6-30-2021

An investigation of the influence of economic cycles on safety performance in Western Australia

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10.1016/j.ssci.2021.105230
This is an author's accepted manuscript of: Jenke, T., Oosthuizen, J., & Cattani, M. (2021). An investigation of the influence of economic cycles on safety performance in Western Australia. *Safety Science, 138*, aticle 105230. https://doi.org/10.1016/j.ssci.2021.105230

Safety Science

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--Manuscript Draft--

Manuscript Number:	SAFETY-D-20-00642R2
Article Type:	Research Paper
Keywords:	Occupational Injuries, Economic Cycles, Industry Groups, Resilience, Safety Performance
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Manuscript Region of Origin:	Asia Pacific
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Response to Reviewers:	

Highlights

- Occupational injuries impacted by economic cycles in Western Australia
- Safety management systems should be built to be resilient to economic changes
- Global Financial Crisis and COVID-19 have triggered economic changes
- Organisations are required to ensure workforce is safe at all times

Abstract

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Title Page (with Author Details)

An investigation of the influence of economic cycles on safety performance in Western Australia

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Declaration of Interests: None

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Keywords

Occupational Injuries, Economic Cycles, Industry Groups, Resilience, Safety Performance

1. Introduction

The International Labour Organisation (ILO), a United Nations agency responsible for international labour and social protection standards estimates that globally 6,300 workers die every day as a result of occupational injuries or diseases (International Labour Organisation, 2017). Widely viewed

as unacceptable, ILO initiatives bring together governments, employers and workers of 187 member States (including Australia), to set labour standards, develop policies and devise programmes promoting safe work for all (International Labour Organisation, 2017).

In Australia, 144 employees died in 2018 due to occupational injuries (SafeWork Australia, 2019) at a cost of $62 billion dollars annually or 4% of Australian's Gross Domestic Product (GDP). In comparison to other developed countries such as the United States and the United Kingdom, the number of occupational fatalities in Australia is lower than the 5,250 deaths due to occupational injuries reported in the United States in 2018 (Occupational Health and Safety Association, 2020), and the 147 worker deaths in the United Kingdom in 2018 (Health and Safety Executive, 2020).

The International Organization for Standardization (2018) identifies in the *ISO 31000-Risk Management: Guidelines* that organisations must examine internal and external factors when managing risk. Internal factors such as the composition of the workforce, safety culture and competency of the leadership team have been shown to influence the risk of occupational injuries (Fabiano et al., 2008; Geldart et al., 2010; Khanzode et al., 2012). Whilst most research is concerned with understanding the management of risk associated with internal factors, it has also been shown that external factors such as the economy, political environment, technology changes and globalisation play a role (Adeleke et al., 2018; Asfaw et al., 2011; Chang et al., 2018; Hovden et al., 2010). There are a variety of factors which can influence an organisation's ability to effectively prevent injuries. Organisations must consider the impact of the internal and external stakeholders in the development of their risk based approach, which forms the foundation of their operational management plans (International Organization for Standardization, 2018). Subsequently, in pursuit of an increase in performance organisations must investigate these factors to provide insight into the causes of injuries, and inform the development of interventions to prevent recurrence or other injuries (SafeWork Australia, 2017).

Changes to economic stability, government resourcing and priorities, for example, have the potential to create change within organisations and may influence safety performance, however the influence of economic cycles is not well understood in the Australian context.

Economic cycles are natural fluctuations in the economy, characterized by periods of growth and decline (Lim et al., 2010). Macroeconomic measures such as GDP, unemployment rates and consumer spending are used to determine if the economy is in a growth or recession stage of the cycle. GDP is the value of all goods and services produced in a country over a period (Hartzell et al., 2015).

Economic growth is characterized by an increase in GDP, a decrease in unemployment and high consumer spending (Hartzell et al., 2015; Lim et al., 2010). Conversely, a decrease in GDP and a rise in unemployment are characteristics of a period of economic decline (Lim et al., 2010). While economists consider GDP the broadest indicator of economic output and growth, they also recognize that this single aggregate factor may not illustrate a complete picture of the economy and advise looking at other macroeconomic factors such as unemployment rate as well (Asfaw et al., 2011).

This research will provide some additional insight into the impact of the external factor, economic cycles on safety performance in Western Australia over a period of 16 years.

1.2. Background

1.2.1. Procyclical

De la Fuente et al. (2014) describe a procyclical relationship as periods when the economy grows and the number of occupational injuries increase, and conversely when the number of occupational injuries decrease during a recession. Davies et al. (2009) observed that a 1% increase in the GDP of the United Kingdom was strongly associated with a 3% increase in occupational injury rates. In 2014, De la Fuente et al. (2014) identified a 50% decrease in the number of occupational injuries from 2009 – 2013, a period of recession for Europe, compared to 2007 when the economy was in a growth period. Boone et al. (2011) support procyclical behavior, as logically during economic growth there is more work being done which increases the likelihood of injuries. Fabiano et al. (2008) suggest that the increase in hiring new unskilled workers during a period of economic growth contributes to an increase in occupational injuries. Fernández-Muñiz et al. (2016) posited that economic growth increases the demand for goods and services, which leads to less maintenance and results in unsafe equipment which may increase the risk of injuries. While there are differing conclusions as to the causes of procyclical behaviour, the concept of a procyclical relationship is supported by several economic researchers.

As the pace of work is slower during recession Asfaw et al. (2011) argues that there is sufficent time to train and upskill workers during employement thus decreasing the risk of injury. It also suggested that there are less workers available to report injuries during a recession. Of those remaining workers, as many as 20% fear harassment and risk of dismissal when reporting occupational injuries during periods of recession (Boone et al., 2011; Palali & Ours, 2017). In a study conducted in the United States Hartzell et al. (2015) reported 21% of injured employees lost their job after filing an occupational injury claim during a recession and 25% of employees were discouraged by their employer to submit a claim. This form of “risk secrecy” can further facilitate an atmosphere of underreporting injuries,

resulting in unsafe work environments not being rectified and false sense of security in actual safety statistics (Dekker & Pitzer, 2016).

Moreover, during a recession there are less workers employed in high risk industries such as mining and construction (International Labour Organisation, 2013). Fernández-Muñiz et al. (2016) propose that if high-risk industries lay off more employees during a recession then this will lead to lower accident rates. They further suggest that during recession a "natural selection" pheonomena occurs, whereby older more skilled workers are maintained and thus are less likely to be injured (Fernández-Muñiz et al., 2016).

It is evident that while a procyclical relationship is described in the literature for the United States, United Kingdom and European Union, the underpinning mechanisms are yet to be confirmed. Further research into this area for Australia, a country not previously researched, may provide opportunity to gain insight in the causal mechanisms.

1.2.2. Countercyclical

A countercyclical relationship is when the economy grows and the number of occupational injuries decrease and when the economy undergoes recession the number of occupational injuries increase (Boone et al., 2011). Sønderstrup-Andersen and Bach (2018) reported a countercyclical association in Denmark (for occupational health and safety performance for Danish employees) in 2011, during a period of economic recession when compared to 2006, a period of economic growth. Probst et al. (2018) reported countercyclical behavior of occupational injuries when conducting surveys of workers in Italy, specifically for temporary contract workers.

