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An Analysis of Socio-economic Determinants Affecting Occupational Accidents

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산업재해에 영향을 주는 사회경제적 요인에 관한 연구

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Abstract

This study has found the socio-economic factors that affect occupational accidents and measured the influence quantitatively. We built the panel data of 4 countries (Japan, Germany, the U.S., and the U.K.) and the analysis model counted on the fixed effect model to reflect the countries' differences. The fatal occupational injury rates in the analyzed countries had a statistically significant relationship with the level of per capita GDP, the proportion of the construction industry, the rate of male workers, annual average working hours, the rate of workers in manufacturing and construction industries, etc. The annual average working hours have a positive correlation with the fatal occupational injury rate. To reduce occupational accidents effectively, we should be monitoring and researching various factors that can affect the occurrence of occupational accidents such as worker characteristics, changing industrial structure, and changes in working hours.

Keywords : Occupational accident rate, Socio-economic factors, Fixed effect analysis, Panel data

1. Introduction

Occupational accidents cause considerable national damages such as loss of lives, loss of labor capacity, and delay in production at business entities. In order to seek solutions to such damages, researchers are studying various factors that are related to the occurrence of occupational accidents. In particular, researchers in the area of social sciences are paying attention to not only the working environment of individual workers but also socio-economic factors including the level of economic growth, characteristics of industrial structure, the structure of labor market, etc. Kossoris (1938), a pioneer of related research, noted that the increase in demand for products caused by economic growth changes the possibility of occupational accidents by requiring workers to work faster and increasing the input of unskilled workers. The study showed that the occupational accidents rate could rise as unskilled workers enter the labor market during a rapid economic expansion period through an empirical analysis of the U.S. manufacturing industry. Asfaw et al. (2011), Neumayer (2004), and Ruhm (2000) also reported that occupational accidents grew during economic expansion with increasing gross domestic product (GDP) or industrial production indices, while occupational accidents decrease during economic recession. In addition, the studies mentioned that the incentives to report the occurrence of occupational

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accidents are also affected by the economic fluctuation. Leigh (1985) already expressed this viewpoint saying that workers tend not to report minor accidents during recession for fear of layoff.

Davies et al. (2009) analyzed the relationship between economic fluctuations and occupational accident rates in the U.K. from 1986 to 2004. It was an empirical analysis of how much occupational accident rate changed in accordance with the variation of GDP in nine industries. According to the analysis, minor accidents were related to the change of GDP while serious accidents had no statistical relationship. The study also analyzed the relationship between the conditions of the labor market and occupational accident rates from 1993 to 2005. As Breslin et al. (2007) mentioned, new employment and serious and minor accidents had a positive correlation. Moreover, working hours, the degree of concentration during working hours, etc. had positive correlation with both serious and minor accidents. Kim and Park (2020) showed that the number of occupational accidents per month is associated with the production index of manufacturing industry, the status of construction commencement, the ratio of male workers, etc. Kim(2022) pointed out that the employment instability of workers can adversely affect safety behavior and lead to occupational accidents.

In addition, there are also comparative studies between nations regarding the connection between socio-economic factors and occupational accidents. Mouza and Targoutzidis (2010) analyzed the relationship between the indexes of occupational accidents (fatal injuries, non-fatal injuries) and economic changes (per capita GDP, unemployment rate, and wage level) in six European countries (Austria, Finland, France, Italy, Germany and Switzerland), based on the data from 1990 to 2005. According to the study, per capita GDP had a statistically significant negative relationship with occupational accidents in all the countries. It can be interpreted that, if GDP increases, occupational accidents decrease due to improvement of safety consciousness, maintenance of related law systems, etc. Meanwhile, different results were deduced in terms of an unemployment rate among countries, and it was interpreted that the reason consisted in differences in labor intensiveness, flexibility of the labor market, etc. among countries. Nishikitano and Yano (2008) analyzed the difference in occupational accident mortality in OCED countries from 1993 to 1998. The study divided 27 OECD countries into three groups based on the annual occupational accident rate, and mentioned that the difference in mortality among groups originated from the industry proportion, expenditure in the public sector, the social insurance system related to compensation for occupational accidents, etc. Benavides et al. (2005) conducted an empirical study of the trend of diminution in the fatal occupational accident rate in five European countries (Austria, Finland, France, Spain and Sweden). The study pointed out that the reduction in the occupational accident rate of each country occurred in the transition from dangerous to safe jobs. The study also mentioned that such an analysis result could have derived from the so-called "export of hazard (Herbert and Landrigan, 2000)" where relatively dangerous jobs are transferred to developing countries as a result of international exchanges.

