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Investigating the long-term change of injury pattern on severity, accident types and sources of injury in Taiwan's manufacturing sector between 1996 and 2012

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ABSTRACT

The purpose of this study is to explore the long-term changes of occupational injury patterns from macro-perspective. Correspondence analysis was applied to chart longitudinal changes in occupational injury patterns (including severity, accident type, and source of injury) based on 92,577 cases reported by manufacturing firms in Taiwan between 1996 and 2012. Cluster analysis revealed three phases for injury severity and two for accident type and source of injury. The Kruskal–Wallis test revealed whether and which injury severity, accident type and source of injury had significant difference among different phases. Factors such as business cycles and industrial structure that contribute to the change of occupational injury patterns were elucidated. The results showed that, even within an industry, the injury pattern and epidemiology vary according to contextual factors such as longitudinal business cycle and cross-sectional industrial structure. Safety policy or injury prevention evaluation must be implemented in response to the influence of contextual factors, industrial characteristics and the main industries.

1. Introduction

Various individual, occupational and organizational factors contribute to accidents and injuries at the workplace (Khanzode et al., 2012), and these factors may differ across industries or nations. Some studies focus on general fatalities causation patterns across industries or within a nation (Conte et al., 2011; Williamson et al., 1996). Other studies identified factors contributing to occupational injuries in such industries as the construction sector (Cheng et al., 2010, 2012; Liao and Perng, 2008). In terms of accident types, Chi et al. (2005) focused on falls; Lu et al. (2012) analyzed fire; Nenonen (2013) studied slipping, stumbling and falling. Chi et al. (2004) studied the relationship between accident type and source of injury. Examining working contexts, organizational mechanisms and contributing factors that influence occupational injury provides information which can be drawn on to improve workplace safety.

The longitudinal change of injury pattern or epidemiology were also studied or compared. Laflamme and Menckel (1999) studied the distribution, patterns and associated characteristics of injuries in Swedish schools during recesses. Bakhtiyari et al. (2012) investigated the epidemiological patterns of occupational accident in Iranian workers between 2001 and 2005. Chen et al. (2012) studied the tendency of accidents in China's coal mines and the characteristics of human factors. Leinert et al. (2012) investigated the epidemiology of lawn trimmer injuries in the United States during 2000–2009.

Empirical studies also confirmed a longitudinal association between the business cycle and workplace injury at national level (e.g., Boone and van Ours, 2006; Song et al., 2011) and industrial level (e.g., Asfaw et al., 2011; Davies et al., 2009). That is, the incidence of workplace injury increases during economic upturn but decrease during economic downturn.

A majority of works discussed only longitudinal relationships such as the association between business cycle and incidence of workplace injury, or cross-sectional relationships such as the association among industry, accident type, and injury source. Understanding the long-term change of injury pattern and the underlying mechanism within a given industry may produce fruits needed to boost policymaking and accident/injury prevention. Considering both longitudinal time-series fluctuations and cross-sectional change of injury pattern or injury epidemiology, this study seeks to answer the following questions:

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(a) Do occupational injury patterns/epidemiology change over time?
(b) Does this change happen randomly or gradually?
(c) Is there any mechanism that explains the change of injury pattern?

Therefore, this study examined long-term changes in occupational injury patterns of the manufacturing sector in Taiwan. Different phases and the corresponding injury patterns (including injury severity, accident type and source of injury) would be identified. Factors that contribute to changes in injury patterns (business cycle and changes in industrial structure) would also be discussed.

2. Materials and methods

2.1. Data sources and terms

According to Labor Safety and Health Act in Taiwan, companies with more than fifty employees must report monthly lost working hours caused by disabling injuries to inspection agency. Each formal occupational injury report covers the type of industry, worker information (i.e. age, gender, and experience level), injury source, accident type and other contributing factors. To investigate the long-term change of injury pattern, we examined 92,577 occupational injuries reported in the manufacturing sector between 1996 and 2012. These reported cases are recorded in the occupational accident database of the Council of Labor Affairs (CLA) of Taiwan.