The International Labour Organisation (2013), indicated that while recessions can provide challenges to occupational health and safety there is no conclusive causal link between recessions and increased occupational injuries. One theory to explain the mechanism of countercyclical behavior is that during a recession there are fewer workers, resulting in higher hazard exposures to individual employees, resulting in more injuries (Asfaw et al., 2011). Probst et al. (2018) suggest that that job insecurity, as experienced during recession periods increases safety non-compliance for workers, leading to greater adverse safety outcomes. This indicates that employees who are worried about maintaining a job during a recession may tolerate higher risk behaviour, possibly leading to more occupational injuries. The ILO determined that there were severe threats to workplace health and safety as a direct result of the restructuring and downsizing from the Global Financial Crisis, resulting in injuries, but also an increase in mental health issues including suicide (International Labour Organisation, 2013).

During economic growth companies are more likely to have budgets to allocate to safety training and performance, which will lead to a decrease in rates of occupational injuries. Additionally, during economic expansions there are more likely to be jobs focused on health and safety performance improvement, resulting in more resources for safe work. Provan and Pryor (2019) noted a significant demand for safety professionals in Australia in early 2000's, a period of economic growth and investment into the resource and construction industries.

The Global Finacial Crisis, which occurred in 2007 – 2009 had a drastic impact on the international financial system. Many economies saw a sharp decrease of over 10% in GDP (International Labour Organisation, 2013). The reduction in GDP put substantial pressure on governments and companies to reduce spending and re-organize business functions. This resulted in severe cuts to spending by governments and, by multiple corporations, and to jobs, specifically in the safety field (Johnson, 2014).

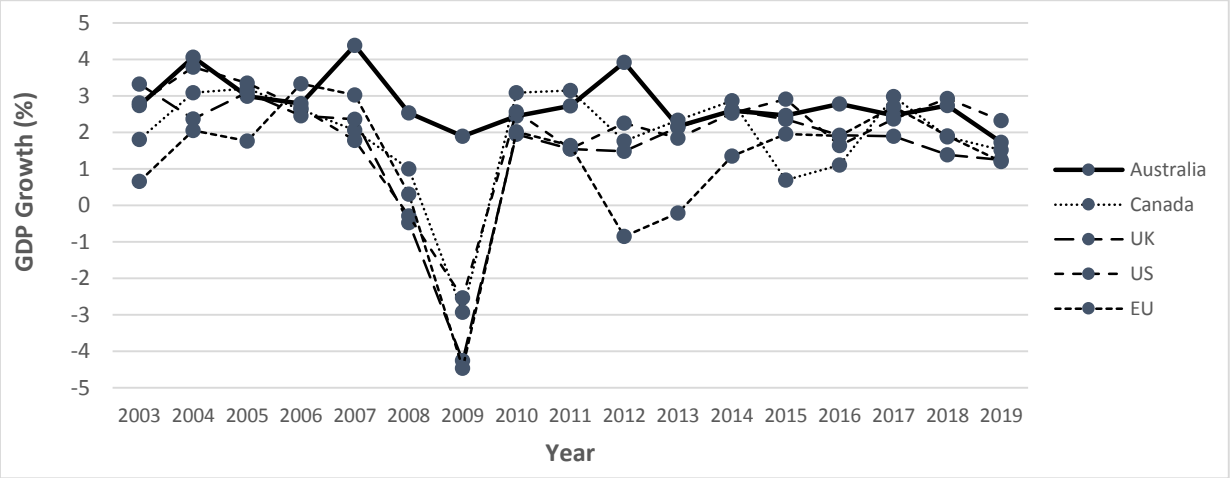


Fig. 1. Time Series Graph of GDP for Australia, Canada, United Kingdom (UK), United States (US) and European Union (EU). (Organisation for Economic Co-operation and Development, 2020).

In an effort to counteract the effect of the Global Financial Crisis, the Japanese Government laid off hundreds of professionals, including safety regulators. Johnson (2014), asserts that the Fukushima nuclear disaster may have been avoided had previously laid off safety regulators been employed to predict and proactively mitigate the impact of the tsunami that killed hundreds of people who lived near the Fukushima nuclear facility which exploded.

In *Ten Pathways to Death and Disaster: Learning from Fatal Incidents in Mines and Other High Hazard Workplaces* (Quinlan, 2014) identified the external factor of reduction in regulator action as one of the ten pathways contributing to catastrophic occupational fatalities. When safety regulators are laid off during recession times, then occupational fatalities as seen during Fukushima may occur.

The Australian economy continued to grow during the Global Financial Crisis while many other countries' economies plummeted (see Figure 1). The stabilisation of the Australian economy is mostly attributed to a strong macroeconomic policy response, continued high prices in the commodity markets and a financial system more resilient than many other Western countries (Organisation for Economic Co-operation and Development, 2017). Rapid industrialisation in China continues to be a prominent driver for expansion in the mining industry of Western Australia, resulting in increased growth in this industry group. The influence of the Global Financial Crisis on occupational injury rates has not been published for Australia.

1.2.3. Variation Between Industries

The industry composition of the economies of Western Australia, the United States and United Kingdom are different. When reviewing the industry composition of Western Australian economies compared to the United States and United Kingdom, mining and construction are the predominant industries in Western Australia, employing 20% of the population (Australian Bureau of Statistics, 2019b) compared to 8% in the United States (Occupational Health and Safety Association, 2020) and 11% in the United Kingdom (Health and Safety Executive, 2019). The United States and United Kingdom have a higher percentage of workers employed in the manufacturing industry (Health and Safety Executive, 2019; Occupational Health and Safety Association, 2020). Industry composition is important as the sensitivity of injury rates industries could be dependent on the contribution and composition of each industry to Western Australian aggregate economic factors (Asfaw et al., 2011).

Globally, construction is considered a hazardous industry accounting for 1 in 5 (20%) of occupational fatalities in the United States in 2016 (Occupational Health and Safety Association, 2020). In Australia, 30 construction fatalities occurred in 2017, which represents 16% of Australian occupational fatalities (SafeWork Australia, 2018). Although the agriculture industry employs less than 3% of the Australian and United Kingdom workforce, on a per capita basis, it has the highest rate of occupational fatalities in both countries 25% and 22%, respectively (Health and Safety Executive, 2020; SafeWork Australia, 2019).

A limitation of many studies exploring the relationship between economic cycles and occupational injuries has been the issue that data has not been analysed by specific industry group thus assuming that all industries are equally affected by economic cycles. Asfaw et al. (2011) and Fernandez-Muniz et al (2016) identified this omission as limitations in their studies, that would provide further insight into the impact of economic cycles on industry occupational injury rates.

Cycles of economic growth and recession have impacted the agriculture, manufacturing mining and construction industries in different ways. For example, each of these industries have changed worker shift length and intensity of work pace due to increased demand for goods and services and increased recruitment of inexperienced employees. This acceleration in the pace of work has increased the risk of injuries (Chang et al., 2018; Davies et al., 2009). The changes in workplace composition (i.e. younger, temporary workers) have resulted in a decline of occupational injuries during recession and an increase during growth, specifically in construction industry (Lander et al., 2016; Nielsen et al., 2015).

The differences of this study when compared to similar studies is that this research is specifically looking at the impact of economic cycles in Western Australia, which is significant because Australia was not severely impacted by the Global Financial Crisis in 2008. Additionally, this study combines an assessment of both macro and micro economic indicators to determine the sensitivity of four specific industry groups (agriculture, manufacturing, mining and construction). Previous studies have looked at aggregated factors across multiple industries or microeconomic factors for one specific industry. Assessment of the combination of factors provides further insight into the mechanisms associated with economic cycles on safety performance in Western Australia.