This study uses long time series data compared to previous studies and presents empirical research results by setting countries with relatively low occupational accident rates as research subjects. In addition, this study is designed to analyze the relationship with occupational accident rates by using the index reflecting the characteristics of the labor market, etc. The preceding studies have not approached such areas. This study aims to provide policy implications necessary for reducing occupational accidents rates to policymakers and researchers in countries with high occupational injury rates

2. Data and Methods

2.1 Data

This study counts on the data of occupational accidents and socio-economic factors in the countries subject to the analysis. The data of occupational accidents by country is collected from

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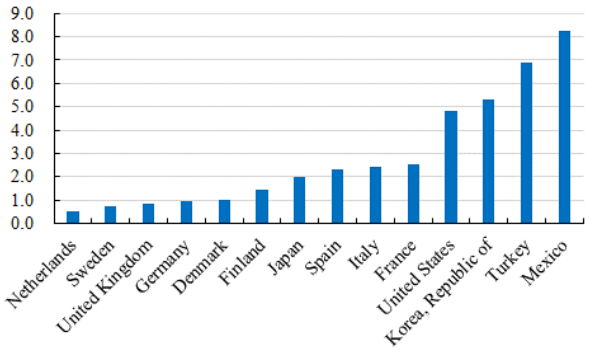
the agency in charge of the statistics of occupational accidents in each country. The data of socio-economic factors is obtained from OECD, ILO, IMF, UN, WEF, etc. The countries subject to the analysis correspond to Japan, Germany, the U.S., and the U.K. that can provide long-term data of occupational accidents with relatively low-rate occupational accidents. [Figure 1] By establishing as long as possible time series panel data of the countries with currently low rates of occupational accidents, this study aims to analyze which socio-economic factors worked to reduce occupational accidents



[Figure 1] Fatal occupational injury rates, ILO. 2015 (2016 in Japan)
(Unit: Fatal occupational injuries per 100,000 workers)

The data of occupational accidents is analyzed focused on occupational injury accidents. Among occupational accidents, occupational diseases are excluded since some countries including Japan do not publish the data. Moreover, in the case of diseases, there may be considerable time difference between the time of outbreak and that of working. Thus, it is highly difficult to grasp the time of working when a disease occurs, and it is thought inappropriate to analyze the influence of socio-economic factors.

For the analysis, the occupational injury rate is calculated as the rate of occurrence of accidents per 100 workers and the fatal occupational injury rate is calculated as the rate of occurrence of fatal accidents per 10,000 workers (‰). The number of workers used for calculation of occupational injury rate and the rate of fatal accidents per 10,000 workers is the one announced by the ILO to make an accurate comparison among nations. The socio-economic factors expected to affect the rate of occupational accidents are selected as shown in the following table referring to the aforementioned preceding research [Table 1].

