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The business cycle and the incidence of workplace injuries: Evidence from the U.S.A.

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ABSTRACT

Introduction: The current study explored the association between the business cycle and the incidence of workplace injuries to identify cyclically sensitive industries and the relative contribution of physical capital and labor utilization within industries. *Method:* Bureau of Labor Statistics nonfatal injury rates from 1976 through 2007 were examined across five industry sectors with respect to several macroeconomic indicators. Within industries, injury associations with utilization of labor and physical capital over time were tested using time series regression methods. *Results:* Pro-cyclical associations between business cycle indicators and injury incidence were observed in mining, construction, and manufacturing but not in agriculture or trade. Physical capital utilization was the highest potential contributor to injuries in mining while labor utilization was the highest potential contributor in construction. In manufacturing each effect had a similar association with injuries. *Conclusion:* The incidence of workplace injury is associated with the business cycle. However, the degree of association and the mechanisms through with the business cycle affects the incidence of workplace injuries was not the same across industries. *Impact on Industry:* The results suggest that firms in the construction, manufacturing, and mining industries should take additional precautionary safety measures during cyclical upturns. Potential differences among industries in the mechanisms through which the business cycle affects injury incidence suggest different protective strategies for those industries. For example, in construction, additional efforts might be undertaken to ensure workers are adequately trained and not excessively fatigued, while safety procedures continue to be followed even during boom times.
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1. Introduction

Aggregate fluctuations in the economy, commonly known as the business cycle, affect a variety of factors that may directly or indirectly influence occupational safety and health. Several empirical studies support this assertion, demonstrating increases in work-related injuries and illnesses associated with increases in various business cycle indicators, such as the Gross Domestic Product (GDP; e.g., Davies, Jones, & Nuñez, 2009), capacity utilization (e.g., Bowers, 1981), and unemployment rate (e.g., Brooker, Frank, & Tarasuk, 1997). Workplace injuries measured directly as incidence rates (e.g., Boone & van Ours, 2006), or indirectly as workers' compensation claims and costs (e.g., Shuford, 2008), showed similar associations. Some of the studies focused narrowly on one state (e.g., Anderson, 2002) or industry (e.g., Fortin, Lanoie, & Laporte, 1996), while others compared a few industries in one province (e.g., Brooker & Sullivan, 1994), several states (e.g., Hartwig, Kahley, Restrepo, & Retterath, 1997), or different countries (e.g., Ussif, 2004). Injury types also were studied. Davies et al. (2009) in the United Kingdom, for example, studied both minor injuries resulting in more than three days of absence and specifically defined "major" injuries. Only minor injuries were pro-cyclical in that study. In addition mechanisms through which the business cycle affects workplace injuries have been examined. Shea (1990) reported that injury rates were more cyclical in low labor turnover industries. Fairris (1998) observed that low worker bargaining power in manufacturing was associated with increased injury rates. Leigh (1985) and Boone and van Ours (2006) showed that injury rates increase during economic expansions because workers over-report.

Workers' compensation studies were summarized in a recent policy brief by the Institute for Work and Health (IWH, 2009). The reviewed evidence indicated less frequent claims during recessions –claims per worker covered by workers' compensation or claims per hours worked. The results were less straightforward for severity, or cost per claim, though both wage replacement costs and medical costs appeared to decrease per hour worked during recessions. Potential factors contributing to these trends during recessions include fewer inexperienced workers remaining employed, especially those in hazardous industries, and injured workers, who fear losing their jobs, deferring filing for workers' compensation benefits. The pace of work also is slower and unsafe equipment may be used less frequently (IWH, 2009).

Surprisingly few studies have directly examined injury rates by industry sector on a national level, despite the fact that certain industries are more sensitive to the business cycle than others (e.g., Shuford, 2008). Among nine sectors examined by Davies et al. (2009), construction and manufacturing injury rates were most sensitive to the business cycle. We know of no other such studies using national-level data. Consequently, we used national-level time series data from the United States to compare the impact of the business cycle on the