Based upon a review of literature there has been minimal investigation into the influence of economic cycles in Australia. Additionally, there have not been any studies that have combined an assessment of both macro and microeconomic factors to determine the sensitivity occupational injury rates in four specific industry groups. This is important to note as the relationship of these external factors on safety performance is unknown. The aim of the current study was to evaluate the influence of economic cycles in Western Australia against injury rates, in different industries.

2. Method

The objectives of the study were to assess:

1. The influence of economic cycles on safety performance in Western Australia
2. Determine if the economic cycles influence industry specific injury rates
3. Evaluate the sensitivity of specific industry groups to economic cycles

2.1. Data Sources

Research ethics approval to analyse de-identified secondary occupational injury data and macro and micro economic indicators was obtained from the Human Research Ethics Committee of Edith Cowan University. The following databases were used:

1. WorkCover WA Injury database. WorkCover is an Australian governmental organization established under the *Workers' Compensation and Injury Management Act 1981*, responsible for managing compensation and injuries (Work Cover, 2018). WorkCover WA collects and maintains a record of all injuries and fatalities, categorized by industries, under the Workers' Compensation and Injury Management Act in Western Australia (WA). With approval from WorkCover WA this data was made available for research. The database used contains all occupational injury data for Western Australia from January 1, 2003 to June 30, 2019. The WorkCover WA databases were used to calculate injury rates in Western Australia broadly stratified by the following industry groups; agriculture, mining, manufacturing and construction.
2. Australian Bureau of Statistics (ABS) data is Australia's national statistical agency, providing publicly available statistics on a wide range of economic, social, population and environmental areas. Macro and micro economic indicators for Western Australia were gathered from the ABS database from financial years 2004 – 2019 to determine which phase of the economic cycle (growth or recession) Western Australia was in during financial years 2004 -2019.

2.2. Description of Variables

2.2.1. Occupational Injury Rate

Safety performance was measured by occupational injury rate. Occupational injuries are reported to WorkCover WA under the *Workers' Compensation and Injury Management Act 1981*, this includes all occupational injuries that require medical treatment and above, including fatalities (Work Cover, 2018). Consistent with the reporting outputs from WorkCover WA, occupational injury rates for this study were reported per 100 workers. The date that a claim was lodged was used to calculate the number of occupational injuries that occurred in a financial year from the dataset provided by WorkCover WA. Financial year was used as a measure of time as the data collected from the ABS was reported in financial years.

2.2.2. Industry Specific Occupational Injury Rate

Four industries were selected for this study based on the information available in the WorkCover Western Australia database and economic factors available from the ABS and were consistently identified for the time period assessed. These four industries represent a significant share of the Australian workforce. The Australian and New Zealand Standard Industrial Classification (ANSIC) code was used to identify which injuries were associate with four key industry sectors: Agriculture, Manufacturing, Mining and Construction. The number of occupational injuries associated with these 4 specific industries was be used to calculate the industry specific occupational injury rate. The total number of people employed in the industry sectors was extracted from ABS database.

2.2.3. Economic Cycles

Both macro and micro economic factors were extracted from the ABS (Australian Bureau of Statistics, 2019a), to determine where in an economic cycle the financial year lies. Macroeconomic indicators (Gross State Product, Unemployment Rate) were used to confirm the economic cycle, and microeconomic factors (Gross Value Add, Industry Sector Employment) were used to determine if there is a sensitivity of industries to occupational injuries during economic cycles. Gross State Product is used in place of GDP as it is specific to a State, Western Australia in this paper. Gross Value Add can be interpreted as the equivalent of GDP but is specific to an industry, and Industry Sector Employment is the annual number of employees in an industry. Industry specific indicators were used, as macroeconomic indicators can be partially dependent on the industry composition in Western Australia. The microeconomic indicators were collected from the ABS for each of the industries assessed. All four of these economic indicators were selected as they present ways to measure the economic cycles in Western Australia and were selected based upon literature review of similar studies (Asfaw et al., 2011; Davies et al., 2009; Nielsen et al., 2015). In this study, occupational injury rate is the dependent variable and the various economic factors were considered independent variables.

2.3 Data Analysis

Descriptive statistics were used to describe:

- Macroeconomic Indicators
- Microeconomic Indicators
- Industry specific occupational injury rates

In order to determine the association and strength of relationship between the predictor (injury rate) and the outcome (various economic factors), multiple linear regression analysis was conducted in IBM SPSS version 25 to determine the influence of the combination of macro or microeconomic

indicators on occupational injury rates. Assumptions for multiple linear regression testing were completed for each dataset: linearity, normality, outliers, homoscedasticity, line of best fit and assessment of residual distribution. Residual data for each variable was plotted and assessed to confirm assumptions. Linearity was assessed by plotting each variable on a scatterplot. Normality was confirmed using Shapiro-Wilks tests for each variable and accepted if value was greater than 0.05. Homoscedasticity was assessed using Levene's Test and the assumption was met if less than 0.05. Assessment of each variable using box-plot analysis indicated that there did not appear to be any outliers. Statistical significance will be evaluated with $p>0.10$, this value is consistent with similar studies (Asfaw et al., 2011; Davies et al., 2009). All four dependant variables (Gross State Product, Unemployment, Gross Value Add and Industry Sector Employment) measure the same underlying occurrence and high level of intercorrelation was expected. In order to determine if the model is biased by collinearity among variables the correlation coefficient was measured and accepted if less than 0.9. The equations used in this study were based the research conducted by Asfaw et al. (2011) and were adapted to assess the association for economic factors for each industry group separately. The following equations were identified to address the objectives of this study:

$$_{y} = Þ_0 + Þ_1X1 + Þ_2X2 + Ɛ \quad (1)$$

$$_{yi} = \alpha_{0i} + \alpha_1 Z1 + \alpha_2 Z2 + Ɛ_i \quad (2)$$

$$_{yi} = \Upsilon_{0i} + \Upsilon_1 W_i + \Upsilon_2 W_i + Ɛp \quad (3)$$

Eq. (1) examines the influence of economic cycles on safety performance, where $_y$ indicates Injury Rate in Western Australia from 2003 - 2019. X1 represents the economic cycle indicator GSP for Western Australian and X2 represents Unemployment Rate for Western Australia. The error term is denoted by Ɛ and Þ is the coefficient to be estimated. Eq. (2) was used to determine if economic cycles influence industry specific occupational injury rates (yi), i ranges from 1-4 and represents each of the four industries assessed in this study: agriculture, mining, manufacturing and construction. Z1 represents the economic cycle indicator for GSP for Western Australia and Z2 represents the Unemployment Rate for Western Australia. The error term is denoted by $Ɛ_i$ and α is the coefficient to be estimated. Eq. (3) was used to explore the sensitivity of industry to economic cycles using microeconomic indicators. yi indicates the industry specific occupational injury rate, W1 represents Gross Value Add for the corresponding industry and W2 represents the Industry Sector Employment. The error term is denoted by Ɛp and Υ is the coefficient to be estimated. This equation was run for each industry assessed. The

combination of these assessments generated a model to determine the influence of economic cycles on safety performance in Western Australia.

3. Results

Coefficients were reported to capture the percent change in occupational injury rates due to a 1% change in economic factors. Data was plotted in time series to provide a visual representation of the influence of economic factors prior, during and after the global financial crisis (Fig. 3).

