employed by long-haul bus carriers are also the oldest, have the highest body mass index (BMI), as well as the most years of service and the longest average daily driving and working hours, on average. The short-haul bus carrier drivers have similar characteristics but at a weaker level. On the other hand, railroad drivers are distinct from bus drivers as being younger, having a lower BMI and shorter driving and working hours.

The age difference between railroad and bus drivers may partially be the result of different recruitment requirements and licensing systems. The young railroad drivers are mainly from two mass rapid transit (MRT) corporations. The MRT drivers require basic computer, word processing and English communication skills, which may favour young people. On the other hand, to obtain a professional passenger bus driver's license in Taiwan, a driver must have had a professional truck driver's license for at least one year or a professional automobile driver's license for at least two years. In other words, bus drivers are more likely to be experienced drivers.

Bus drivers have longer and more varied average driving and working hours due to the different driving environment and shift systems. There are several types of shifts for railroad drivers differentiated by shift starting times; however, regardless of which type, the shift length is limited to eight hours including driving and non-driving hours. Moreover, the railroads in Taiwan have exclusive right of way, and railroad driving is not influenced by traffic congestion. On the other hand, the shift schedules for bus drivers vary according to route length and customer needs. In addition, bus driving is much affected by traffic congestion especially in downtown areas or on certain freeway segments.

Table 1 Driver characteristics

Variable	Carrier type		
	Railroad (*n*=279)	Long-haul bus[1] (*n*=384)	Short-haul bus[2] (*n*=401)
Age	36.94 (9.87)[3]	42.83 (8.15)	41.48 (8.29)
Gender (male percentage)	91.24%	98.96%	97.25%
BMI	23.95 (3.15)	25.53 (3.58)	25.38 (3.60)
Years of Service	8.49 (9.97)	11.18 (8.59)	8.33 (7.35)
Daily average driving hours	6.17 (1.21)	9.58 (1.89)	8.95 (1.80)
Daily average working hours	7.87 (1.59)	10.71 (2.47)	10.40 (2.44)

[1] Bus carriers who mainly operate on freeways and have more than 1000 drivers

[2] Bus carriers who operate on both freeways (usually shorter than 100 kilometres) and local roads, or local roads only

[3] Number in the parenthesis refers to standard deviation.

4.2 Health problems

Railroad drivers had the most health problems reported within the past year, accounting for more than 60 percent. As shown in Table 2, musculoskeletal problems are common to both railroad and bus drivers. The relatively high percentages of musculoskeletal problems for bus drivers may partially result from the sedentary nature of driving and almost continuous exposure to whole-body vibration, as has been suggested by past studies (Bovenzi et al., 2005; Magnusson et al., 1996). Vision problems are the other type of health problem that is common for all drivers. On the other hand, hearing problems are particularly common for railroad drivers, which might be due to the noisy railroad driving environment, especially for those employed in the traditional railways. Hypertension and hyperlipidemin problems are relatively common with bus drivers, which may be related to their relatively high BMI values.

Table 2 Reported health problems

Variable	Carrier type		
	Railroad	Long-haul bus	Short-haul bus
Percentage reported[1]	62.50%	54.04%	37.53%
Health problems encountered			
Most frequently	Musculoskeletal (28.53%)[2]	Musculoskeletal (41.80%)	Musculoskeletal (46.45%)
Second most frequently	Hearing (25.39%)	Vision (15.11%)	Hyperlipidemin (10.38%)
Third most frequently	Vision (14.11%)	Hypertension (13.50%)	Vision & Hypertension (9.84%)

[1] Percentage of drivers who experienced any health problems in the last year

[2] Percentage of health problems based on all reported health problems

4.3 Associations and reliability

The Pearson correlation and Cronbach's α[1] for these measurements are summarized in Table 3. Regarding reliability of the measurements, the Cronbach's α for the effort and reward scales of the ERI measurement are 0.86 and 0.90, respectively. Moreover, the Cronbach's α for the CBI and for the GAIN safety culture scores are 0.89 and 0.97, respectively. These values are all above 0.7 and the corresponding measurements are considered reliable.