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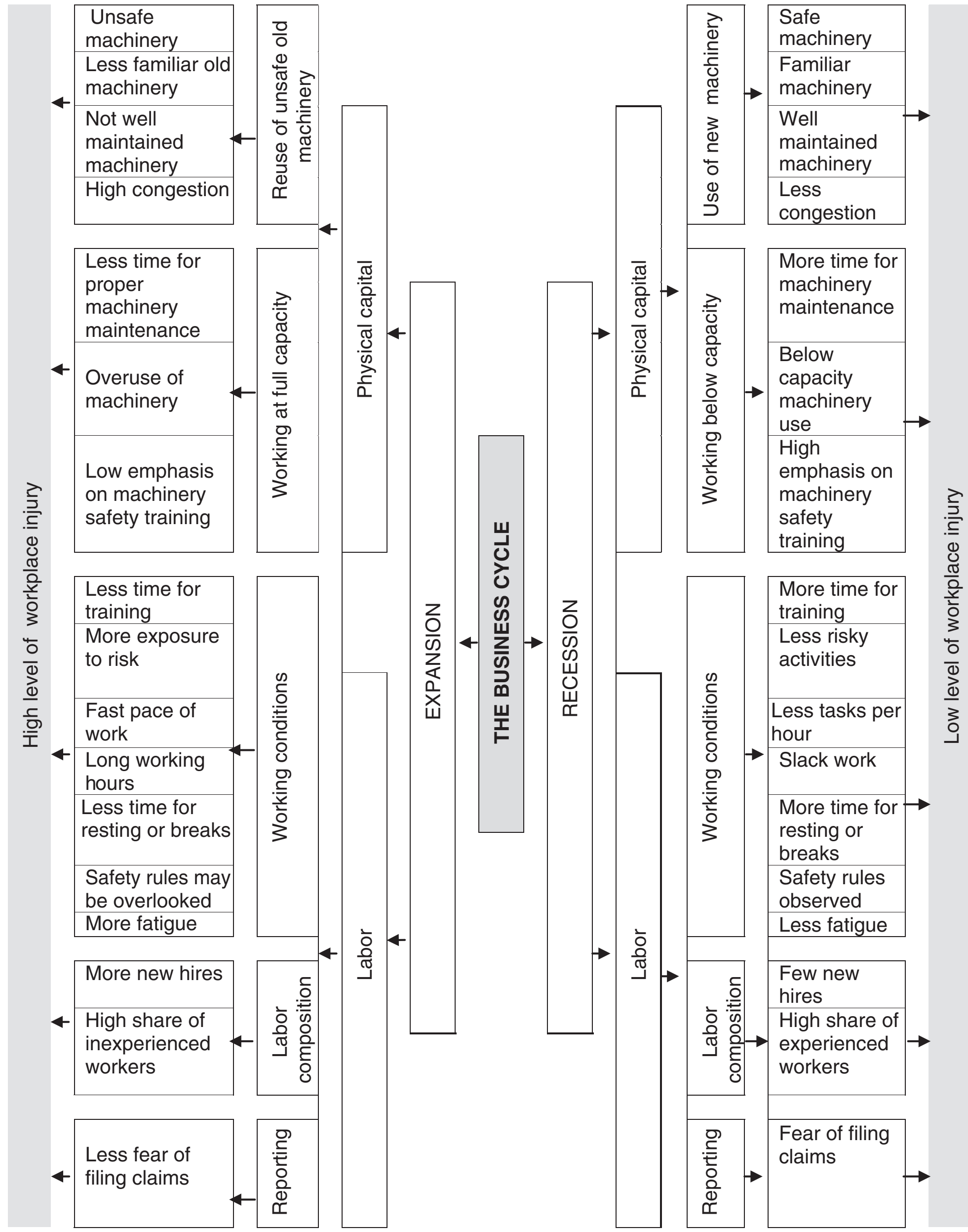

Fig. 1. The business cycle and workplace injuries: Conceptual map.

incidence rate of workplace injuries among industries. We further examined human and physical capital utilization as broad mechanisms through which the business cycle affects the rate of injuries in those industries.

2. Theoretical Framework

Fig. 1 illustrates how business cycle fluctuations in human and physical capital utilization might influence other factors affecting workplace injuries. With respect to human capital, the share of new or inexperienced workers in the total labor force increases during economic expansions (Boone & van Ours, 2006; Kossoris, 1938; Robinson, 1988; Root & Hoefer, 1979). This change could increase the probability of workplace injuries. Moreover, the relatively low unemployment rate during expansions might positively influence the willingness of workers to report workplace injuries. As indicated by Boone and van Ours (2006) and Davies et al. (2009), this opportunistic behavior of workers can increase their probability of reporting more injuries and illnesses during economic expansion.[1] The opposite happens during periods of sluggish growth; no new hiring takes place and workers who were hired last are more likely to be laid off first. Therefore, new or inexperienced workers would constitute a smaller share of the workforce. Workers facing layoffs during times of high unemployment may also refrain from reporting workplace injuries (Boone & van Ours, 2006). As a result, reported workplace injuries would be expected to decline during recessions (Shuford, 2008).

In addition to changing the composition of the labor force, the business cycle might affect work organization. During business upswings, the time allocated to rest breaks is relatively short and the

[1] However, this issue is not considered in the empirical analysis due to lack of information to approximate the opportunistic behavior of workers, The unemployment rate could not be used since it is highly correlated with the business cycle indicator variables.