The establishment of a national legal and institutional

<Table 1> Data descriptions and Sources

Factors	Variables	Description	Source
Occupational accident	fi_rate	Fatal occupational injury rate per 10,000 workers (‰)	Japan: Department of Welfare & Labor, U.S.: Bureau of Labor Statistics, Germany: BAuA, U.K.: HSE, No. of employees: ILO
	nfi_rate	Non-fatal occupational injury rate (%)	
Economic development	GDP_W	Per capita GDP (current 1,000 US$, PPP)	World Bank
	GDP_r	GDP growth rate (%)	UN
Industry structure	C_rate	Proportion of construction industry in the total added value (%)	UN
	M_rate	Proportion of manufacturing industry in the total added value (%)	
Labor market	Emnum_L	Number of employed people (1000 people)	ILO
	MEmnum_r	Rate of male workers (%)	
	Emnum65_r	Rate of employed people aged 65 or over (%)	
	EmInR_I	Rate of workers in manufacturing and construction industries (%)	
	UemR_I	Unemployment rate (%)	IMF
	Emwh_O	Annual average working hours (hour/year)	OECD
	PTemR_O	Rate of part-time workers (%)	
	TU_r_o	Union membership rate (%)	

system related to occupational safety and health is expected to be affected by the level and speed of economic development first, so per capita GDP and economic growth rate are used as socio-economic factors. Per capita GDP is based on U.S. dollars adjusted for purchasing power. For the index related to the industrial structure, the respective rate of the construction industry and the manufacturing industry in the total national added value are used. As the index related to the labor market, it counts on the number of employed people, the rate of male workers, the rate of employed people aged 65 or over, the rate of workers in manufacturing and construction industries among all workers, unemployment rate, annual average working hours, the rate of part-time workers, and the union membership rate. The number of employed people announced by the ILO is linked to the aforementioned data of occupational accidents to calculate the occupational injury rate and the fatal occupational injury rate per 10,000 workers, and it is also used to calculate the rate of male workers and the rate of employed people aged 65 or over.

The data established this way becomes panel data, which is a combination of time-series data that records phenomena or characteristics of a specific individual (business entity, nation, etc.) in chronological order, and cross-sectional data that collects phenomena or characteristics of multiple individuals at a specific time. The type of data to be analyzed in this study is a balanced panel data of four countries during the period from 1992 to 2018

2.2 Methods

The fixed effect analysis is used to analyze the established panel data in this study (Wooldridge, 2010). The reason why the fixed-effects model was chosen as the analysis method is that it has the advantage of being able to control characteristics in time series and between countries that are not observed in the data. If the explanatory variables included in the analysis are not perfect, the fixed effect model was judged to be a more advanced statistical estimation method than the OLS in that it controls features that are not generally observed between countries through a fixed effect using a dummy between countries.

Let's suppose that the dependent variable is y_{it} and the independent variable affecting the dependent variable is x_{it} . Here, $i$means an individual and t means the time when the data was generated. In this study, i stands for an individual nation and t refers to the year. In addition, the dependent variable (y_{it}) is the nation's occupational accident indicators such as occupational injury rate, fatal occupational injury rate, etc. The independent variables (x_{it}) are socio-economic factors such as per capita GDP, the proportion of the construction industry, the proportion of aged workers, etc. Suppose that the following linear regression model is estimated using these dependent and independent variables.

$$y_{it} = \alpha + \beta x_{it} + u_i + e_{it}, i = 1,2,\cdots,n, t = 1,2,\cdots,T \qquad (1)$$

α is the constant term, β means the degree of change in industrial accidents according to the change in x_{it} by 1 unit. There are two error terms of u_i, e_{it} in the panel data analysis. The error term u_i shows the characteristics of separate individuals that do not change over time and the error term e_{it} changes with time and individuals. The fixed effect analysis conducts an analysis by setting the error term u_i not as a random variable but as a parameter to be estimated. In such a fixed effect model, the above estimation can be expressed as follows.

$$y_{it} = (\alpha + u_i) + \beta x_{it} + e_{it} \qquad (2)$$

In this model, it is assumed that the constant term is different for each individual and is fixed. According to this assumption, the slope parameter of β is the same for all individuals but the constant term $(\alpha + u_i)$ differs for each individual. If the explanatory variable is related to u_i, it is regarded as the individual fixed effect. For example, this effect can be the cultural attributes, which are not observed in the panel data of nations. The β estimated in such a fixed effect model can be considered the average change of y_{it} due to the change of x_{it} when u_i is controlled. Like this, as β shows the effect

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when u_i is fixed, the fixed effect model basically defines the relationship extracted from within-individual variation. The between-individual variation is estimated by absorbing it as an unobserved error. This study uses the fixed effect model to eliminate the effect of fixed characteristics that cannot be observed in each nation, and the fitness of the model is judged by the F-test result.