As for sleep quality, the Cronbach's α for the global PSQI and for the sleep disturbance in this study are 0.53 and 0.82, respectively. The low alpha value of the global PSQI indicates the inconsistency of the seven component scores. The negative association between the third component – sleep duration – and the other components is the primary reason for this low alpha value. If this sleep duration item is deleted, the global Cronbach's α

[1] Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a group.

value will go up to 0.67 which is similar to the reliability assessment of PSQI found in other studies (see, for example, Carpenter and Andrykowski, 1998).

The associations between each measurement are all significant at 0.05. While the ERI, PSQI and CBI are positively correlated, they are all negatively related to safety culture. In other words, the higher the stress level of the drivers, the worse the sleep quality and the higher the work-related burnout level they would show, and vice versa. On the other hand, if drivers perceive a higher level of safety culture, they would present a lower stress level, better sleep quality and lower work-related burnout level.

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Table 3 Pearson correlation and Cronbach's α

Measurement	Measurement				Cronbach's α
	ERI	PSQI	CBI	Safety culture	
ERI	1.00	0.49**	0.58**	-0.43**	Effort: 0.86; Reward: 0.90
PSQI		1.00	0.57**	-0.34**	Global: 0.53; Disturbance: 0.82
CBI			1.00	-0.40**	0.89
Safety Culture				1.00	0.97

** 0.05 significance level

4.4 Distribution of measurements

The boxplots for each measurement are illustrated in Figure 1, where the red dotted horizontal lines represent the theoretical thresholds for each measurement. Figure 1(a) shows the boxplot for the ERI measurements. While more than 75 percent (i.e., top of the boxes) of professional drivers have a stress level below the theoretical threshold, 1.0, each carrier type has some "outliers" whose stress levels are well above 1.0, indicating a significantly high stress level. On the other hand, the PSQI boxplot (Figure 1(b)) shows that most of the drivers have poor sleep quality, since their PSQI scores are above 5.0. In particular, the median PSQI level (i.e., the band near the middle of the boxes) shows that the railroad drivers have the poorest sleep quality, followed by long-haul bus drivers.

The median work-related burnout level, shown in Figure 1(c), suggests that railroad drivers have the highest burnout level, followed by long-haul bus drivers, while short-haul bus drivers have the lowest burnout level. Note that each carrier type has some drivers with an extreme high burnout level as indicated by the additional dots.

The boxplot for the safety culture measurement is shown in Figure 1(d). While the railroad and long-haul bus drivers perceive similar levels of safety culture across whole distributions, the short-haul bus drivers perceive a relatively higher level of safety culture. Moreover, although most drivers consider their corporate safety culture to be good (values exceed 92), some drivers still think their corporate safety culture is poor, as shown by the dots below the bottom end of the whiskers.