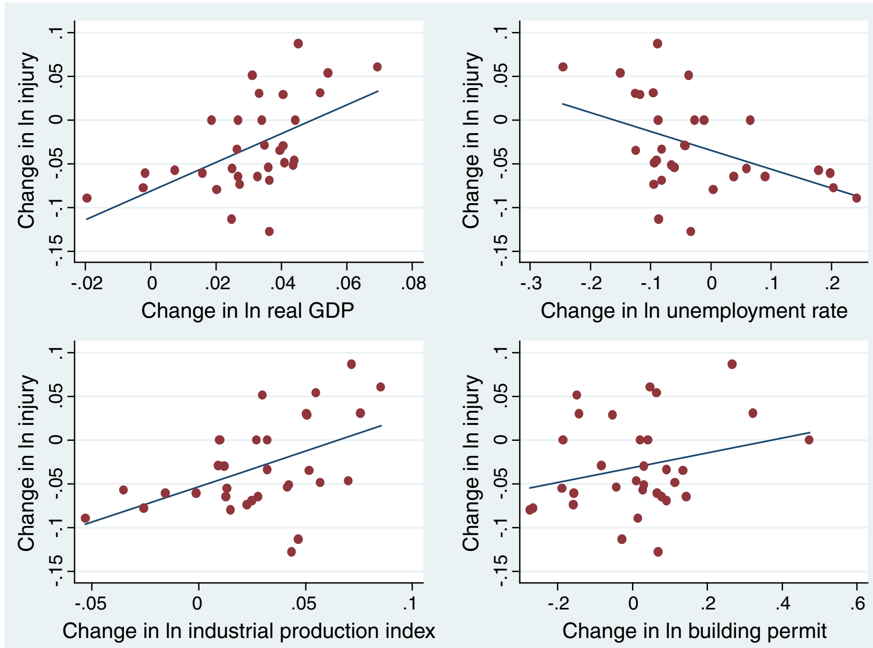

Fig. 2. Association between workplace injuries and business cycle indicators, 1976–2007.

pace of work is fast in order to meet production demands (Salminen, Saari, Saarela, & Rasanen, 1993). Workers may also be encouraged to work more hours per day. These changes could lead to greater worker fatigue, which could contribute to injury or poor health (Baker, 1985; Fay & Medoff, 1985; Ruhm, 2000; Schuster & Rhodes, 1985; Sokejima & Kagamimori, 1998). Moreover, due to time pressures, adequate training might not be given and safety rules could be overlooked. As the economy weakens, the pace of work is likely to be slower with fewer working hours, which could decrease the risk for workplace injury.

The impact of the business cycle on workplace injuries might also be observed by examining the composition and utilization of the physical capital of firms. During periods of expansion, firms working at high capacity to meet demands may schedule less time for proper maintenance of machinery and equipment and also may use equipment for longer periods of time than recommended by manufacturers. Both of these conditions might contribute to higher injury rates. Firms also might return older, less efficient machinery to service in order to meet their production targets. This machinery may be less safe overall, or new workers may not be familiar with its use and safety features. In recessions, firms working below capacity might allow more time for proper equipment operation and maintenance, and might tend to use safer, more efficient machinery.

On the other hand, some researchers suggest that workplace injuries are countercyclical. It is argued that workers who face layoffs during economic contractions have more incentive to file claims since workers' compensation benefits are usually higher than the unemployment benefits (Boone & van Ours, 2006). Fear of layoffs during recession might also increase the stress of employees, which could increase the probability of injuries (Beale & Nethercott, 1988; Jenkins, MacDonald, Murray, & Strathdee, 1982; Mattiasson, Lindgfirde, Nilsson, & Theorell, 1990). It also could be argued that during economic expansion firms have more resources to buy new and efficient equipment, train workers, and maintain equipment than during periods of economic contraction. During recession, troubled firms might also force layoffs, which could result in more hours, higher workloads, and more exposures for those who remain employed. All of these factors can create a negative association between the business cycle and the incidence of workplace injuries.

We hypothesized that the net impact of the business cycle on workplace injuries would be positive in our data. We further expected this relationship to vary by industry sector and the relative influence of labor and physical capital utilization in those sectors. Based on available data, five industry sectors were selected for analysis of economic fluctuations over three decades.

Table 1
Percent change in workplace injuries as a result of a one-percent change in business cycle indicators.

Business cycle indicators+	% Change	Standard Error	R^2
Real GDP	1.645***	0.457	0.30
Unemployment rate	-0.216***	0.071	0.24
Industrial production index	0.810***	0.262	0.24
New building permits	0.084	0.057	0.07

+ The first difference of the variables was used in the regression analysis.
* P≤0.10, ** P≤0.05, and *** P≤0.01.