3.1. Descriptive Statistics

Descriptive statistics using IBM SPSS version 25 were used to describe the following datasets presented in Table 1:

- Macroeconomic Indicators and Injury Rate for Western Australia
- Macroeconomic Indicators and Injury Rate for Agriculture, Injury Rate for Mining, Injury Rate for Manufacturing and Injury Rate for Construction
- Microeconomic Indicators and Injury Rate for Agriculture, Injury Rate for Mining, Injury Rate for Manufacturing and Injury Rate for Construction

Multiple variations of measures of economic growth (Gross State Product, Real Gross State Product, Gross State Product growth, Gross State Product Annual Change, Percentage Change) and recession (Unemployed Persons, Unemployment Rate, Annual Change, % Change) were statistically evaluated and ranked based on statistical significance. The indicators used in this study are listed in Section 2.2.3. The occupational injury rate was highest for manufacturing, followed by mining, construction and then agriculture, indicating that for Western Australia manufacturing is the most hazardous industry. While the construction industry employs the most people with an annual average of 122,000, the mining industry contributes the largest amount of dollars, $52 billion, to the Western Australian economy (See Table 1).

Table 1. Descriptive Statistics for Indicators

	Mean	SD	N	LCL	UCL
GSP Growth	4.08	2.65	16	2.67	5.49
Unemployment Rate	4.81	1.00	16	4.27	5.34
IR for Western Australia	3.05	0.75	16	2.65	3.45
IR Agriculture	2.92	0.47	16	2.67	3.17
IR Mining	4.00	1.40	16	3.30	4.70
IR Manufacturing	7.30	2.40	16	6.00	8.60

IR Construction	3.90	0.80	16	3.50	4.30
GVA Agriculture	5147.38	818.46	16	4711.25	5583.50
GVA Mining	52388.13	18296.58	16	42638.57	62137.68
GVA Manufacturing	12791.81	1267.35	16	12116.49	13467.14
GVA Construction	21693.50	5977.34	16	18508.40	24878.60
ISE Agriculture	38.66	7.35	16	34.75	42.58
ISE Mining	79.43	25.36	16	65.91	92.94
ISE Manufacturing	89.16	6.56	16	85.67	92.66
ISE Construction	122.53	17.24	16	113.35	131.72

GSP = Gross State Product Growth Percent, IR = Injury Rate per 100 employees, GVA = Gross Value Add in million Australian Dollars, ISE = Industry Sector Employment in 1000 employees

3.2. Economic Cycles and Occupational Injury Rates in Western Australia

The association between two economic cycle indicators and occupational injury rates in Western Australia between financial years 2004 – 2019 are presented in Fig. 2 and the results of regression analysis are presented in Table 2. Correlation between the two macroeconomic indicators was 0.66 and there was no multicollinearity within the dataset. Assessment of linearity, normality and homoscedasticity was completed on the data and all assumptions were met to complete Multiple Linear Regression analysis. An analysis of residuals was carried out on this data and there did not appear to be any outliers.

A statistically significant ($p<0.05$) effect of economic cycles on occupational injury rates was found. Results indicate that occupational injury rate was positively related to GSP Growth and negatively related to unemployment rate. A change in unemployment rate results in a greater change to occupational injuries compared to a change in Gross State Product growth. Between the financial years 2004-2019 a 1% growth in Gross State Product for Western Australia increased occupational injury rates by 0.1% per 100 employed persons, while a 1% increase in the rate of unemployment decreased occupational injuries by 0.3% decrease. The association of occupational injury rates increasing during economic growth and decreasing during recession indicates procyclical behaviour.

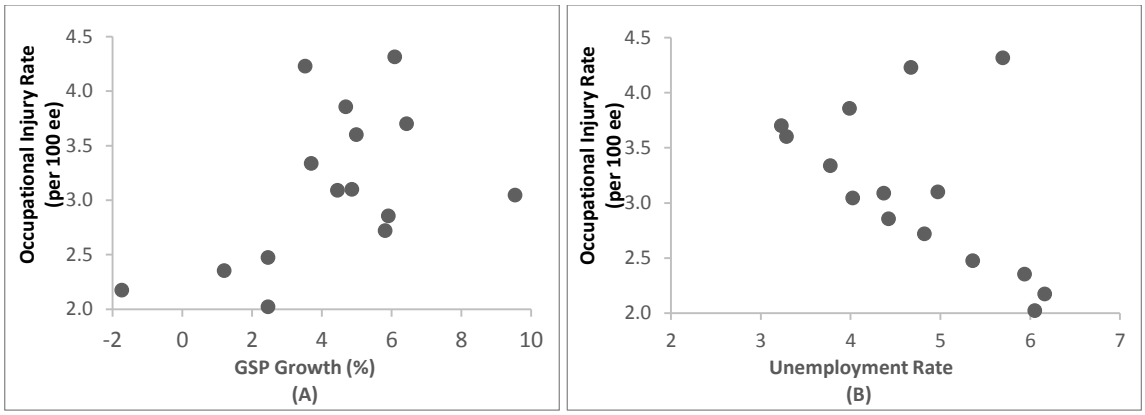


Fig. 2. Association between occupational injury rates and macroeconomic factors indicating economic cycles for Western Australia from financial years 2004 -2019. **a.** Association for occupational injuries, expressed in number per 100 employees and GSP, expressed in percentage growth **b.** Association for occupational injuries, expressed in number per 100 employees and unemployment rate.

Table 2. Change to injury rates as a result of changes in macroeconomic indicators

Macroeconomic Indicators	% Change	Standard Error
Gross State Product (%)	0.10	0.09
Unemployment Rate (%)	-0.32	0.21

*$p \leq 0.05$

When occupational injury rates and Gross State Product growth for Western Australia are plotted on a time-series graph the overall trend is procyclical, with deviations to countercyclical behaviour in 2012, 2015 and 2017 (see Fig. 3). Dividing the time series into phases results in 3 separate sections (see Table 3), Phase 1 and 3 follow a procyclical trend, whereas Phase 2 follows a countercyclical trend. Phase 1 and 3 are identified as procyclical because from Fig. 3, as the economy increases so do the number of occupational injuries. During Phase 2 Gross State Product growth consistently decreased from 2012 – 2017, occupational injury rates also decreased compared to Phase 1. Overall, a general procyclical trend can be seen.

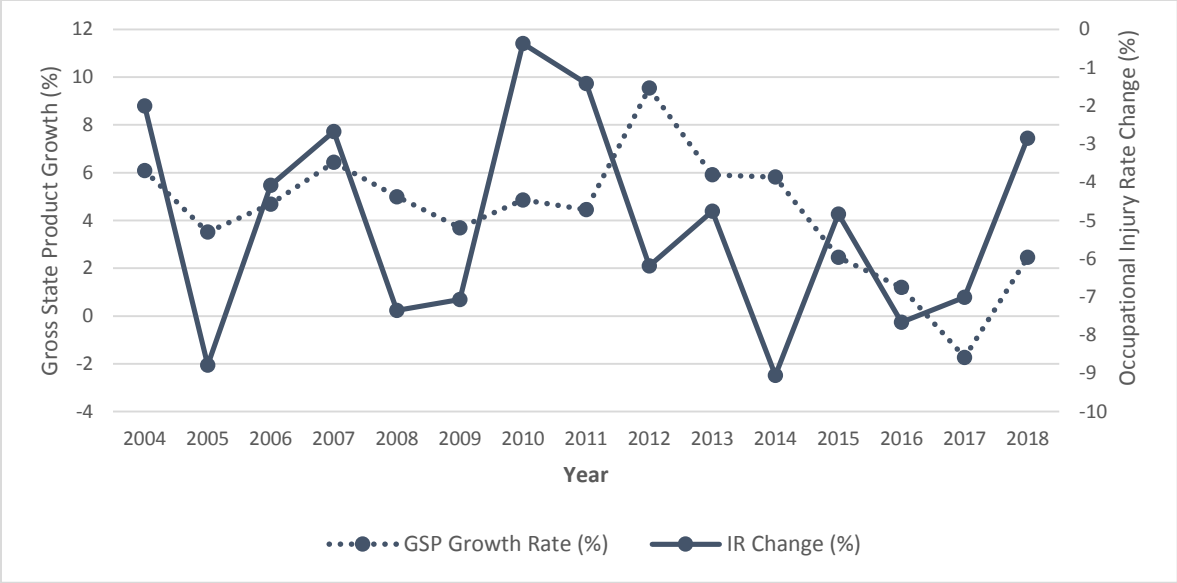


Fig. 3. Time Series Graph of GSP percentage growth for Western Australia (Australian Bureau of Statistics, 2019b) and Occupational injury rates percentage change for Western Australia for financial years 2004-2018. Occupational injury rate change and GSP growth change calculated year over year.