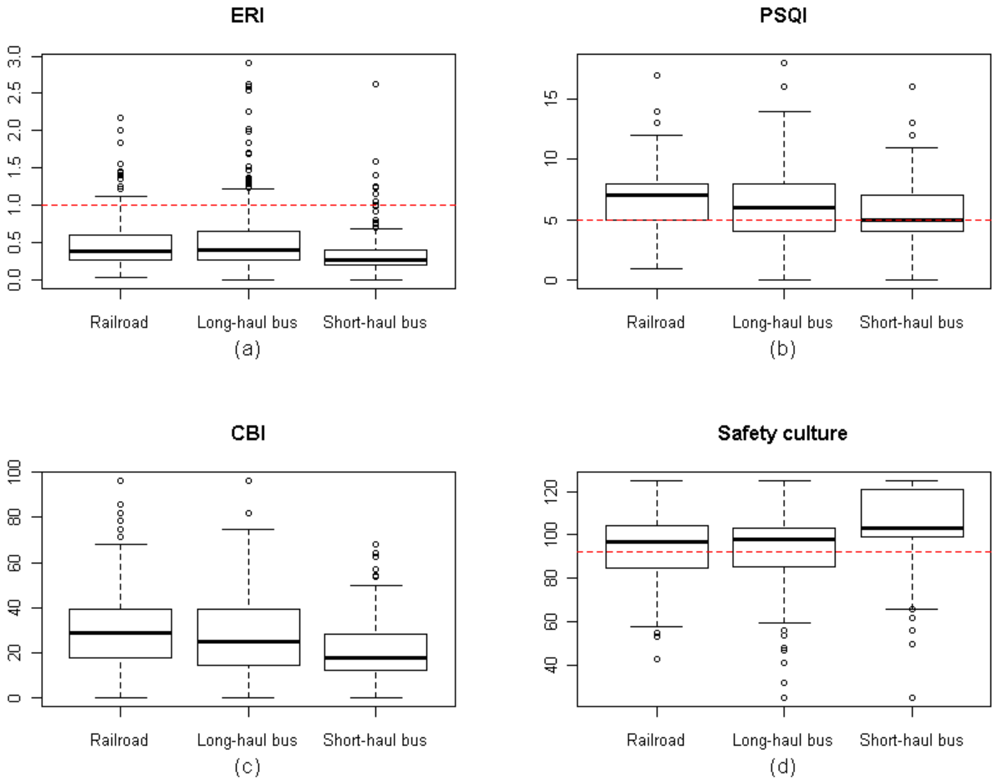

Figure 1 Boxplots for measurements

5. RESULTS OF QUANTILE MODELS

The quantile models are built using the software *R* (R Development Core Team, 2009) with the package *quantreg* (Koenker, 2009). The boostrap method is applied to compute standard errors and confidence limits for the quantile regression coefficient estimates (Koenker and Hallock, 2001). The best models are developed using a Wald test suggested by Bassett and Koenker (1982). Three models are developed as summarized in Table 4.

To help explain the derived intercepts, all the numerical covariates are transformed into their deviation form; in other words, the mean values are subtracted. Consequently, the derived intercepts imply the value of the dependent variable while all the covariates stay at the *average* level. This transformation does not change the results of regression coefficient estimates (Aiken and West, 1991).

Table 4 Research models

	ERI Model		PSQI Model		CBI Model	
	D.V.*	Covariate	D.V.	Covariate	D.V.	Covariate
Occupational stress (ERI)	✓			✓		✓
Sleep quality (PSQI)			✓			✓
Work-related burnout (CBI)					✓	
Driver characteristics		✓		✓		✓
Organizational factors		✓		✓		✓

* D.V. refers to dependent variables.

5.1 ERI model

Figure 2 presents a summary of quantile regression results for the ERI model. The best ERI model consists of the intercept and seven covariates including drivers' age, gender, BMI, health problems, carrier type, safety culture and an interactive effect between carrier type and safety culture. Among these covariates, gender, health problems and carrier type are binary variables, where values are coded as 1 if the corresponding driver is male, has reported any health problems within the past year, or he or she is employed in a long-haul bus carrier.

For each coefficient, 81 distinct quantile regression estimates are plotted for τ , ranging from 0.10 to 0.90, indicated by the solid curve with filled dots. The horizontal axis refers to quantiles τ , and the vertical axes indicate the covariate effects. The two dotted red lines represent conventional 90 percent confidence intervals for the least squares estimate, while the solid red lines are the average effect for the least squares estimate. The shaded gray area depicts a 90 percent pointwise confidence band for the quantile regression estimates.

Figure 2(a), the intercept panel, shows the estimated conditional quantile function for the ERI value of a driver with average age, female in gender, average BMI value, no health problems within the past year, and employment with a short-haul bus or railroad carrier with average safety culture. The intercept steadily increases until the 0.8 quantile where a sudden increase is observed.

The age effect estimated by the ordinary least squares is significant at -0.0024, which suggests that the older the drivers' age, the lower the stress level. This negative age effect remains at a modest level in the lower and middle quantiles but becomes more negative in the upper quantile, as shown by the quantile regression results (Figure 2(b)). Nonetheless, the wider confidence bands shown with the increase of the quantiles does not necessarily make the negative effect significant in the upper quantiles.

The stress levels of male drivers are lower than those of female drivers by about 0.1 according to the ordinary least squares estimates of the mean effect. However, as is clear from the quantile regression results shown in Figure 2(c), this disparity is only obvious between the 0.4 and 0.8 quantiles. When the stress level is extremely low or extremely high, the gender effect is not significant, as shown by the gray area covering the zero horizontal line.