3. Results

In this study, the model, which analyzes the effect of the national-level socio-economic factors on occupational accidents is set as follows

$$Y_{it} = \alpha + \beta X_{it} + \gamma I_{it} + \delta L_{it} + \tau D_t + \mu_i + \epsilon_{it} \quad (3)$$

Here, i and t mean each nation and year, respectively. Y means occupational accidents, X means the size of the nation's economy(GDP lebel), I refers to an industrial structure(Proportion of construction or manufacturing industry in the total added value), L means factors showing the features of the nation's labor market(Rate of male workers) while D means the year dummy. Table 2 demonstrates the descriptive statistics of the data, and the analysis model is set in consideration of both explanation power of the regression model and the significance of the included variables [Table 2].

<Table 2> Descriptive statistics of data

Variables	Obs.	Mean	Min.	Max.
fi_rate	108	0.25	0.04	0.54
nfi_rate	108	1.86	0.18	5.66
GDP_W	108	37,999	18,389	62,887
GDP_r	108	1.78	-5.70	4.75
C_rate	108	5.31	3.37	8.48
M_rate	108	17.70	9.92	26.15
Emnum_L	108	67,101	25,478	155,761
MEmnum_r	108	55.27	52.67	59.53
Emnum65_r	108	4.12	0.88	12.94
EmInR_I	108	26.35	18.13	37.27
UemR_I	108	5.96	2.20	11.00
Emwh_O	108	1,640	1,390	1,965
PTemR_O	108	19.88	12.25	24.97
TU_r_o	108	20.85	10.10	39.50

According to the examination of the fatal occupational injury rate as a dependent variable (Model 1), it turns out that there is a statistically significant correlation with per capita GDP[1] showing the economic level of a nation's people, the proportion of the construction industry, the rate of males among employed people, and the annual average working hours [Table 3]. According to the analysis results of Model 1, the fatal occupational injury rate decreases with an increase in per capita GDP. As mentioned in aforementioned preceding studies, it means that the fatal occupational injury rate can decrease in line with the rise in the income level of the nation by reorganization of safety-related systems, improvement of awareness level, etc. In addition, as the proportion of the construction industry, which is recognized to have a relatively higher risk of fatal accidents compared to other industries, increases by 1%, the fatal occupational injury rate is estimated to increase by 0.0325‰. Likewise, the rate of male employees has a statistically significant positive relationship with the fatal occupational injury rate. This is considered to be related to the high possibility of male workers being put into industry/work with relatively high risk of occupational accidents. It appears that the fatal occupational injury rate increases by 0.0002‰ if annual average working hours enlarges by one hour. It confirms that prolonged working hours can be a factor accelerating the occurrence of fatal accidents.

<Table 3> Analysis results of socio-economic factors and fatal occupational injury rate

Variables	Model 1
ln(GDP_W)	-0.1977 ***
C_rate	0.0325 ***
MEmnum_r	0.0393 ***
Emwh_O	0.0002 *
EmInR_I	-0,0338 ***
constants	-0.6344 **
	Including year dummy
Obs.	108
within R-sq.	0.9724
Prob > F	0.0000

Statistical Significance: ***1%, **5%, *10%

1) The variable GDP_W has a unit root, therefore the unit root was removed by log transformation

Meanwhile, contrary to intuitive expectation, it is evaluated in Model 1 that, the higher the proportion of workers in the manufacturing and construction industries, the lower the fatal occupational injury rate. In relation to this, this study intends to examine if the same results come out if the dependent variables are substituted with occupational injury rate or non-fatal occupational injury rate, and inquire into the reasons through additional models.

<Table 4> Analysis results of socio-economic factors and non-fatal occupational injury rate

Variables	Model 2	Model 3
ln(GDP_W)	-7.3502***	-5.3118***
C_rate	0.2587***	
M_rate		-0.1510***
MEmnum_r	0.5698***	0.4751***
Emwh_O	-0.0050***	-0.0044***
EmInR_I	-0.6429***	-0.5550***
UemR_I	-0.1779***	-0.1996***
constants	21.7497***	21.9918***
	Including year dummy	
Obs.	108	108
within R-sq.	0.9196	0.9176
Prob > F	0.0000	0.0000

Statistical Significance: ***1%, **5%, *10%

In addition, a correlation analysis is conducted between the non-fatal occupational injury rate and socio-economic factors (Model 2 and 3). The proportion of the manufacturing industry in Model 3 has a negative relationship with the occupational injury rate. It means that the occupational injury rate decreases as the proportion of manufacturing industry increases during the period of analysis in the countries subject to the analysis. Such analysis results can derive from; firstly, the countries included in this analysis may have reduced occupational accidents in the manufacturing industry effectively through occupational accident prevention policies while increasing the creation of added value. Secondly, as Benavides et al. (2005) mentioned, it can originate from export of hazard of occupational accidents to developing countries in accordance with the expansion of international trade.

The higher the unemployment rate, the lower the occupational injury rate. It is the same result as in preceding studies including the one conducted by Asfaw et al. (2011). It is interpreted that, if the unemployment rate decreases due to economic recovery, the employment of relatively unskilled workers expands bringing about rise in the rate of occupational accidents.

However, the difference between the fatal injury rate analysis and the analysis of the injury rate & the non-fatal injury rate is confirmed particularly in the variable of annual average working hours. In the analysis of fatal injury rate, it is estimated that, if the annual average working hours increases, the fatal occupational injury rate also rise. On the contrary, in the analysis of the injury rate & the non-fatal injury rate, it turns out that the occupational injury rate decreases in proportion to increase of the annual average working hours. Such a result may be due to the fact that fatal accidents and non-fatal accidents have different correlations with working hours. This is speculated that the rate of part-time workers is significantly involved. According to the research result of Kossoris (1938) and Leigh (1985), the cyclical change in the occupational injury rate is related to the incentive to report the occurrence of an accident. That is, workers may not report minor accidents during recession for fear of layoff. Unlike the fatal occupational injury rate analysis model, legal working hours can be one of the causes of the decrease in the occupational injury rate and non-fatal occupational injury rate as the annual average working hours increase. Advanced countries, including the four countries in this study, have conducted the policies to reduce legal working time, and, as a result, the absolute time for input of one worker into the production line has decreased. Thus, it is probable that a business entity hired new workforce to compensate for the shortage of production quantity. There is a high probability of having hired relatively unskilled workers as new workforce and this can lead to increment of the risk of occupational accidents. Therefore, it is assumed that such reasons may have brought about deduction of these analysis results.[2)]

2) In addition, besides the data included in the preceding models,

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4. Conclusion

This study has found out the socio-economic factors such as the economic level of a nation's people, industrial structure, the characteristics of the labor market, etc., which affect the occurrence of occupational accidents and measured the influence in a quantitative manner. The purpose of this study consists in providing suggestions for other countries that are making every effort to reduce occupational accidents, by conducting an analysis based on the data of Japan, Germany, the U.S., and the U.K., which have a relatively large economic size and low rates of occupational accidents. The analysis model used in this study is the fixed effect model considering that the statistics related to occupational accidents differ from country to country depending on the scope of inclusion of occupational accidents, the standards for recognition of occupational accidents, etc. Moreover, this study counted on the fixed effect model to reflect the difference among countries that are not observed.

According to the analysis, the fatal occupational injury rates in the analyzed countries had a statistically significant relationship with the level of per capita GDP, the proportion of the construction industry, the rate of male workers, annual average working hours, the rate of workers in manufacturing and construction industries, etc. Besides, it was analyzed that the higher the proportion of the construction industry, the rate of male workers, and the annual average working hours, the higher fatal occupational injury rate. On the contrary, it was confirmed that, the higher per capita GDP and the ratio of manufacturing and construction workers, the lower the fatal occupational injury rate. In the non-fatal occupational injury rate analysis model, the proportion of manufacturing industry had a negative correlation with the occupational injury rate differently from the proportion of construction industry. It can be interpreted as a positive effect of policies of the countries subject to the analysis to prevent occupational accidents in manufacturing industry. In addition, it is possible that the industrial structure of the relevant countries has changed to put emphasis on the manufacturing industry with lower risk of occurrence of occupational accidents. Meanwhile, it was examined that the annual average working hours have a positive correlation with the fatal occupational injury rate but a negative correlation with the non-fatal occupational injury rate. It means that, when a nation reduces the legal working hours in terms of policies and business entities hire more unskilled workers to maintain their production, it can lead to the increase of minor accidents such as non-fatal accidents.

Though this study has a limitation of analyzing limited countries, it is meaningful that it contributed to identifying the factors that affect the occupational accident rate and analyzing their quantitative effects. Countries with relatively higher rates of occupational accidents will be able to more effectively prevent occupational accidents by designing their policies based on the cases of advanced countries that have achieved reductions in the occupational accident rates at a relatively earlier time. It will also help establish policy directions to effectively reduce occupational accidents if monitoring and research on various factors that can affect the occurrence of occupational accidents such as worker characteristics, changing industrial structure, and changes in working hours are properly maintained.

this study included for the analysis such as the variables of economic growth rate, the ratio of part-time workers, labor union membership, efficiency of the labor market, total medical expenses, etc. However, no significant results were deducted as the significance of estimated coefficient was not high or the explanatory power of the model sharply decreased.

5. References

[1] A. Asfaw, R. Pana-Cryan, R. Rosa(2011), "The business cycle and the incidence of workplace injuries: Evidence from the U.S.A." Journal of Safety Research, 42(1):1-8.

[2] F. G. Benavides, J. Benach, J. M. Maritinz, S. Gonzalez(2005), "Description of fatal occupational injury rates in five selected European Union countries: Austria, Finland, France, Spain and Sweden." Safety Science, 43:497 - 502.

[3] F. C. Breslin, J. Polzer, E. McEachen, B. Morrongiello, H. Shannon(2007), "Workplace injury or part of the job? Towards a gendered understanding of injuries and complaints among young workers." Social Science & Medicine, 64(4):782 - 793.
[4] B. J. Kim(2022), "Servant leadership makes safety the effect of job insecurity on safety behavior." J. Korea Saf. Manag. Sci., 24(1):21-30.
[5] R. Davies, P. Jones, I. Nunez(2009), "The impact of the business cycle on occupational injuries in the UK." Social Science & Medicine, 69:178-182.
[6] R. Herbert, P. J. Landrigan(2000), "Work-related death: A continuing epidemic." American Journal of Public Health, 90:541 - 545.
[7] D. K. Kim, S. Park(2020), "Business cycle and occupational accidents in Korea." Safety and Health at Work, 11(3):314-321.
[8] M. D. Kossoris(1938), "Industrial injuries and the business cycle." Monthly Labor Review, 46:579-594.
[9] J. P. Leigh(1985), "The effects of unemployment and the business cycle on absenteeism." Journal of Economics and Business, 37:159-170.
[10] A. M. Mouza, A. Targoutzidis(2010), "The effect of the economic cycle on workplace accidents in six European countries." Ege Academic Review, 10(1):1-13.
[11] E. Neumayer(2004), "Recessions lower (some) mortality rates: Evidence from Germany." Social Science & Medicine, 58(6):1037-1047.
[12] M. Nishikitani, E. Yano(2008), "Differences in the lethality of occupational accidents in OECD countries." Safety Science, 46:1078-1090.
[13] C. J. Ruhm(2000), "Are recessions good for your health?" The Quarterly Journal of Economics, 115(2):617 - 650.
[14] J. M. Wooldridge(2010), Econometric analysis of cross section and panel data (3rd ed). MIT Press: London, England, pp. 300-315.

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