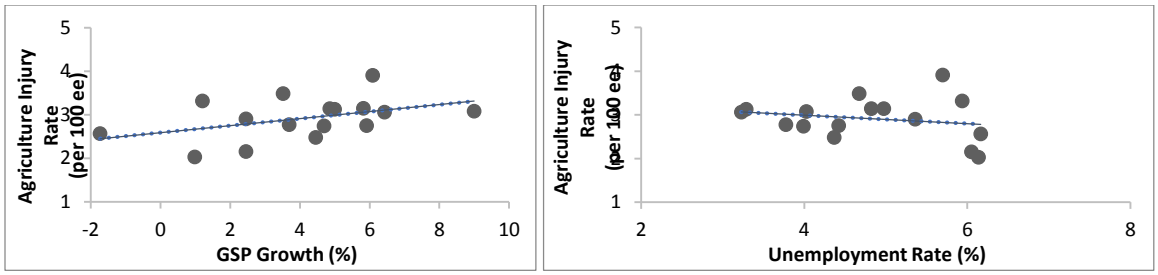
Table 3. Analysis of Year and Change Behaviour

Year	GSP Growth	Injury Rate Change	Behavior between GSP and Injury rate	Phase
2004 – 2005	Decrease	Decrease	Same	**1**
2005 – 2006	Increase	Increase	Same	**1**
2006 – 2007	Increase	Increase	Same	**1**
2007 – 2008	Decrease	Decrease	Same	**1**
2008 – 2009	Decrease	Increase	Different	**1**
2009 – 2010	Increase	Increase	Same	**1**
2010 – 2011	Decrease	Decrease	Same	**1**
2011 – 2012	Increase	Decrease	Different	**1**
2012 – 2013	Decrease	Increase	Different	**2**
2013 – 2014	Decrease	Decrease	Same	**2**
2014 – 2015	Decrease	Increase	Different	**2**
2015 - 2016	Decrease	Decrease	Same	**2**
2016 - 2017	Decrease	Increase	Different	**3**
2017 - 2018	Increase	Increase	Same	**3**

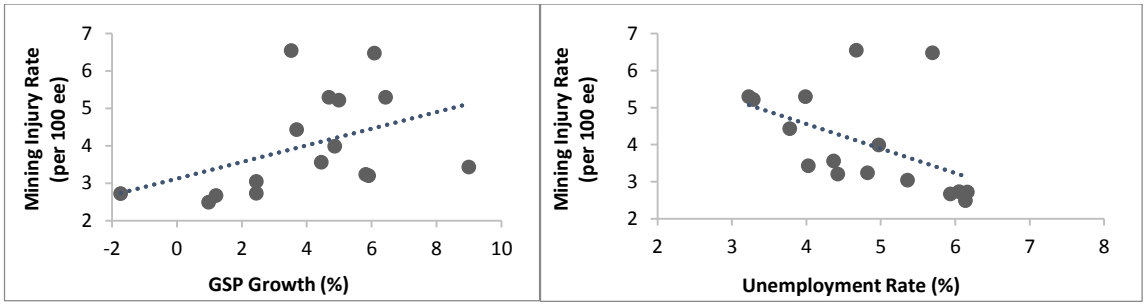
3.3. Economic Cycles and Injury Rates by Industry

Associations between macroeconomic factors and occupational injury rates for agriculture, mining, manufacturing and construction for Western Australia between financial years 2004- 2019 are presented in Fig. 4. Regression analysis for impact of change in macroeconomic indicators in each of the industry groups is presented in Table 4. Correlation between the independent variables Gross State Product growth and unemployment rate for each industry was less than 0.6. Assessment of linearity, normality and homoscedasticity was completed on data and all assumptions were met. An analysis of residuals was carried out on this data and there did not appear to be any outliers.

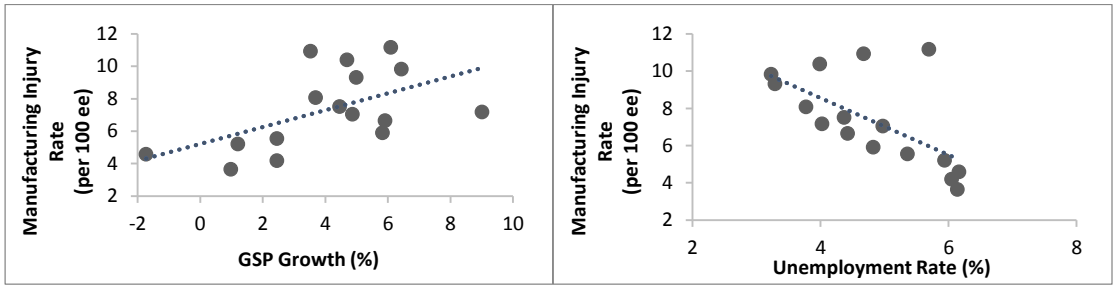
A. Agriculture



B. Mining



C. Manufacturing



D. Construction

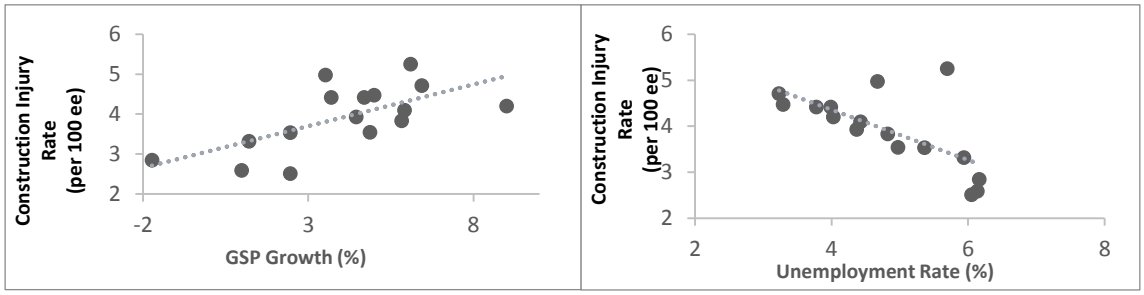


Fig. 4. Association between industry occupational injury rates and macroeconomic factors indicating economic cycles for Western Australia from financial years 2004 -2019. Macroeconomic factors measured are GSP growth, unemployment rate for **a**. Agriculture **b**. Mining. **c**. Manufacturing **d**. Construction

The influence of economic cycles on safety performance was statistically significant for the manufacturing and construction industries but not for agriculture or mining. Across all four industry groups an increase in GSP, increased occupational injuries and an increase in unemployment decreased occupational injuries. This follows the same procyclical trend when looking at macroeconomic factors across Western Australia presented in Fig 2A-B. Manufacturing occupational injury rates decreased by 1.2 per 100 employees as the unemployment rate increased by 1. The construction industry occupational injury rate decreased by 0.33 per 100 employees as unemployment increased. The manufacturing industry was more sensitive to changes in economic cycles, specifically unemployment rate.