The BMI value enters the model as a quadratic effect, as shown in Figure 2(d). In the lower and middle quantiles, the BMI value tends to be more concave, having a non-significant effect on stress level. In the higher quantiles, the BMI effect becomes positively significant. In other words, the positive BMI effect is only significant for drivers whose stress level is relatively high.

As shown in Figure 2(e), drivers who have reported health problems within the past year have a significantly higher stress level than those who have reported no problems. Moreover, the health problem effect clearly changes across all quantiles; the higher the stress level, the more serious the impact of the health problem. The effect shows a stable rise and the pointwise confidence band becomes wider with the increase of quantile.

As shown in Figure 2(f), long-haul bus drivers clearly show higher stress levels when other covariates are held fixed. Similar to the health problem effect, the long-haul bus effect becomes larger with the increase of quantiles.

The safety culture effect, shown in Figure 2(g), negatively affects the stress level. The reduction of the stress level becomes stably larger with the increase in the stress level. When interacting with the long-haul bus effect, the safety culture effect is still negative, but only significantly negative in the middle quantiles, as shown in Figure 2(h).

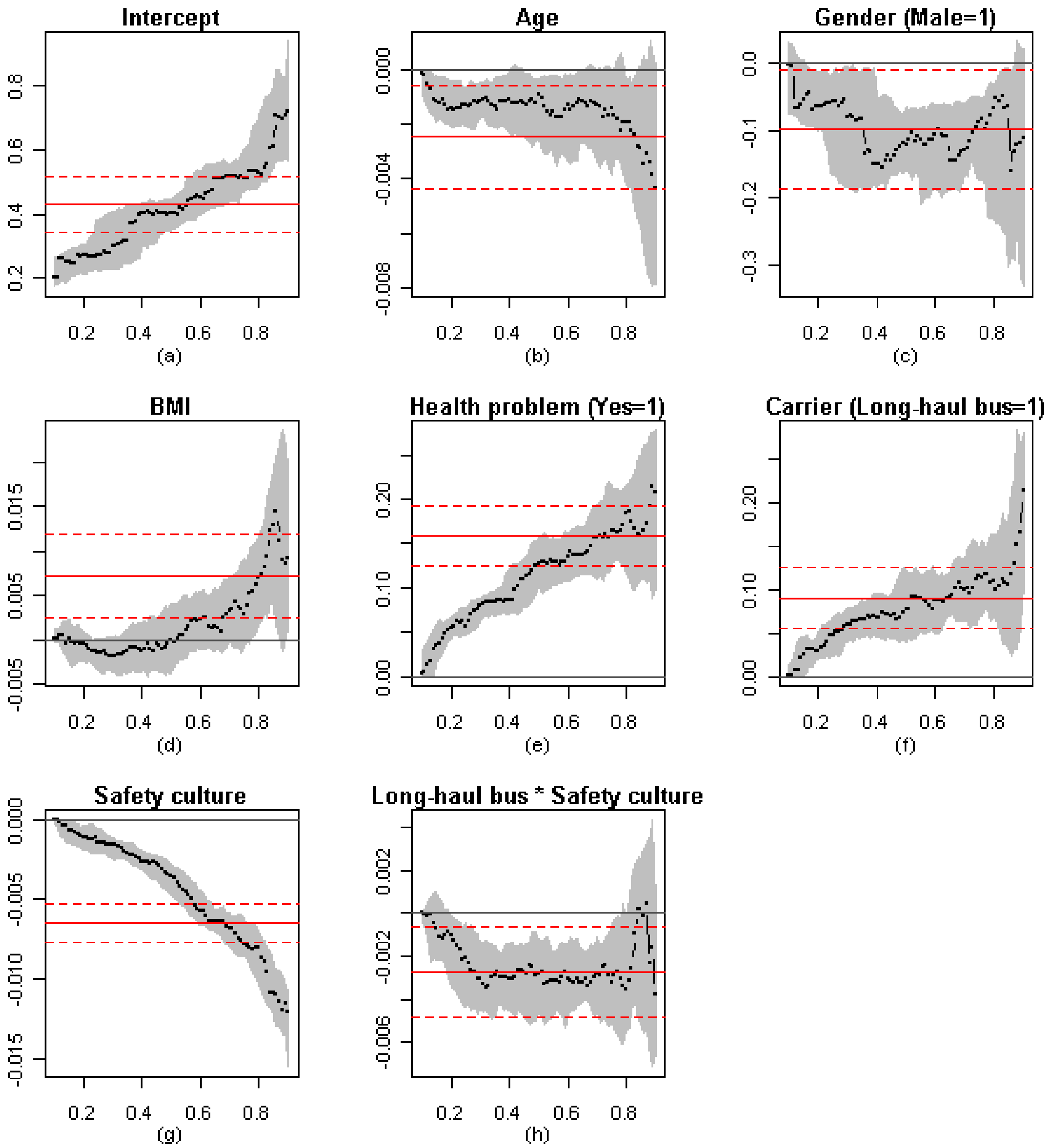

Figure 2 Quantile regression coefficient plots for the ERI model

5.2 PSQI model

As summarized in Figure 3, the best sleep quality model consists of the ERI value, gender, health problems, average daily driving hours, carrier type (where railroad drivers are coded as 1), and safety culture and the its interaction with carrier type as the included covariates.

Figure 3(a) shows the estimated intercepts which imply the conditional quantile function of the PSQI value of a driver with average stress level, female in gender, no health problems within the past year, average daily driving hours, and employment in a bus carrier with average safety culture. The intercept steadily increases with an average of around six, which is higher than the theoretical threshold of five.

There is quite a uniform effect for ERI, gender, health problems and average daily driving hours over the whole range of the distribution, as shown in Figure 3(b)-(e). A one-unit change in the ERI level and average daily driving hours is associated with about a 3.0 and 0.05 unit change in the PSQI value, respectively. The PSQI levels of male drivers are generally lower by 0.7. Drivers who have reported health problems within the past year generally have higher PSQI levels by 0.9. These effects appear to exert an approximately uniform shift on the conditional distributions. Consequently, the quantile regression results are roughly consistent with the ordinary least squares results.

On the other hand, drivers who are employed by a railroad carrier generally have higher PSQI values by 0.7. However, this disparity becomes more obvious in the higher quantiles, as can be seen in the quantile regression results in Figure 3(f). However, drivers who are employed by a carrier with a better safety culture generally have lower PSQI values by -0.02 (Figure 3(g)). This disparity also becomes more obvious in the higher quantile.