CLA adapted the standards of the accident classification scheme of the American National Standards Institute, Z.16.2 (ANSI, 1995) to yield occupational injury patterns that include injury severity, accident type, and injury source. Accident type refers to the event that results in injury, whereas the source of injury is the object, substance, exposure or bodily motion that leads to the injury (Lortie and Rizzo, 1999). Similar classifications of accident type and source of injury have been applied in earlier studies (Cheng et al., 2010; Chi et al., 2004; Chi and Wu, 1997) to yield descriptions of accident characteristics that shed a light on the underlying co-relations and occurrence mechanisms.

By CLA's criteria and research purpose (Table 1), the severity of injury is divided into four grades, from death to temporary disabling injury. Accident type covers 17 categories,[1] such as fall, collapse and clamp; and the source of injury yields 8 categories such as power machinery, construction equipment, and chemicals and materials.

Clearly, the contingency table presents the statistics as annual records. In line with the previous studies, all the injury patterns were transformed into frequencies of injury reported per million hours worked. To offset interference by denominator size (i.e. variations in annual working hours), correspondence analysis of the relative ratio of injury to per million hours worked were conducted. With this analysis performed, relative ratio would be more statistically appropriate than accumulation accounts for allowing for comparisons not only by year and but by sector.

2.2. Data analysis

2.2.1. Correspondence analysis

Correspondence analysis (CA) is a multivariate statistical technique for describing cross-tabular data by converting tables into two-dimensional graphical display.[2] It is conceptually similar to principal component analysis, but applies to categorical rather than continuous data and allows for exploring the structure of categorical variables included in the table.

Table 1
Category and code description of injury severity, accident type, and source of injury.

Injury pattern	Description
Severity	
S1	Death
S2	Whole body permanent disabling injury (hemiplegia and paralysis)
S3	Partial permanent disabling injury (handicapped)
S4	Temporary disabling injury (hospital care for hours or days)
Accident type	
AT1	Tumble (fall from a tree, building, machine, car, ladder, slope, stair, etc.)
AT2	Trip or slip
AT3	Collision or bump
AT4	Falling objects
AT5	Collapsed objects
AT6	Struck by (except due to traffic accident)
AT7	Clamped between objects (except due to traffic accident)
AT8	Cut, puncture, or abrasion
AT9	Prick
AT10	Contact with extreme temperatures (burn or frostbite)
AT11	Poison (including radiation, carbon monoxide poisoning, anoxia)
AT12	Electrical shock
AT13	Explosion
AT14	Broken objects or container
AT15	Fire
AT16	Improper actions or behaviors
AT17	Others
Source of injury	
SI1	Power machinery (motor and gear)
SI2	Loading, handling, and hauling machinery (e.g., cranes and forklifts)
SI3	Other equipment (e.g., pressure vessels and furnaces)
SI4	Construction equipment
SI5	Chemicals and materials
SI6	Cargos and goods
SI7	(Unsafe) environments
SI8	Others

CA reveals relationships that are otherwise undetected in a series of pair-wise comparisons of variables and helps to portray how variables are associated—not merely that an association exists (Lu et al., 2012). Hence, CA has been conducted to describe accident causation sequence, the relationship among occupational groups, and the nature of the accident precursor (Williamson et al., 1996). By applying CA, Conte et al. (2011) identified three risks and injury groups for all Spanish companies, and Lu et al. (2012) found influential factors involving place, cause, time of day, month, year and province in high-casualty fires. To chart the changes of injury pattern, we performed CA on the statistics (these are cross-tabular data) derived from the CLA. Calculation steps of CA are presented in Appendix A.

2.2.2. Cluster analysis

Clustering means to classify data that share similarities into groups (Mohamed et al., 2013). A technique for statistical data analysis used in many fields, cluster analysis is widely applied to exploratory data mining and pattern recognition.

Cluster analysis enables mathematical calculation in two phases: first, using a hierarchical method to decide that cluster numbers are "k", and secondly, using a nonhierarchical method to move variable numbers within clusters while the cluster numbers still keep "k". The initial cluster numbers are decided by employing Ward's method as a basis of calculating the best solution (Clausen, 1998).The clustering is yielded by integrating Ward's method and K-means (Punj and Stewart, 1983). Therefore,

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[1] Non-workplace related accident types such as commuting traffic accident and drowning were not included.

[2] CA is a widely applied multivariate statistical technique, and its algorithm and methodology can be found on Wikipedia or in Lu et al. (2012).