Table 4. Change to Industry Injury Rates as a result of changes in macroeconomic indicators

Macroeconomic Indicators	% Change			
	Agriculture	**Mining**	**Manufacturing**	**Construction**
GSP Growth (%)	0.10	0.08	0.20	0.12*
	(0.06)	(0.17)	(0.26)	(0.08)
Unemployment Rate	0.08	-0.51	-1.2*	-0.33*
	(0.16)	(0.44)	(0.71)	(0.22)

Standard Error in Parentheses, *p≤0.10

3.4 Industry Specific Indicators and Injury Rates by Industry

The effects of Gross Value Add and Industry Sector Employment on occupational injuries are presented in Fig. 5. Regression analysis for change in microeconomic indicators in each of the industry

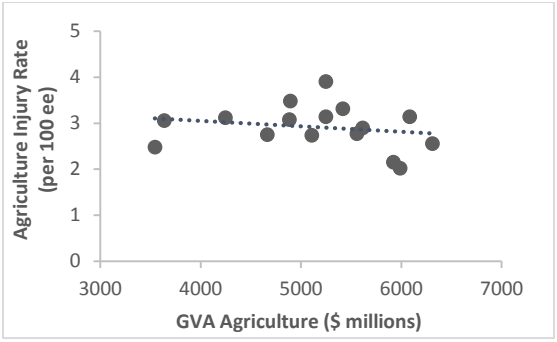
groups is presented in Table 5. Correlation between independent variables Gross Value Add and Industry Sector Employment for each industry was less than 0.8. Assessment of linearity, normality and homoscedasticity was completed on data and all assumptions were met. An analysis of residuals was carried out on this data and there did not appear to be any outliers. Gross Value Add and Industry Sector Employment were statistically significant for each industry occupational injury rate, except for agriculture. The linear regression model (Eq. 3) for mining, manufacturing and construction indicate that microeconomic indicators explain a significant amount of the variance in industry specific occupational injury rates ($R^2_{Adjusted}$ = 0.93, 0.77, 0.70). Mining, manufacturing and construction industries all had minor decreases due to increased Gross Value Add. Manufacturing occupational injury rate increases by 0.16 per 100 employees as employment in manufacturing increased. In the mining and construction industry the opposite occurred, whereby increased employment resulted in a decrease in occupational injury. The impact to the mining and construction occupational injury rates was less compared to manufacturing, however the data indicates that mining, manufacturing and construction are impacted by economic cycles.

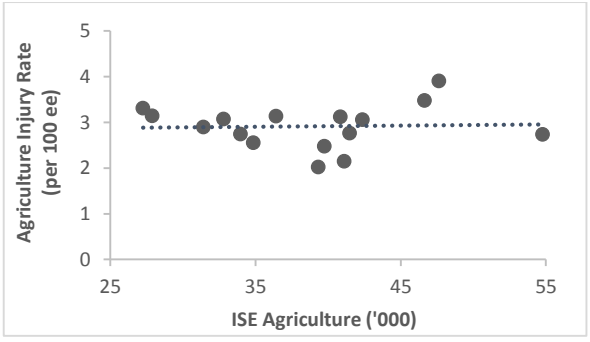
Table *5*. Change to industry injury rates as a result of changes to microeconomic indicators

	Agriculture	Mining	Manufacturing	Construction
Gross Value Add ($ million)	<0.001	<-0.001*	-0.001*	<0.001*
	(<0.001)	(<0.001)	(<0.001)	(<0.001)
Industry Sector Employment	0.002	-0.031*	0.16*	-0.066*
	(0.018)	(0.006)	(0.05)	(0.012)

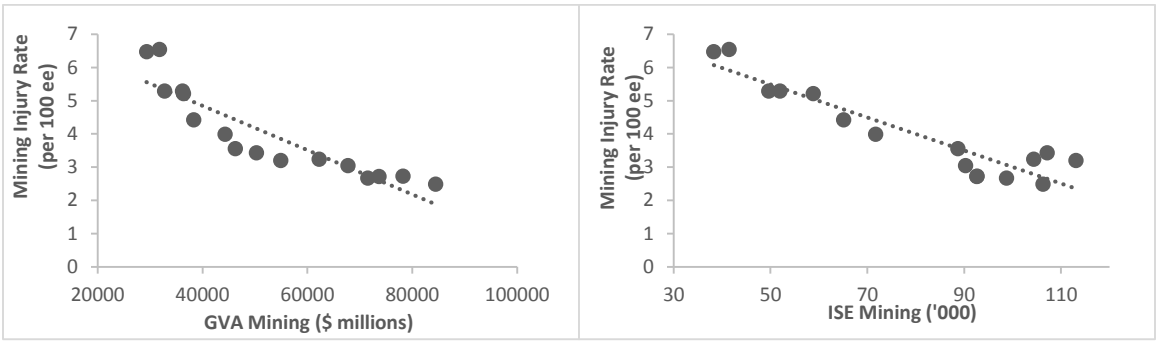
Standard Error in Parentheses, *p≤0.05

A. Agriculture

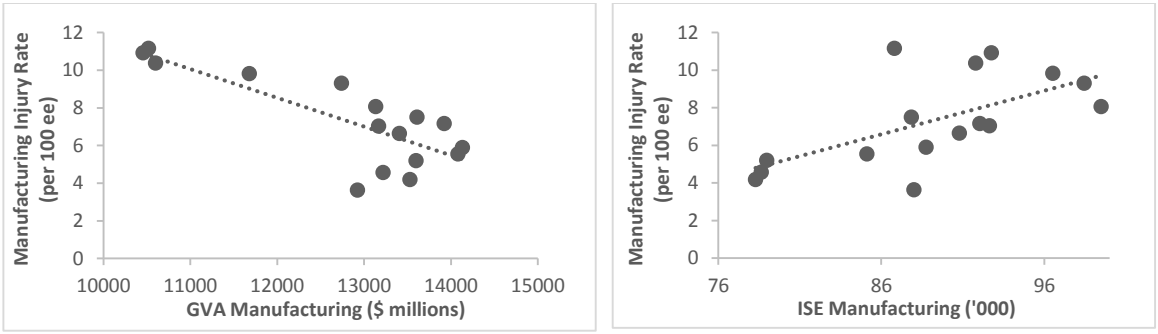




B. Mining



C. Manufacturing



D. Construction

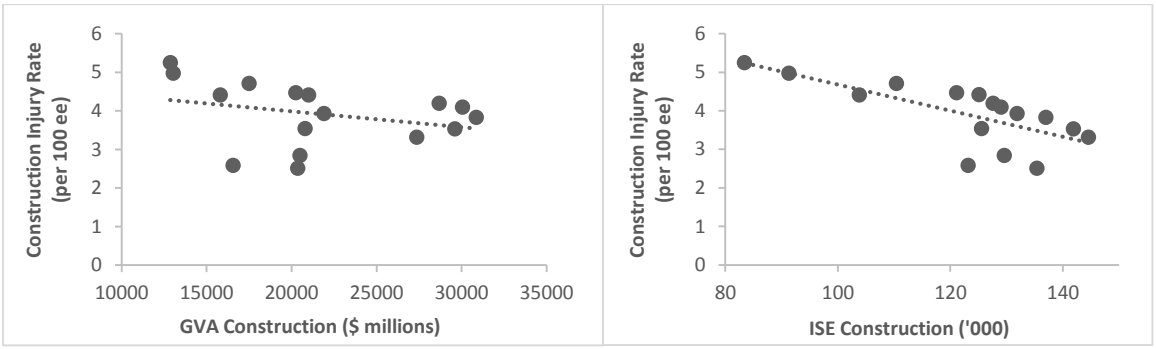


Fig. 5. Association between Industry Occupational Injury Rates and Microeconomic Factors indicating Economic Cycles for Western Australia from Financial Years 2004 -2019. Microeconomic factors measured are GVA in Million Dollars and ISE in Number of Employed Persons ('000) for **a**. Agriculture. **b**. Mining. **c.** Manufacturing **d**. Construction