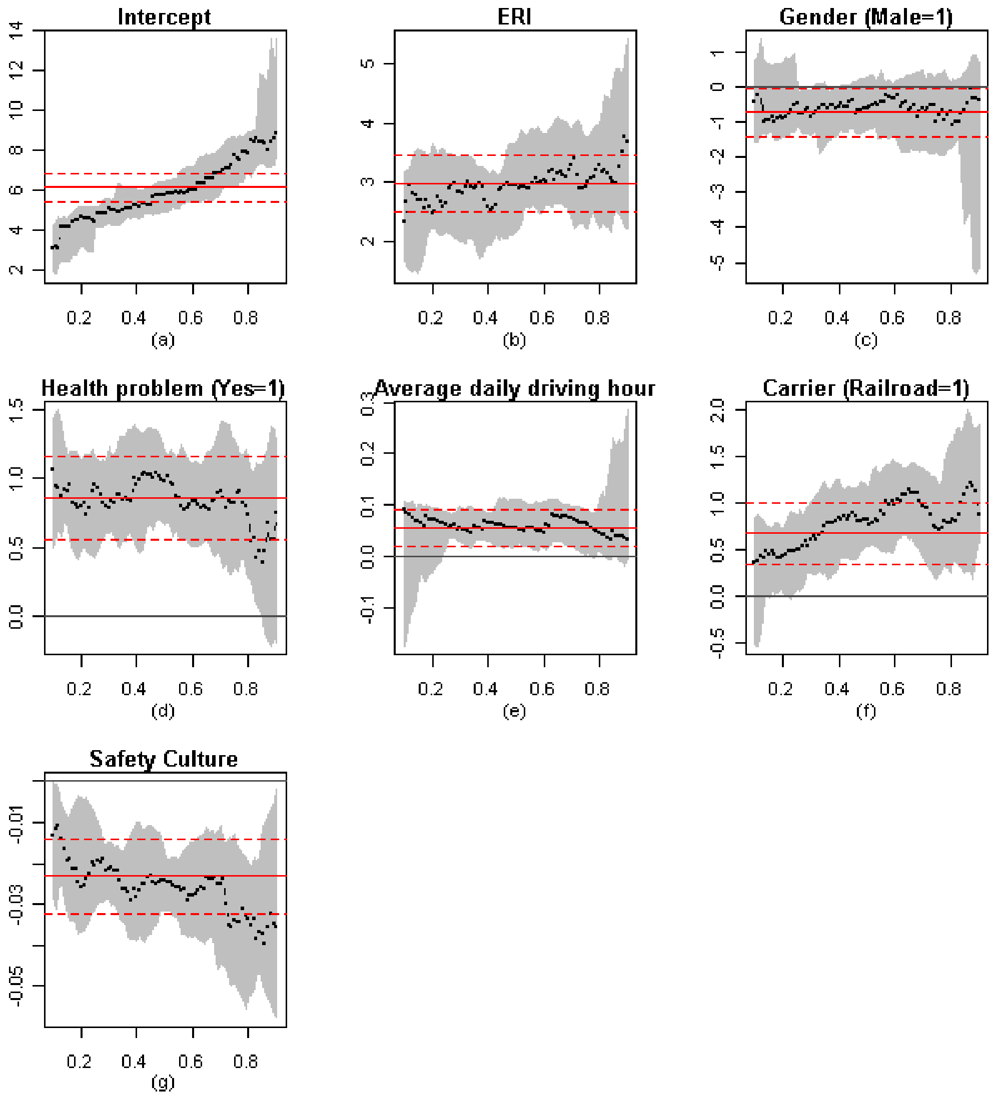

Figure 3 Quantile regression coefficient plots for the PSQI model

5.3 CBI model

The best model for work-related burnout contains an intercept plus eight covariates including ERI, PSQI, age, health problems, average daily driving hours, carrier type, and safety culture and its interaction with carrier type, as shown in Figure 4.

Figure 4(a) shows the estimated intercepts. The results suggest the conditional quantile function of the CBI value for a driver with average stress level and sleep quality, average age, no health problems within the past year, average daily driving hours, and employment with a bus carrier with average safety culture. The intercept steadily increases with an average of around 21.

The quantile regression results suggest that most covariate effects are not uniform over the whole range of the distribution. The ERI, PSQI, health problems and average daily driving hours show positive effects and these effects become more obvious in the upper quantiles. The ERI (Figure 4(b)) has the largest effect on the work-related burnout level, an average of 18, steadily increasing to more than 25 in the 0.9 quantile. Drivers who have reported health problems within the past year (Figure 4(e)) have the second largest positive effect, at an average level of 3.3, and increasing stably to 5.2 in the 0.9 quantile. The average impact of PSQI (Figure 4(c)) and average daily driving hours (Figure 4(f)) are at an average level of 2.1 and 0.9, respectively. Their impacts become larger at a decreasing rate; the impacts flatten out in the upper quantiles.

With the ordinary least squares method the age effect is significant at an average level of -0.1, as shown in Figure 4(d). However, this negative impact is only significant in the upper quantile, as shown by the quantile regression results.

Drivers who are employed by railroad carriers generally have a higher CBI level than those employed by bus carriers, as shown in Figure 4(g). This effect shows a decreasing trend over the whole distribution, with an exception around the 0.4 quantile, where the covariate effect suddenly increases.

Drivers who are employed by a carrier with a better safety culture have lower levels of CBI, at an average level of -0.1, as shown in Figure 4(h). This negative impact becomes more obvious with the increase of quantiles, levelling off in the upper quantile to a level of -0.16. Drivers employed by a railroad carrier with a better safety culture generally have a lower level of CBI, as shown in Figure 4(i). This interaction effect is rather uniform over the whole distribution.

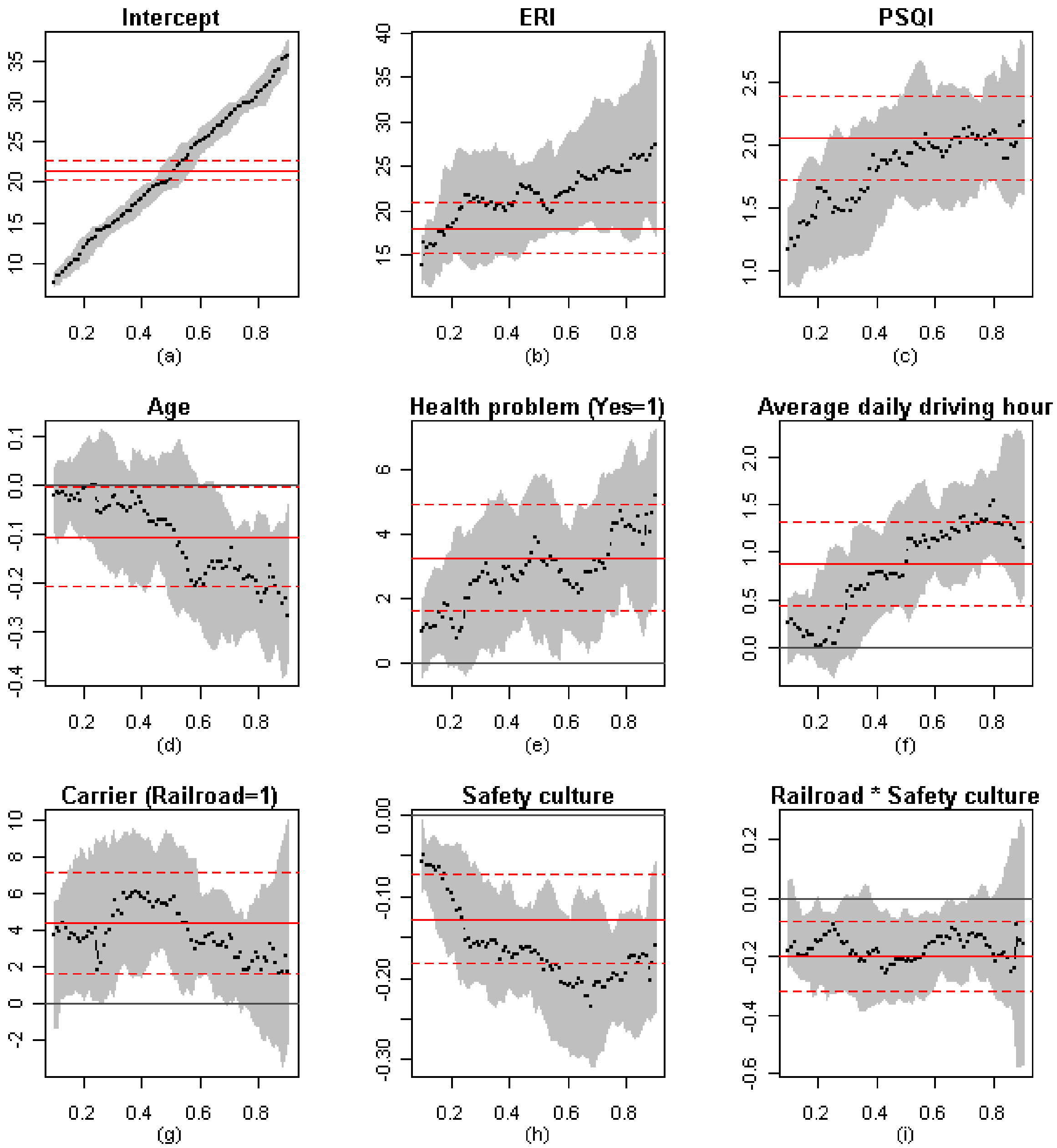

Figure 4 Quantile regression coefficient plots for the CBI model

6. DISCUSSION

This study investigates how driver characteristics and organizational factors are associated with the level of occupational stress, sleep quality and work-related burnout levels of railroad and bus drivers. We use the quantile regression method to examine the associations over the whole distribution. This is particularly useful because special attention should be paid to drivers with a higher stress level, poorer sleep quality and a higher burnout level.

The results show that most associations evaluated in this study are varied over the whole distribution, and either linear or quadratic in shape, a result which cannot be observed using the ordinary least squares method, where only the average impact is estimated. Most of the results suggest that the covariate effects become larger and the pointwise confidence bands are wider in the upper quantiles. A one-unit change in the covariate generally produces a larger impact in the upper quantiles than in the middle or lower quantiles. In other words, if only ordinary least squares are applied, one could underestimate the covariate effects in the upper quantiles.

Among driver characteristics, health problems are the most critical factor associated with stress level, sleep quality and burnout level. Railroad and bus driving takes a high physical and psychological load. Any impairment prevents drivers from working properly, which leads to further deterioration due to heavy stress. This is shown in the empirical results where stress plays the most critical role in determining drivers' sleep quality and burnout levels. Many health problems were reported during the survey, of which musculoskeletal problems were the most significant type, followed by hearing, vision, hypertension and hyperlipidemin problems. These health problems require a comprehensive system for health risk safety management, as has been proposed for the aviation industry, although much still needs to be done for the railroad and bus industries, especially in Taiwan.

BMI is another significant driver characteristic in the stress model. Drivers who have higher BMIs or have reported health problems within the past years are more likely to have higher stress levels. Overweight and obesity problems have been found for professional drivers in many countries (Aguilar-Zinser *et al.*, 2007). BMI is considered a risk factor to professional drivers since it usually relates to other physical health problems such as cardiovascular problems. In this study, drivers often reported concern about the ergonomic design of driver seats during the survey, which could be one possible reason for the higher stress levels reported by drivers with higher BMIs. Moreover, some sleep disorders are commonly associated with people with a higher BMI (Chin *et al.*, 2010) which might also increase the stress level.

Regarding organizational factors, safety culture has consistently been found to have a significant effect on reducing stress and burnout levels, and on improving sleep quality, especially for those in the upper quantiles. How drivers perceive their company's safety culture influences their own safety behaviour. Studies have shown that drivers who consider following the schedule to be more important than driving safety are more likely to report higher stress levels (Oz *et al.*, 2010). Furthermore, better safety culture is also found to be associated with fewer absences due to sickness (Bjornskau and Longva, 2009). The empirical results in this study reinforce the advantages of having good safety culture for professional drivers' health and wellness management.

Carrier type is the other significant organizational factor associated with the three dependent variables, which suggests the heterogeneity of different carrier types. Railroad, long-haul bus and short-haul bus carriers have distinct shift designs and working environments. These differences may not be fully explained by the considered covariates. To more effectively devise professional drivers' health and wellness management programs, these differences should be further clarified.

Compared to driver characteristics and organizational factors, stress plays a more critical role in the sleep quality and burnout level models, especially for drivers in the upper tail. This result echoes the importance of stress programs for professional drivers' health and wellness management, as has been suggested by past studies (Krueger et al., 2007; Tse et al., 2006). Railroad and bus drivers have been considered to be jobs with high levels of mental strain, partly because of their highly varied working environments and relatively weak connections to society and family. Professional drivers require shift rotation and long working hours. They also need to work at nights and on weekends, which reduces time with friends and family and increases their stress level.

Males and older drivers are found to have better outcomes in terms of stress level, sleep quality or burnout level. Female drivers are likely to report higher levels of stress than male drivers because of tension related to traffic (Hill and Boyle, 2007). Moreover, railroad and bus driving requires a high physical load, which may be a burden to some female drivers. In addition, since most professional drivers in Taiwan are males, female drivers work with colleagues of a different gender, which might also bring additional pressure. In past studies, older drivers have reported higher (Hill and Boyle, 2007) or lower (e.g. Langford and Glendon, 2002) stress levels, possibly due to the compromise between older drivers' deteriorating physical condition and their driving experience. In Taiwan, a professional driver's license will be revoked if he or she cannot pass the annual medical examination. The physical condition of older drivers who have survived for years in this job should be acceptable and these drivers have accumulated abundant experience to handle the stress in the daily working environment. This is why older professional drivers express a lower level of stress. However, there are more female and young drivers in railroad and bus driving, which suggests the requirement of devising strategies to assist these drivers to cope with stress and thus improve driving safety.

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