3. Method and Measurement of Variables

The following equations were specified to address the objectives of the study:

$$I_t = \lambda_0 + \lambda_1 B_t + \varepsilon_t \quad (1)$$

$$I_i t = \beta_0 + \beta_1 B_t + \mu_{it} \quad (2)$$

$$I_i t = \gamma_0 + \gamma_1 L_{it} + \gamma_2 C_{it} + \nu_{it} \quad (3)$$

The first equation examined the impact of the business cycle on the incidence rate of workplace injuries, where I indicated the rate of injury in industry i on year t, B was an indicator of the business cycle, and ε was the error term. The second equation was used to examine if the cyclical variation in the incidence rate of workplace injuries varied across different industries.[2] Finally, we used the third equation to explore the mechanisms by which the business cycle affected the incidence rate of workplace injuries in different industries. In this equation, L measured labor input, C represented physical input utilization, and υ was the error term. In all equations, λ, β, and γ were parameters to be estimated.[3]

[2] Due to lack of information, we could not use industry specific business cycle indicators. As a result, the sensitivity of injury rates to the aggregate business cycle could partially depend on the contribution of each industry to the national economy.
[3] Since most of the variables were not stationary their first difference (change) was used in the analysis.

In line with the literature in this area, we expected a positive association between workplace injury and the aggregate business cycle, so λ_1 was expected to be positive (negative for unemployment). In addition, we anticipated the incidence rate of injuries in the agriculture and trade industries to be less responsive to aggregate economic fluctuations than those in manufacturing, mining, and construction. The employment rate in agriculture and trade does not seem to be sensitive to the aggregate business cycle (Shuford, 2008). In Eq. (3), we expected both γ_1 and γ_2 to be positive, with potential variations in their magnitude across industries. In industries where the level of employment shows a large cyclical response to the business cycle, the labor effect was expected to be higher than the physical capital effect. On the other hand, in industries that have large variation in the use of physical capital, the converse was expected.

Eqs. (1) to (3) were not directly estimated since most economic time series variables are not stationary. Regressing non-stationary variables produces spurious results even if the sample size is very large (Granger & Newbold, 1974). To determine whether the variables were stationary, we used the augmented Dickey-Fuller (ADF) test. The ADF (with constant) test revealed that the hypothesis of stationarity was rejected for most but not all of the variables. However, the first difference (the change score) of most variables was stationary. The ADF test results presented in Appendix 1 show that the first difference of the variables was stationary. Therefore, first all the variables were converted to their natural logarithms and then their change scores were used to estimate the equations.

Data on the incidence rate of nonfatal occupational injuries and illnesses with days away from work (i.e., requiring at least one day away from work with or without days of job transfer or restriction) were

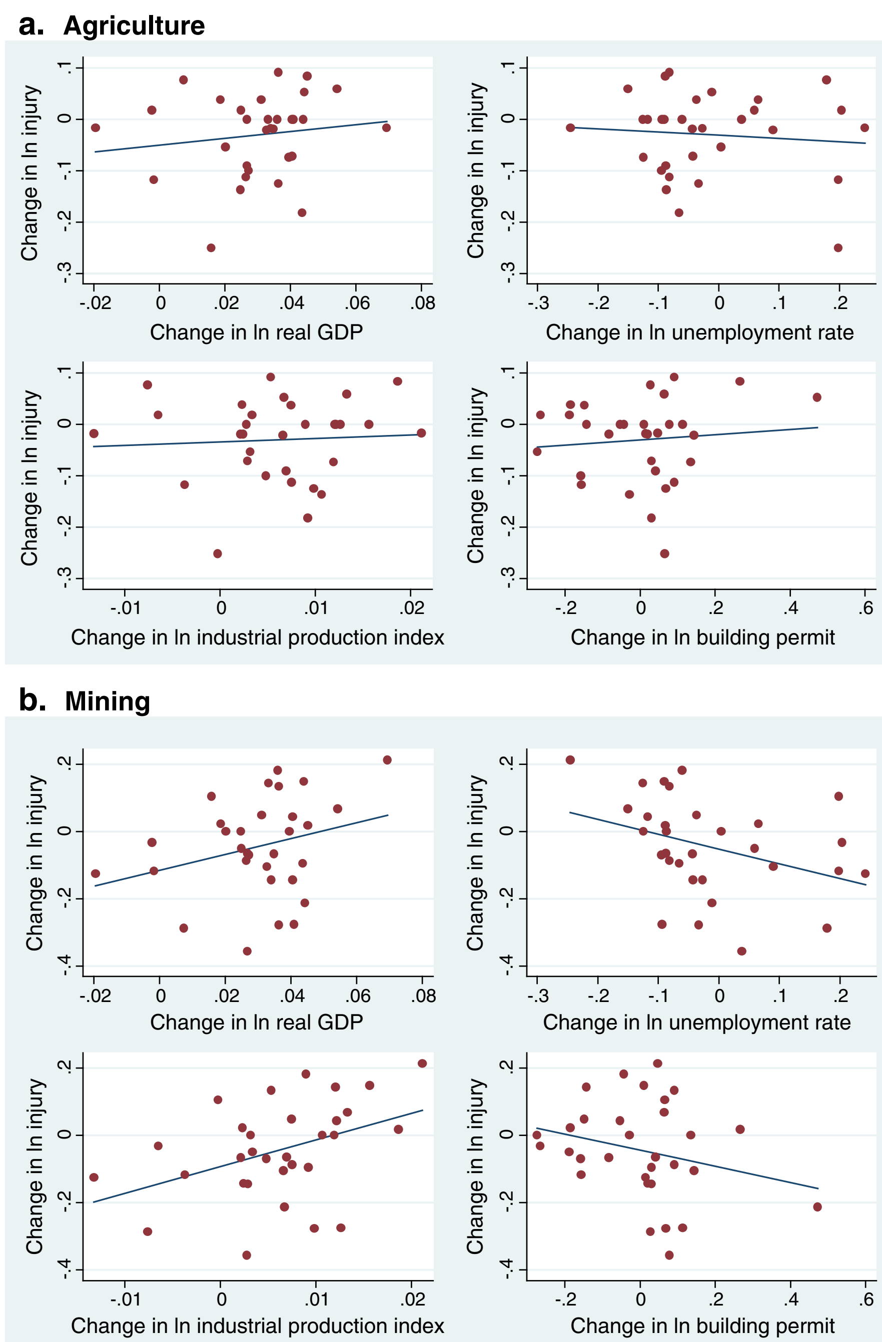

Fig. 3. Association between workplace injuries and business cycle indicators by industry, 1976–2007.

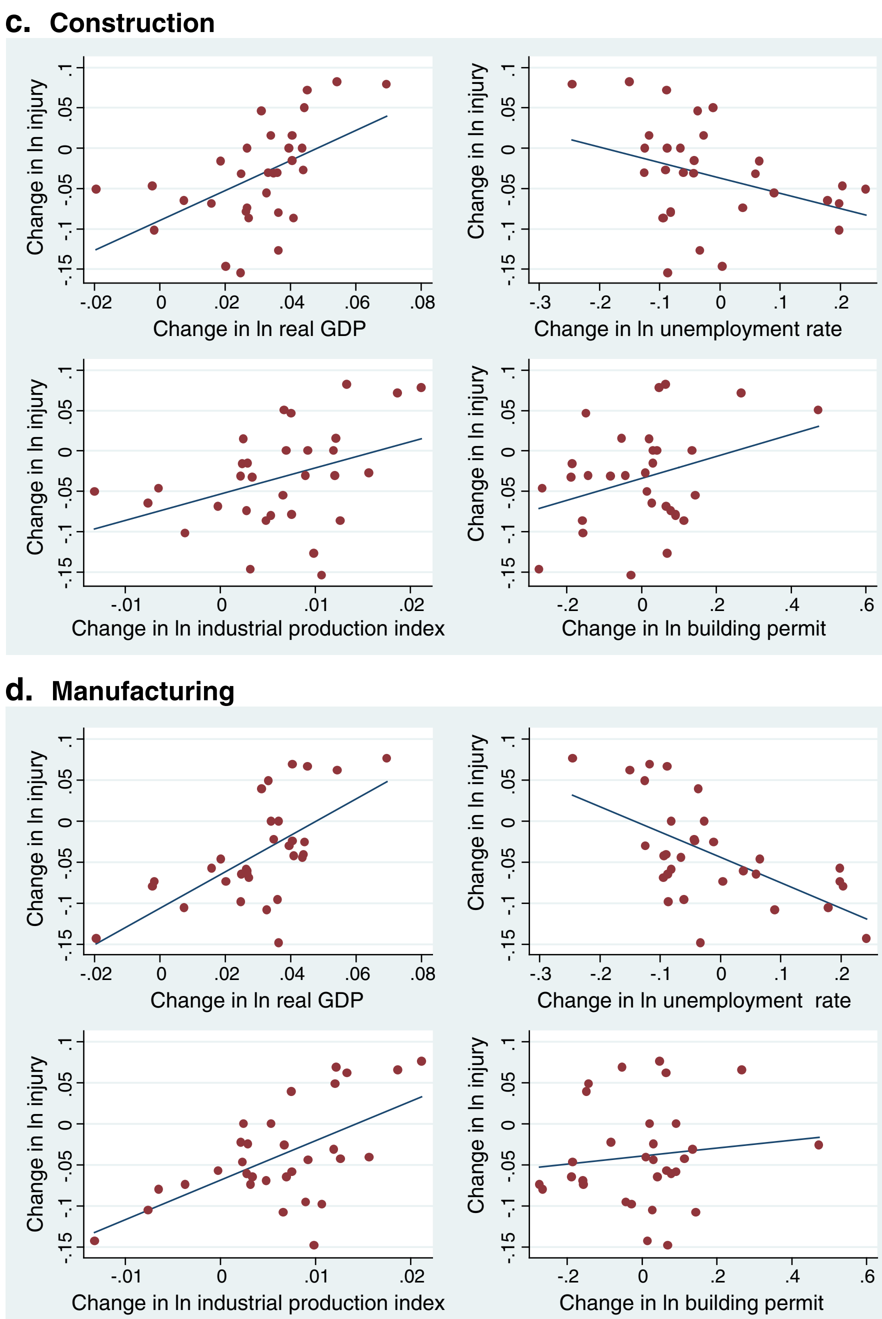

Fig. 3 (*continued*).

obtained from the Bureau of Labor Statistics (BLS), Survey of Occupational Illnesses and Injuries (http://www.bls.gov/iif/data.htm). Data on five industries (agriculture, mining, construction, manufacturing, and trade) were included based on the availability of relatively consistent industry level information for the years 1976 through 2007. Other industries, such as transportation or services, were not examined because industry classification changes that were implemented in 2003 (from standard industrial classification (SIC) to the North American industrial classification system (NAICS)) do not allow comparisons between the periods before and after that year. For the five industries we examined, we regrouped intact subsectors from the previous to the current classification system in order to utilize the years from 2003 to 2007, despite the 2003 break in the series (see the correspondence tables for SIC to NAICS at http://www.census.gov/epcd/naics02/N02TOS87.HTM).

To estimate Eq. (1), a variety of indicators was used to characterize the business cycle because no single variable accurately captures all aspects of aggregate economic fluctuations. Among several possible variables (see http://pages.stern.nyu.edu/~nroubini/bci/bcibase.htm) we selected Gross Domestic Product (GDP) (Bureau of Economic Analysis, http://www.bea.gov/index.htm), unemployment rate (BLS, http://www.bls.gov/bls/unemployment.htm), the industrial production index (Federal Reserve Board, http://www.federalreserve.gov/econresdata/default.htm), the number of building permits for new private homes (U.S. Census Bureau, http://www.census.gov/const/www/permitsindex.html), consumer confidence (Federal Research Bank of St. Louis, http://research.stlouisfed.org/fred2/data/UMCSENT.txt), and employment rate (BLS, http://www.bls.gov/data/#employment) as business cycle indicators. The results for the last two indicators were similar in sign and significance level to the results for the other four indicators and are not presented for the sake of brevity. To estimate Eq. (2), the same four indicators were used along with the industry-specific injury rates rather than economy-wide injury rates from BLS (http://www.bls.gov/iif/data.htm).

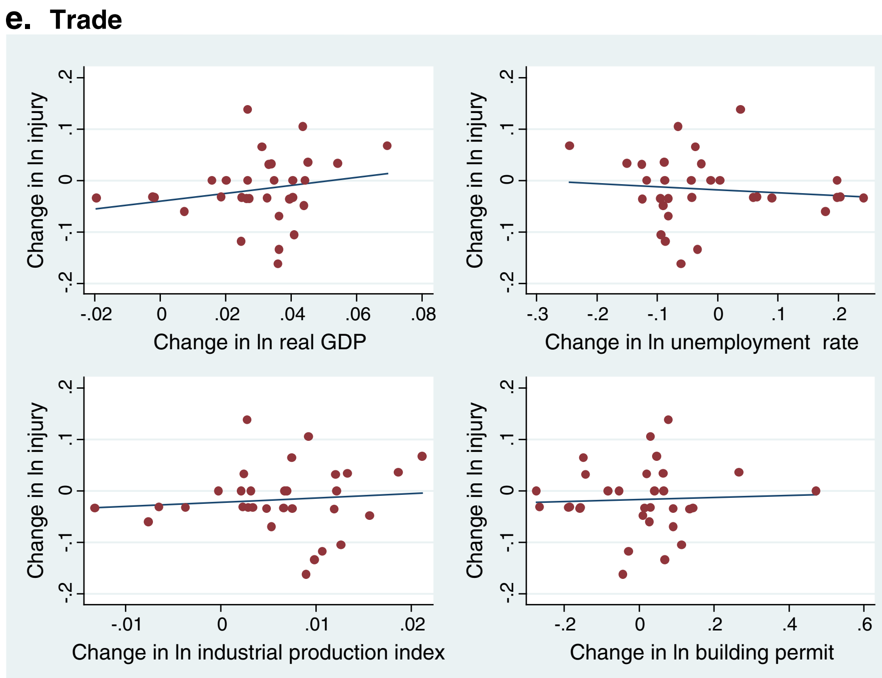

Fig. 3 (*continued*).

To estimate Eq. (3), the number of workers[4] employed in each industry and year from the BLS Occupational Employment Statistics (http://www.bls.gov/oes/), was used to capture the labor utilization effect of the business cycle. However, time series data were not available to measure the physical capital utilization variable. Therefore, capacity utilization (Federal Reserve Board, http://www.federalreserve.gov/econresdata/default.htm) was used to approximate the physical capital utilization variable. The capacity utilization variable captures both labor and capital inputs utilization. Since we had separate information on the labor utilization effect, we assumed that capacity utilization would approximate the physical capital utilization effect after partitioning the variance attributable to the labor utilization effect. Other potentially important predictors of workplace injuries, such as wages, average number of hours worked, and workforce composition such as share of production workers, were not included in the regression analysis due to either lack of data or multicollinearity problems.

4. Results

4.1. The business cycle and workplace injuries

Associations between the four business cycle indicators we used and the incidence of workplace injuries between 1976 and 2007 are presented in Fig. 2 and results of the regression analysis are presented in Table 1. All indicators except building permits took the expected signs and were statistically significant at $p<0.01$. The incidence rate of workplace injuries was negatively related to unemployment and positively related to real GDP, the industrial production index, and the number of building permits. Between 1976 and 2007, a 1% increase in real GDP was associated with a 1.6% increase in the incidence rate of workplace injuries. During the same time period, a similar increase in the industrial production index was associated with a 0.8% increase in the incidence rate of workplace injuries, while a 1% increase in the rate of unemployment was associated with a 0.2% decrease in the incidence rate of workplace injuries.

4.2. Cyclicity of workplace injuries by industry

Associations between aggregate business cycle indicators and the incidence rate of workplace injuries between 1976 and 2007 are presented for each industry in Fig. 3 and Table 2.[5] Consistent with expectations, the injury incidence rate in mining, construction, and manufacturing increased during times of economic expansion and declined during periods of sluggish growth. The incidence rate of workplace injuries in agriculture and trade was not sensitive to any business cycle indicator.

4.3. Business cycle mechanisms affecting workplace injuries

The effects of labor and physical capital utilization on workplace injuries are presented in Fig. 4 and Table 3 for the three industries where injury rates were sensitive to the business cycle. As shown in the figure, labor utilization was statistically insignificant in the mining industry while physical capital was statistically significant at $p<0.10$. In the construction sector, labor utilization was statistically significant at $p<0.10$, while in manufacturing, both effects were similar and statistically significant at $p<0.05$.

5. Discussion and conclusion

We used U.S. time series data for the years 1976-2007 to empirically estimate the impact of the business cycle on the incidence rate of workplace injuries across five industries. Results indicated that changes

[4] We did not have access to reliable time series data on the number of full-time and part-time workers separately in each industry. Therefore, we used the total number of workers employed in each industry.

[5] Note that the business cycle indicators were aggregate variables and did not necessarily reflect the economic cycle in each industry.

Table 2
Percent change in workplace injuries by industry as a result of a one-percent change in business cycle indicators.

Business cycle indicators+	% Change				
	Agriculture	Mining	Construction	Manufacturing	Trade
Real GDP	0.664	2.364	1.859***	2.218***	0.760
	(0.848)	(1.474)	(0.563)	(0.498)	(0.676)
Unemployment rate	-0.064	-0.439**	-0.191**	-0.309***	-0.057
	(0.125)	(0.209)	(0.090)	(0.075)	(0.100)
Industrial production index	0.693	7.963**	3.256**	4.816***	0.835
	(1.993)	(3.265)	(1.416)	(1.213)	(1.603)
New building permits	0.051	-0.240	0.137*	0.049	0.020
	(0.097)	(0.168)	(0.070)	(0.073)	(0.078)

Standard errors in parentheses.
+ The first difference of the variables was used in the regression analysis.
* $P \leq 0.10$, ** $P \leq 0.05$, and *** $P \leq 0.01$.

in GDP, the unemployment rate, and the industrial production index were associated with the overall rate of workplace injuries. These results are consistent with Davies et al. (2009), who found that minor injuries were positively associated with changes in GDP, unemployment, labor tenure, overtime, and work intensity (long hours). For example, using a data transformation similar to ours, Davies et al. reported that a 1% increase in GDP resulted in a 3.3% increase in the overall injury rate. However, they found no significant relationship between business cycle indicators and major injuries, which they attributed to opportunistic behavior during expansions that increase the number of "self reported" minor injuries.

Aggregate business cycle indicators also were associated with injury rates within industry sectors. Changes in GDP, the unemployment rate, and the industrial production index affected rates within the construction and manufacturing sectors. Construction also was associated with the number of new building permits. Mining was associated only with the unemployment rate and the industrial production index. Injury rates in agriculture and trade were not sensitive to the business cycle indicators we used. Results reported by Davies et al. (2009) were similar, showing a 1% increase in GDP resulted in a 1.7% increase in the injury rate in manufacturing, and a 2.6% increase in the injury rate in construction. Their results for agriculture also were not statistically significant.

Additional analyses demonstrated an association of injuries with our estimate of physical capital utilization in mining and labor utilization in construction. In manufacturing, injury rates were sensitive to both physical capital and labor utilization. The mechanisms through which changes in physical capacity utilization affect the incidence of workplace injuries cannot be determined in the present analysis. Potential mechanisms that can be examined in future studies may include introduction of new machinery and equipment, or increased use of inefficient, older, or less safe machinery. In the construction industry,

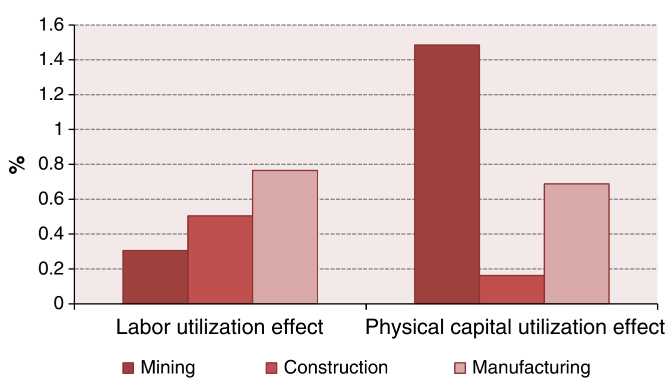

Fig. 4. The labor and physical capital utilization effects of the business cycle on the incidence of workplace injuries by industry, 1976–2007.

the association with labor utilization might indicate that increased hiring, an increased share of inexperienced workers, or faster, more fatiguing work during expansions could contribute to higher rates of workplace injuries. In their discussion of similar results, Davies et al. (2009) suggested that the sensitivity to the business cycle in construction could be attributed to a large number of relatively small firms that may be more financially constrained and reliant on temporary and contract workers. They also suggested that, because of the sensitivity to the business cycle in construction, workers in this industry may be vulnerable to complex pyramids of control that are due to multiple subcontractors. Hartwig et al. (1997) also pointed out that during the initial period of economic expansion, employment in construction, manufacturing, and other hazardous industries expands rapidly.

In the manufacturing industry, a 1% increase in the number of persons employed was associated with a 0.76% increase in the incidence of workplace injuries. The same percentage increase in physical capital utilization of firms was associated with a 0.69% increase in the incidence of workplace injuries. Consequently, both the hiring of new workers and the use of additional machinery and equipment (which might be less safe or very new to workers) are potential reasons for the increase in workplace injuries during expansions in this industry. Davies et al. (2009) also cited the fast pace of work in manufacturing as a potential contributor to increased job strain and ultimately injuries. They encouraged development of policies aimed at improving training for new recruits, controlling the integration of relatively unskilled workers into the production process, limiting the increased productive effort during periods of economic expansion, and promoting the fair reporting of injuries by employees.

In agriculture and trade, it appears that the turnover of labor and physical capital does not move in tandem with aggregate economic fluctuations, at least in the indicators we selected. The available data were insufficient to speculate on the reasons for those outcomes.

Overall, the results appear consistent with previous studies but potential biases may limit their interpretation. First, physical capital input

Table 3
Percent change in workplace injuries as a result of a one-percent change in labor or physical capital utilization.

	% Change		
	Mining	Construction	Manufacturing
Labor utilization	0.306	0.504*	0.765**
	(0.442)	(0.278)	(0.372)
Physical capital utilization	1.485*	0.162	0.688**
	(0.811)	(0.194)	(0.296)

Standard errors in parentheses.
* $P \leq 0.10$, ** $P \leq 0.05$, and *** $P \leq 0.01$.

was measured indirectly. Second, due to lack of data and multicollinearity problems, demographic, regulatory, and socio-economic variables that may affect the incidence of workplace injuries were not analyzed. Third, we only examined nonfatal injuries that may be influenced by reporting effects.

Our results have at least two policy implications. First, employers in construction, manufacturing, and mining should be aware of the strong association between the business cycle and the incidence of injuries, which would point to the need for additional safety measures during expansions. Second, the mechanism through which the business cycle affects the incidence of workplace injuries was not the same across different industries, which points to the need for different prevention strategies in each of the industries we examined. In mining, for example, employers may need to ensure that the machinery and equipment that are added to the production process as the economy expands be thoroughly inspected and that workers be trained on their safe use. In construction, more emphasis might be placed on adequately training workers and reducing fatigue during expansions, while all safety procedures continue to be observed. During expansions in manufacturing, employers might need to ensure that both newly hired workers are trained and that additional machinery brought into the production process is safe to use.

In future research, fatal injuries could be examined to understand their sensitivity to the business cycle. Additional analyses could be conducted using industry-specific rather than economy-wide variables as business cycle indicators. This might be especially important to better understand industries, such as agriculture, that seem to be insensitive to economy-wide fluctuations. Capacity utilization could be modeled using more specific variables such as new equipment purchases. Lastly, but importantly, the validity of the mechanisms we portrayed in Fig. 1 could be empirically tested. At present, however, employers should at least be aware of these mechanisms for their potential contributions to worker injuries.

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Disclaimer

The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

Appendix 1

Augmented Dickey-Fuller test for unit root (number of years = 31).

Variable	Label	First Difference
Ln total occupational injury incidence rate	0.910	-3.123**
Ln real GDP	-0.571	-4.622***
Ln unemployment rate	-2.692	-4.758***
Ln number of building permit	-4.433**	-5.992***
Ln industrial production index	-0.188	-4.892***

* $P \leq 0.10$, ** $P \leq 0.05$, and *** $P \leq 0.01$.
The null hypothesis is unit root.

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