4. Discussion

This study utilised occupational injury data from 2004 – 2019 to determine the influence of economic cycles on occupational injury rates for Western Australia within agriculture, mining,

manufacturing and construction industries. Our findings indicate a procyclical behaviour, whereby changes to the macroeconomic factors of GSP growth and unemployment rate influenced safety performance for Western Australia. This is consistent with studies conducted by both Asfaw et al. (2011) and Davies et al. (2009) who concluded that occupational injuries were procyclical in their association to economic cycles in the United States and the United Kingdom, respectively. Asfaw et al. (2011) reported a 1% increase in GDP was associated with 1.5% increase in occupational injuries and a similar increase in unemployment rate was associated with a 0.2% decrease in occupational injuries. When reviewing data from the United Kingdom, Davies et al. (2009) reported a 1% increase in GDP was associated with a 3.3% increase in occupational injury rates. Understanding the pattern of behaviour of occupational injuries when there are changes to the economic state will provide organisations a better opportunity to implement effective and resilient safety management systems.

4.1. Economic Cycles and the Western Australian Economy

Western Australia results follow a procyclical trend (see Fig. 3), that is as the economy improves there are more occupational injuries. We suggest the increase in occupational injuries seen during economic growth is attributed to increased employment of untrained workers, contractors and longer work shifts, however further research is needed to test this hypothesis. A similar observation was made when studying the influence of economic changes on injury rates in the European Union. Palali and Ours (2017) concluded that contract workers had a higher risk of occupational injuries, 3.3 per 100 employees compared to 2.9 per 100 permanent employees. The temporary nature of contract work means that if the task, hazards and safety processes are unfamiliar to workers there are likely to be more injuries.

While the overall trend for occupational injuries in Western Australia is procyclical there are periods during 2004 – 2018 that diverge from this behaviour (see Fig. 3, Table 3). Within Phase 1 (2004 - 2012) there is a trend of GSP growth and occupational injury rates increasing and decreasing together each year. The Global Financial Crisis occurred in 2008 and the Western Australian economy continued to grow during this time, however, the impact of diminished global financial growth did not impact the Australian economy until after 2012 where countercyclical behaviour is seen.

During Phase 2 (2012-2016) there were many global resourced based companies with operations based in Western Australia. This means that while Western Australia did not directly experience a recession some global companies with operations in Western Australia were exposed to restructuring and reorganisation. As a result of the global economic situation companies may have

altered their focus on safety measures by reducing supervision or the number of safety roles, thus increasing the risk of operations. Additionally, the International Labour Organisation (2013) indicated that to keep jobs, many global companies deployed their employees to Australia. This increased the number of workers unaccustomed with the Western Australia work environment and local regulations, which could have contributed to the increase in injuries during this period.

In 2012 the Gross State Product growth increased by 5% and occupational injury rates decreased by 5%. The decrease in occupational injuries could be a reaction to the increase in injuries seen in 2010. As there was more Gross State Product growth in 2012, additional funding into occupational health and safety jobs as well as training may have decrease injuries. The peaks in occupational injuries and Gross State Product seen in 2010 and 2012 (see Fig. 3), respectively, are not likely to be related, as it is unlikely that a rapid increase in occupational injuries will result in a delayed rapid increase in Gross State Product growth 2 years following. Further investigation is suggested as this relationship was not assessed in this study.

In 2013 both Gross State Product growth and occupational injuries decreased, possibly as a result of diminished employment in high-risk industries. If there are less people employed in mining and construction this could result in fewer occupational injuries occurring. Further research is required to investigate the causes.

In Phase 3 beginning in 2016, Gross State Product and occupational injuries trend is towards a procyclical trend with fewer injuries as the economy increases into 2018, but the analysis of the trend beyond 2018 requires further data, which was not available (April 2020). A recent report by the International Labour Organisation (2019), indicates that on a global scale it has taken nine years for the employment rate to recover to the levels prior to the Global Financial Crisis. It is possible that the trend towards procyclical behaviour seen for Western Australia in Phase 3 is influenced by the global recovery towards a stronger economy.

The COVID19 pandemic has had a significant impact on both the economy and workplace safety. The unique effects of the pandemic should be investigated as the world moves into a new global recession and this research has shown it is highly likely there will be an impact on the number of workplace injuries (Nicola et al., 2020).

4.2. Macroeconomic Indicators and Industry Occupational Rates

The findings of this study indicate that aggregated economic indicators were associated with injury rates withing the manufacturing and construction industry groups. This finding is in agreement with previous studies' findings that report strong association of business cycles and injury rates in manufacturing and construction industries (Chang et al., 2018; Nielsen et al., 2015). Davies et al. (2009) reported a 1% increase in GDP resulted in an occupational injury rate increase of 1.7% in manufacturing and 2.6% in construction.

In this study manufacturing was more sensitive to changes in unemployment compared to the other industry groups analysed. As occupational injury rates increased with increased employment in manufacturing this may reflect the fact that manufacturing does not have strong safety practices in place for new hires and as such more workers are being injured. Within the Danish construction industry, Lander et al. (2016) reported that the injury rates during economic growth periods was 2-3 times higher for workers under 30 years of age compared to those more than 30 years old. Lander et al (2016) indicates that during growth periods, in the Danish construction industry is hiring younger less experienced workers who are at greater risk of occupational injuries. The tenure and age of injured employees was not evaluated in this study

When reviewing the global companies employing individuals in Western Australia there are more in the mining and construction industry when compared to manufacturing, this may explain the sensitivity of manufacturing to industry specific economic factors compared to mining and construction. Large scale, global organisations are not as financially constrained when compared to smaller, local manufacturing companies which may not have the resources or knowledge to successfully implement effective safety strategies and practices. Asfaw et al. (2011) identified a similar behaviour pattern for manufacturing, whereby a 1% increase in the number of people employed was associated with a 0.76% increase in injuries within the manufacturing sector. The reason for an increase in injuries during economic growth was thought to be a result of workers using unsafe equipment and machinery, which they may not be skilled to safely operate (Asfaw et al., 2011).

This research did not observe a relationship between economic cycles and injuries rates in the West Australian agriculture and mining industries, when looking at macroeconomic factors. This contrasts to previous studies' findings which noted that mining was strongly associated to changes in economic cycles (Asfaw et al., 2011; Davies et al., 2009).

4.3. Microeconomic Indicators and Industry Occupational Rates

Analysis of microeconomic indicators demonstrated an association of occupational injuries with mining, manufacturing and construction. Mining and construction industry occupational injury rates decreased when the number of people employed in the industries increased. This could be a result of the rigorous safety practices implemented in these high-risk industries. Due to a combination of high risk and the large proportion of the population employed in these industries (SafeWork Australia, 2019), employees are subjected to rigorous training, inductions and safety auditing standards. It is probable that due to the strong safety standards in mining and construction industries, new employees undergo thorough safety training and are better able to protect themselves from unsafe work. It is also possible that the countercyclical behaviour of the mining and construction industries during recession periods can be attributed to increased mental stress and therefore increased occupational injury rates, as proposed by Boone et al. (2011).

Davies et al. (2009) concluded that procyclical behaviour was stronger within the manufacturing and construction industry, citing that within the United Kingdom there are many small companies in these industries, and this resulted in more injuries during economic growth. Within Western Australia the majority of construction employees are hired by large scale companies, whereas in manufacturing the workforce is mostly employed by smaller companies. As such, if the suggestion from Davies et al. (2009) is applied to this study then the relationship appears to be dependent on the company size as well as the industry. This is further validated by De la Fuente et al. (2014) who reports that more experienced, permanent employees working in a large company (over 250 employees) had a reduced risk of injury for during a recession.

4.4. Macroeconomic Factors vs. Microeconomic Factors

The relationship of occupational injury rates is different when looking at macro compared to microeconomic indicators. For macroeconomic indicators: Gross State Product growth and unemployment rate showed a weaker association to occupational injury change when compared to the industry specific indicators: Gross Value Add and Industry Sector Employment. This is expected as industry specific indicators will reflect economic fluctuations more accurately as they are specific to the industry analysed. Gross State Product growth was positively associated to injury rates for mining, manufacturing and construction, however Gross Value Add was negligible for mining, manufacturing and construction.

Manufacturing industry injury rates decreased as unemployment increased and increased as Industry Sector Employment increased. This behaviour is consistent with results reported by Nielsen et al. (2015), who found a 1% increase in unemployment rate was associated with a decrease of 5% for injuries, and a similar increase in Industry Sector Employment was associated with 3.5% increase in injuries within the construction industry in Denmark.

Within the agriculture industry neither aggregate or industry specific economic indicators influenced occupational injuries. This indicates that there are other factors that influence occupational injuries in this industry that were not assessed in this study. This trend is similar to that described by Asfaw et al. (2011) who concluded mining, manufacturing and construction industries were procyclical but not agriculture.

4.5 Study Limitations

A limitation of this study is that occupational injury rates were calculated based upon the data within the WorkCover WA database. There is strong evidence that not all occupational injuries that occur are reported to government organisations, particularly during recessions (Boone et al., 2011). As such, it is possible that the occupational injury rates calculated are not an accurate reflection of the true number of injuries that have occurred, only ones that were reported. The magnitude of underreporting has been estimated to be between 20 – 78% from studies reported globally (Petitta et al., 2017; Wuellner & Phipps, 2018). Underreporting can undermine the ability to determine the full impact of mechanisms on occupational injuries. Understanding the influence of external factors such as the economy on reporting behaviour of employees requires additional research. Assessment of population demographic, worker types (full-time, part-time, contractor, permanent) and injury severity were out of scope for this study. They will be considered for future research as these variables could provide more insight into the characteristics of workers that are getting injured during economic cycles. Davies et al. (2009) reported that procyclical behaviour was stronger for minor injuries compared to major injuries for the construction industry in the United Kingdom. Their results show that the opportunistic behaviour of employees during favourable market conditions contributed to the number of minor occupational injuries reported during growth periods (2009). As neither minor nor major injuries were categorised in this is study it was not determined if there was a certain type of injury more commonly reported during economic expansion in Western Australia. Further research into the mechanism underlying the association between the influence of external factors on occupational injury rates is required.

The strengths of this study include using a uniform safety classification, inclusion of both industry composition and industry specific indicators. As one database source was used from WorkCover Western Australia, which provided a uniform classification of occupational injuries for both Western Australia and with agriculture, mining, manufacturing and construction industries. Including industry composition of the economy by way of evaluating the influence of macroeconomic changes on individual industries provided an opportunity to evaluate the impact of aggregate factors on industry. Assessing industry specific economic indicators on industry specific industry rates allowed for analysis to focus more on direct impact of economic changes for each industry. The combination of these 2 factors provides a robust assessment of the impact of economic cycles on safety performance. A limitation of this study is that occupational injuries were the only metric assessed to determine safety performance. This provides a one-sided assessment of safety performance as there are other metrics that could be used or included in measuring safety performance. From the government data provided by WorkCover WA only injury data was recorded. Additional measures will be considered for future research.

5. Conclusion

This research shows there is a procyclical influence of economic cycles on the number of occupational injuries using Western Australia Government injury data from 2004-2019. During times of economic growth occupational injuries increased and decreased during economic recession.

Economic cycles had a strong influence on the manufacturing and construction industries when aggregated economic factors were assessed, with occupational injuries decreasing as unemployment increased. Furthermore, the microeconomic indicator Industry Sector Employment, influenced occupational injury rates in mining and construction. In these industries occupational injuries decreased as employment increased and in manufacturing occupational injuries increased as employment increased. Overall, manufacturing was more sensitive to changes in economic cycles.

This research has shown economic cycles can influence of safety performance by the acute removal of funds from an organisation's income during economic recession. As a reduction in resources result in the removal of people from the workforce during a recession period, organisations that are reliant on administrative controls, PPE and supervisors to control risk will be putting their workforce at an increased level of risk. Reductions in safety performance have the potential to significantly add to an organisation's liability. In particular, there are high penalties associated with non-compliance to managing workforce risk in Australia, the UK and other jurisdictions.

This research has shown that injury prevention strategies in the manufacturing industry are not as effective during an economic downturn, such as the Global Financial Crisis in 2008 and the COVID-19 pandemic shows that these economic trends are not one off. The expectation of workplace health and safety regulation is that workplaces are a safe place of work at all times.

Given that globally, an economic recession is forecasted to occur as a result of the COVID-19 pandemic, there is likely to be a procyclical trend in safety performance in Western Australia. Whilst it is beyond this paper to speculate on the injury prevention performance outside of the State of Western Australia, as others have done so, consideration of these findings may assist organisations to review their injury prevention initiatives, in particular to ensure their effectiveness in varying economic conditions.

Additionally, if the level of risk has changed due to an economic recession, it is even more important for people to accurately report occupational injuries in order to determine the actual risk given the current work environment. Working in an environment with reduced manpower is stressful and can have an impact on safety reporting culture, if employees are feeling vulnerable, they may fail to report an occupational injury for fear of dismissal.

Organisations need to determine if their safety management systems are resilient enough to account for the influence of economic changes. This study demonstrates that there is more to injury prevention than organisational culture but also external factors such as the economy. *ISO 31000-Risk Management: Guidelines* highlights the importance of an organisation being dynamic and also references the importance of examining external factors when designing a framework for risk management (International Organization for Standardization, 2018). The economic environment influences the availability of manpower and a change in the economy will impact organisations, making sure organisation can cope with change is important as the number of people in the workforce will change the risk.

Dekker and Pitzer (2016), suggest that the asymptote for safety performance is due to safety systems no longer being adequate to control risks and that the plateauing of performance results in many organisations being surprised by fatal accidents that are seemingly unconnected to the measured and monitored risks. We suggest that organisations may be surprised as they are not considering the influence of economic cycles on safety performance.

This study demonstrates that there is an influence of economic cycles on safety performance, which indicates organisations should consider the impact of external factors during the development and implementation of resilient injury prevention initiatives at all times.

6. Acknowledgements

We would like to thank the Australian Government Research Training Program (RTP) for the Scholarship to complete this research. Thank you to WorkCover WA, for providing the data.

Declarations of Interest: None

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: