Unemployment and Workplace Safety in a Search and Matching Model*

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Abstract

Are recessions really good for workplace safety? This paper develops a model with search to consider the determinant of workplace safety and then investigates a relationship between unemployment and the incidence of work-related injury. There is a view that the rate of work-related injury is pro-cyclical according to Arai and Thoursie (2005), Ruhm (2000) and Boone and van Ours (2006). However, the data from several countries do not necessarily support this view. This paper considers an alternative approach to support the counter-cyclical variants in the rate of work-related injury in which a firm chooses the optimal input for workplace safety.

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1 Introduction

Are recessions really good for workplace safety? This paper develops a model with search to consider the determinant of workplace safety and to explore a relationship between unemployment and the incidence of work-related injury. Assuming that the probability of a worker being injured at the work site depends negatively on the amount of input for workplace safety purchased by firms, there is trade-off for the firms between the cost of its input and the risk of losing a worker.

There is a view that the rate of workplace injury is pro-cyclical, therefore indicating that workplaces are kept safer in recessions. Arai and Thoursie (2005) argued that during an economic boom in which labor demand exceeded labor supply, firms hired even inexperienced workers who were more likely to be injured at the work sites, and therefore that both employment size and flow of absent employed workers because of work-related injuries were larger. To put it the other way around, they are smaller in recessions. Therefore, the unemployment rate and the flow rate of absent employed workers are *negatively* correlated, controlling for the labor force.

Ruhm (2000) showed that the mortality rate was pro-cyclical, indicating that people were healthy in recessions. He argued that workers' health was sapped by the deterioration of working conditions, increased workload and work-related stress caused by longer working hours during the short-lasting economic boom.

Boone and van Ours (2006) also supported that the rate of work-related injury was pro-cyclical, but provided a different explanation from Ruhm (2000). Consider an situation in which the extent of injury incurred by a worker is asymmetric; that is, an employer cannot observe the worker's injury. The worker is less likely to report her/his accident and try to keep working in recessions in which unemployment is high if the worker believes that workers who report accidents and take absenteeism are more likely to be fired by the employer. Even though working conditions remain unchanged, regardless of business cycles, the rate of work-related injury is low in recessions.

However, there is an opposite view supporting that the rate of work-related injury is not necessarily pro-cyclical. Ussif (2004) undertook an international comparative study using time-series data between 1970 and 1999 from several countries and found an opposite relationship; that is, as employment size increased, the number of work-related injuries decreased. In other words, the unemployment rate and the flow rate of absent employed workers are *positively* correlated, controlling for the labor force. Additionally, he found movements of these two rates in the same direction if a time trend was controlled. Ussif (2004) concluded that the number of work-related injuries had declined because of the technical advancement of workplace devices and environments captured by the time trend.

To the best of my knowledge, we have not so far considered other elements determining the number of injuries at the work site, but to do so is of importance from policy makers' point of view. There are many other factors affecting the rate of work-related injury, including employer practices at the work site, employee training, the role of unions, the technical advancement of work goods and environments as pointed out by Ussif (2004), the provision of mandates for safety. This paper focuses attention on the determinant of workplace safety and develops a model that endogenizes the probability for a worker being subject to a work-related injury in which a firm decides how much input to purchase for workplace safety. Then we explore the optimal decision of firms that determines the number of injuries at the work site in response to exogenous shocks. Our contribution is to provide an alternative approach to explain the relationship between the unemployment rate and the incidence of work-related injury by incorporating the determinants of input for workplace safety into a search-matching model. This paper does not discuss the role of mandates to keep workplaces safe by, for example, the Occupational Safety and Health Administration (OSHA) in the United States and its effect on labor market conditions.[1]

There are some theoretical studies in this field. Holmlund (2005) presented the model with individual search behavior and a decision on sickness absenteeism with the framework of the stochastic utility function of sickness and analyzed the impact of social insurance on a worker's labor supply decision. He focused on an individual worker's decision on labor supply and sickness absenteeism. Our paper instead focuses on the determinant

[1] Jolls (2008) surveyed both theoretical and empirical studies on the effects of OSHA and compensation programs of work-related injuries.

of the amount of input purchased by *firms* for workplace safety to reduce the risk of losing employed workers because of work-related injuries. One of the main findings in Holmlund (2005) is that an increase in sickness benefits raises the value of participating in the labor force, thereby resulting in an increase in employment size. Engström and Holmlund (2007) extended to a general equilibrium model with search by incorporating absenteeism from work as an additional state.[2] They derived the optimal compensation package to maximize the expected profit affected by the number of job applications and sick workers' determinant of absenteeism from work under the condition that accidents randomly arrived at workers. They provided the welfare analysis and compared with alternative social insurance policies.

Boone and van Ours (2006) presented empirical evidence showing that the pro-cyclical variant in workplace accidents would rather be attributable to reluctance of reporting accidents in recessions than to changes of working conditions and the composition of experienced and inexperienced workers, using time series data from OECD 16 countries. Other empirical studies in this area have thus far explored the effect of OSHA on work-related injuries using state-level, industry-level or plant-level data from the US.[3] Overall, the effect of OSHA enforcement on the rate of work-related injury was modest in the US (Viscusi 1979 1986, Bartel and Thomas 1985). In contrast, Scholz and Gray (1990) found a significant relationship between OSHA enforcement and the rate of work-related injury using plant-level data of firms that were frequently inspected. According to the recent study by Mendeloff (2005), its significant relationship was observed in the early 1990s but it disappeared afterward.

Our findings are summarized below. In our model, an active employed worker becomes unemployed in two directions. One is a direct separation from active employment to unemployment by an exogenous shock, and the other is an indirect separation from active employment to unemployment through a channel of absenteeism state because of work-related injury. That is, an absent employed's job is not necessarily protected. The

[2] Barmby et al. (1994) presented a model in which the wage is endogenously determined within an efficiency wage setting. They showed that the wage is adjusted to affect the decision on sickness absence. Garibaldi and Wasmer (2001) also built a multistage model where the wage is endogenously determined.

[3] Smith (1992) surveyed empirical studies in the early 1990s.

likelihood that the active employed is injured at the work site depends negatively on the amount of input for workplace safety. Therefore, the firm can control the separation rate by buying input for workplace safety. Productivity improvement encourages firms to enter the labor market, which makes more competitive for the firms to hire a worker. Because it is harder for the firms to meet an unemployed, they are induced to increase input for workplace safety to prevent the current employed worker from being injured at the work site. In addition, productivity improvement leads to an increase in profit, which implies an increase in the opportunity cost that firms would have incurred if their workers had been injured. The firms are then induced to purchase more input for workplace safety to reduce the risk of work-related injury. Overall, productivity improvement unambiguously raises the amount of input for workplace safety. The risk of work-related injury that depends negatively on the input for workplace safety is counter-cyclical.

Looking at the impact on unemployment rate, productivity improvement encourages firms' entry as mentioned before, which raises labor market tightness and thereby lowers the unemployment rate. An increase in the amount of input for workplace safety enlarges active employment size but reduces absenteeism size. The flow rate to the unemployment pool is then larger from the active employment pool but smaller from the absenteeism pool. We find that the latter effect exceeds the former one, and therefore, an increase in the input for workplace safety lowers the unemployment rate. The overall effect of productivity improvement is negative on the unemployment rate, which is consistent with the implication from the past literatures.

The model with the determinant of workplace safety illuminates that both the risk of work-related injury and the unemployment rate are counter-cyclical, which is different from the views from Arai and Thoursie (2005), Ruhm (2000) and Boone and van Ours (2006), but consistent with that of Ussif (2004).

The model is extended to analyzing effects of some policy parameters (sickness benefit and unemployment benefit). Among them, the effect of unemployment benefit is particularly noteworthy. To the best of our knowledge, unemployment benefit and workplace safety have been thus far discussed separately. We here show the strong linkage in policy between them. An increase in the unemployment benefit discourages firms to enter the labor market, which makes less competitive for the firms to hire a worker. Because it is easier for the firms to meet an unemployed, they have less incentive to concern about avoiding work-related injury. Additionally, an increase in the unemployment benefit raises the wage and thus lowers profit, which implies a decrease in the opportunity cost that firms would have incurred if their workers had been injured. Again, the firms do not concern about reducing the risk of work-related injury. Putting oppositely, an increase in unemployment benefits raises the value of unemployment, which makes the state of unemployment more favorable for workers. To attract unemployed workers, firms raise the expected value of employment for an active worker and an absent worker by reducing the risk of losing the wage because of work-related injury. The firms are therefore encouraged to increase the input for workplace safety. The overall impact of unemployment benefit is unambiguous on the risk of work-related injury. However, if the last effect is dominant, we can conclude that the unemployment benefit is one of valid tools to reduce the risk of injury at the work site.

The organization of the rest of this paper is as follows. Data findings are presented in the next section. Section 3 presents a matching model with an endogenous determinant of input for workplace safety. Section 4 illustrates comparative statics exercises and discusses the determinant of a relationship between unemployment and the incidence of work-related injury by productivity improvement. The effects of sickness and unemployment benefits are analyzed in Section 4. The final section provides concluding remarks.

2 Some Data Findings

In this section, we attempt to show relationships between unemployment rates and the rates of work-related injury.

For visual inspections, we compare relative variations of the unemployment rate and the rate of non-fatal injury. Figures 1 displays annual growth rates of these variables, using time-series data from selected countries from Europe, North America and Asia.

The data are obtained from LABORSTA, ILO. It appears a negative relationship between the unemployment rate and the non-fatal injury rate over the sample period in Poland, Romania, Spain, Sweden, Canada, United States. These data findings support the view from Arai and Thoursie (2005), Ruhm (2000) and Boone and van Ours (2006); that is, while the unemployment rate is counter-cyclical, the injury rate is pro-cyclical because inexperienced workers who are more likely to be hired during the economic boom are more likely to be injured at the work site. However, we cannot see a clear negative relationship over the sample period in other countries but rather observe a positive relationship during some periods. For example, in Italy, both the unemployment rate and the non-fatal injury rate are on decline in the 2000s, and in United Kingdom, both have moved in the same direction since the late 1990s. In Japan, both the unemployment rate and the non-fatal injury rate have moved in the same direction during the period of the bubble economy (the late 1980s and the early 1990s) and in the recent years after 2005.

These evidences show that there are any other mechanisms or factors to determine the relationship between the unemployment rate and the injury rate. We will focus attention on the labor demand side approach through a firm's optimal choice of input for workplace safety to prevent accidents from occurring at the work site.

3 The Model

We consider a continuous-time model with matching in which there are a continuum of risk-neutral workers and a continuum of risk-neutral firms. The measure of workers is normalized to one. Workers are infinitely lived and homogeneous with respect to preferences to work. At any moment, a worker is either unemployed, employed, absent from work because of work-related injury, or non labor force participant who cannot look for a job due to injury or sickness. An employed worker is injured at the work site and absent from work at a Poisson rate $\lambda(k)$, where k represents safety and health input, with its price normalized to one, purchased by a firm to improve conditions of workplace safety. Work-related injuries are defined here by immediate health hazard in the course of work that forces workers to be absent from work for treatment such as lower-back pain, cuts, bruises, broken bone, falls, struck by objects, mental illness and so on, but not by long-term latent health hazard from work such as pneumoconiosis. A firm that creates job vacancies through free entry decides on how much input k to buy for each job vacancy after meeting an unemployed worker. We assume that λ is characterized by $\lambda'(\cdot) < 0$, $\lambda''(\cdot) > 0$, $\lambda(0) = \overline{\lambda} \leq \infty$ and $\lim_{k\to\infty} \lambda(k) = \underline{\lambda} \geq 0$. As a firm buys input to improve conditions of workplace safety, the likelihood that an employed worker is injured is reduced at a decreasing rate.

There is search and matching friction. The unemployed and job vacancies are matched randomly according to a matching function, $m(u, v)$ where u is the number of the unemployed and v is the measure of job vacancies across all firms. The matching function is assumed to exhibit constant returns to scale, implying that the rate at which a vacancy encounters an unemployed worker is computed by $m(u, v)/v = m(u/v, 1) \equiv q(\theta)$ where $\theta \equiv v/u$ is labor market tightness, while the rate at which an unemployed worker matches with a job vacancy is represented by $\theta q(\theta)$. Note that $q(\theta)$ is decreasing in θ; that is, $q'(\theta) < 0$.

A job is separated at an exogenous Poisson rate δ, regardless of whether an employed actively works or is absent from work. While the active worker then becomes unemployed and begins to search for a job, the absent worker is out of labor force because of the treatment of injury. Both workers and firms discount the future at the common rate r.

Various value functions are developed below. We begin with the value for an employed worker of engaging actively in work as follows:

$$rW(w) = w + \lambda(k)[W_a(w) - W(w)] + \delta[U - W(w)]. \tag{1}$$

The instantaneous utility is linear with earnings. The second term on the right-hand side of equation (1) represents the expected capital loss incurred by being injured, and the third term indicates the expected capital loss of being unemployed. In a similar manner, the value for an employed worker of being absent from work because of work-related injury is defined by:

$$rW_a(w) = \alpha[W(w) - W_a(w)] + \delta[N - W_a(w)]. \tag{2}$$

We assume in a benchmark case that if being absent from work because of injury at the work site, the worker is not recompensed at all for her earning w. The absent employed worker heals and returns to work at an exogenous Poisson rate α.[4] Note that disutility incurred by the absent employed worker is ruled out in this model without loss of generality. The absent worker loses the status of employment at δ and is out of labor force, where N represents the value of being out of labor force because of the treatment of injury.

The value of unemployment is given as usual by:

$$rU = \theta q(\theta)[W(w) - U]. \tag{3}$$

At any moment, an unemployed worker, who is assumed to receive no instantaneous utility, meets a firm with a vacant job at the transition rate $\theta q(\theta)$. The value of being out of labor force is:

$$rN = \alpha(U - N). \tag{4}$$

A non labor force participant heals at rate α and becomes unemployed, looking for a job.

Equations (1) and (2) thus show that the value of being actively employed is more favorable for the worker than the value of being absent from work due to work-related injury because the absent worker is not compensated. The difference between these values is given by:

$$W(w) - W_a(w) = \frac{w + \delta(U - N)}{r + \alpha + \delta + \lambda(k)}.$$

[4] In fact, the rate of return to work is not exogenous. It depends largely on the amount of compensations as well as the extent of injury or illness if it is difficult to observe whether or not absent workers heal from injury or get well from sickness. Meyer, Viscusi, and Durbin (1995) undertook a natural experiment and found that an increase in compensations received by absent employed workers extends the duration of absence. Similar results are obtained in Ehrenberg (1988) and Krueger (1990).

Substituting this equation, equations (3) and (4) into equation (1) yields a worker's surplus:

$$W(w) - U = \frac{r + \alpha + \delta}{(r + \delta)(r + \alpha + \delta + \lambda(k))} \left[w - \frac{r + \alpha + \lambda(k)}{r + \alpha} rU \right]. \tag{5}$$

Next we discuss value functions for a firm. We consider a firm to be a collection of individual jobs. At any time in point, jobs are either occupied, unfilled, or inactive because employed workers are absent due to work-related injuries. We assume that firms operate under constant-returns-to-scale production technology with respect to labor input. This assumption assures that jobs are independent of one another.

The value of a job being occupied and active is:

$$rJ(w, k) = p - w - k + \lambda(k)[J_a(w, k) - J(w, k)] + \delta[V - J(w, k)]. \tag{6}$$

A matched pair produces p instantaneously. The second term on the right-hand side of equation (6) represents the expected capital loss of a job being inactive because a worker is absent from work owing to work-related injury. The third term indicates the expected capital loss of a job being separated.

Similarly, the value of an occupied job being inactive because of work-related injury is:

$$rJ_a(w, k) = \alpha[J(w, k) - J_a(w, k)] + \delta[V - J_a(w, k)]. \tag{7}$$

The job turns out to be active at rate α and separated at rate δ. We assume for simplicity that there are no disability insurance programs. However, in reality, many firms join the federal or state disability insurance programs with compulsory payroll deductions. If own employees are injured at the work site, they are compensated through its program. Because the disability insurance program is mainly financed by firms, it is interpreted that firms indirectly bear the burden of compensation. Furthermore, there are many firms that have own absence leave programs with payments. According to the survey conducted by Japanese Ministry of Health, Labour and Welfare (MHLW) in January

2008, 58.6% of surveyed Japanese firms have own absence leave programs, and 41.1% of them keep paying average 85.8-93.6% of salaries to absent employees. Putting down to surveyed firms over 1,000 employees, 85.3% have own absence leave programs, and 56.8% pays 88.5-91.8% of salaries to absent workers.[5]

The value of a vacancy is given as usual by:

$$rV = -\phi + q(\theta)[J(w,k) - V]. \tag{8}$$

A vacancy is incurred the instantaneous cost ϕ and filled at the transition rate $q(\theta)$. The free entry condition ensures $V = 0$ in equilibrium.

Equations (6) and (7) give the following equation:

$$J(w,k) = \frac{(r+\alpha+\delta)(p-w-k)}{(r+\delta)(r+\alpha+\delta+\lambda(k))} > 0. \tag{9}$$

$$J_a(w,k) = \frac{\delta(p-w-k)}{(r+\delta)(r+\alpha+\delta+\lambda(k))} > 0.$$

Because $J_a(w,k) > V = 0$, the inactive firm does not choose to fire the absent worker.

A firm and a worker consummate a match if and only if the joint surplus gained through this match is nonnegative, and then they share the joint surplus according to the Nash bargaining rule. Assuming that the worker's share of the surplus is defined by $\beta \in [0,1]$, we have:

$$(1-\beta)[W(w) - U] = \beta J(w,k). \tag{10}$$

The wage is determined, taking account of the possibility of a worker being injured in the future. Substituting equations (5) and (9) into equation (10) gives:

$$w = \beta(p-k) + (1-\beta)\left[\frac{r+\alpha+\lambda(k)}{r+\alpha}\right] rU.$$

According to the Nash bargaining rule, the wage is determined by the weighted-

[5] See *Rodo Sinbun* (Labour Newspaper) No. 2688 (July 14, 2008) in Japanese published by *Rodo Sinbunsha*.

average of the instantaneous profit (the first parentheses on the right-hand side) and the reservation wage rU, accounting for the risk of injury. From equations (3), (8) and (10), the reservation wage rU can be expressed as $rU = \frac{\beta}{1-\beta}\phi\theta$. Substituting this into the above wage equation yields:

$$w(k) = \beta \left[p - k + \frac{r + \alpha + \lambda(k)}{r + \alpha} \phi\theta \right]. \tag{11}$$

The wage depends negatively on k. An increase in k lowers the risk of injury at the work site, which means that it is more favorable for the worker to be employed than to be unemployed. It therefore reduces the worker's bargaining power, directly reflecting the lower wage. In addition, an increase in k lowers the expected profit, leading to a decrease in the wage.

We move to the problem regarding the optimal choice of input for workplace safety. A firm chooses the optimal amount of input for workplace safety per job vacancy to maximize the value of a job being occupied:

$$\max_k J(w(k), k) \Longrightarrow \max_k \frac{(r + \alpha + \delta)[p - w(k) - k]}{(r + \delta)(r + \alpha + \delta + \lambda(k))}.$$

The first-order condition yields:

$$[w'(k) + 1][r + \alpha + \delta + \lambda(k)] = -\lambda'(k)[p - w(k) - k]. \tag{12}$$

The term on the right-hand side represents the expected marginal gain of an occupied job with respect to the input for workplace safety while the term on the left-hand side is its expected marginal cost. We assume $(w'(k) + 1) > 0$ or $(1 - \beta) + \frac{\beta\lambda'(k)}{r+\alpha}\phi\theta > 0$; that is, the instantaneous profit $(p - w(k) - k)$ is decreasing in k to obtain the interior solution. Since $w''(k) > 0$, the second-order condition ensures that the optimal capital level maximizes the value of being actively employed.

Substituting equation (9) into (8), the free entry condition can be rewritten as:

$$\frac{q(\theta)(r + \alpha + \delta)[p - w(k) - k]}{(r + \delta)(r + \alpha + \delta + \lambda(k))} = \phi. \tag{13}$$

Next, steady-state conditions are illustrated to derive the unemployment rate and fractions of absent employed workers. Let u be a fraction of unemployed workers, and let a and n denote a fraction of employed workers who are absent from work and a fraction of non labor force participants who cannot search for a job because of the treatment of injury, respectively. The steady-state conditions require:

$$\begin{aligned} \theta q(\theta)u &= \delta(1-u-a-n)+\alpha n, \\ \alpha n &= \delta a, \\ \text{and } (\alpha+\delta)a &= \lambda(k)(1-u-a-n). \end{aligned}$$

Then we obtain:

$$\begin{aligned} u &= \frac{\delta(1-\delta)\lambda(k)}{(\alpha+\delta)(\alpha+\lambda(k))(\delta+\theta q(\theta))+\delta(1-\delta)\lambda(k)}, \qquad (14) \\ a &= \frac{\alpha\lambda(k)(\delta+\theta q(\theta))}{(\alpha+\delta)(\alpha+\lambda(k))(\delta+\theta q(\theta))+\delta(1-\delta)\lambda(k)}, \\ \text{and } n &= \frac{\delta\lambda(k)(\delta+\theta q(\theta))}{(\alpha+\delta)(\alpha+\lambda(k))(\delta+\theta q(\theta))+\delta(1-\delta)\lambda(k)}. \end{aligned}$$

The fraction of employed workers who are actively engaged in work is therefore computed by:

$$e \equiv 1-u-a-n = \frac{\alpha(\alpha+\delta)(\delta+\theta q(\theta))}{(\alpha+\delta)(\alpha+\lambda(k))(\delta+\theta q(\theta))+\delta(1-\delta)\lambda(k)}. \qquad (15)$$

As one would expect, the higher labor market tightness θ lowers the fraction of unemployed workers u but raises both a and n because the measure of employed e is larger in size. An increase in input for workplace safety k lowers both a and n because workplace safety conditions are improved. An increase in k raises u through a channel of an increase in e, but on the other hand, lowers u through a channel of a decrease in n. Overall, the latter effect is dominant over the former one; that is, an increase in k lowers u.

The unemployment rate is then computed by:

$$\widetilde{u} \equiv \frac{u}{1-n} = \frac{\delta(1-\delta)\lambda(k)}{\alpha(\alpha+\delta+\lambda(k))(\delta+\theta q(\theta))+\delta(1-\delta)\lambda(k)}.$$

Similar to u, the unemployment rate depends negatively on k and θ.

The nature of equilibrium is characterized by the first-order condition to determine the optimal level of input, the free entry condition and the steady-state conditions. Equations (12), (13) and (14) provide a complete description of equilibrium to solve for the vector (k, θ, u, a, n). For convenience, these equilibrium conditions are summarized below.

(i) First-order condition (equation (12))

$$\lambda'(k)[p-w(k)-k]+[w'(k)+1][r+\alpha+\delta+\lambda(k)]=0,$$

(ii) Free entry condition (equation (13))

$$\frac{q(\theta)(r+\alpha+\delta)[p-w(k)-k]}{(r+\delta)(r+\alpha+\delta+\lambda(k))}=\phi,$$

and (iii) Steady-state conditions (equation (14))

$$\begin{aligned}
u &= \frac{\delta(1-\delta)\lambda(k)}{(\alpha+\delta)(\alpha+\lambda(k))(\delta+\theta q(\theta))+\delta(1-\delta)\lambda(k)}, \\
a &= \frac{\alpha\lambda(k)(\delta+\theta q(\theta))}{(\alpha+\delta)(\alpha+\lambda(k))(\delta+\theta q(\theta))+\delta(1-\delta)\lambda(k)}, \\
\text{and } n &= \frac{\delta\lambda(k)(\delta+\theta q(\theta))}{(\alpha+\delta)(\alpha+\lambda(k))(\delta+\theta q(\theta))+\delta(1-\delta)\lambda(k)},
\end{aligned}$$

where the wage equation (11) is:

$$w(k)=\beta\left[p-k+\frac{r+\alpha+\lambda(k)}{r+\alpha}\phi\theta\right].$$

We investigate the characterizations of the equilibrium by examining the comparative statics in the next section.

4 The Relationship between Unemployment and the Rate of Injury

Our concerns focus on a relationship between unemployment rate and the incidence of work-related injury via exogenous parameter changes. We first pick up productivity p as a key parameter. The main purpose in this subsection is to illustrate changes in workplace safety and labor market conditions in response to productivity improvement. Using (i) first-order conditions and (ii) free entry conditions, the comparative statics system is described. The appendix section shows the analytical details.

Proposition 1 *The comparative statics analysis provides the following characterizations: (1) an increase in productivity raises both the amount of input for workplace safety and labor market tightness,*

$$\frac{dk}{dp} > 0, \ \textit{and} \ \frac{d\theta}{dp} > 0;$$

(2) an increase in productivity lowers the unemployment rate (u)*,*

$$\frac{du}{dp} = \underbrace{\left(\frac{\partial \widetilde{u}}{\partial k}\right)}_{-}\underbrace{\left(\frac{dk}{dp}\right)}_{+} + \underbrace{\left(\frac{\partial \widetilde{u}}{\partial \theta}\right)}_{-}\underbrace{\left(\frac{d\theta}{dp}\right)}_{+} < 0,$$

and (3) an increase in productivity raises the employment rate (e) *but exerts ambiguous effects on the fractions of absent workers* (a) *and non labor force participants* (n)*.*

$$\frac{da}{dp} = \underbrace{\left(\frac{\partial a}{\partial k}\right)}_{-}\underbrace{\left(\frac{dk}{dp}\right)}_{+} + \underbrace{\left(\frac{\partial a}{\partial \theta}\right)}_{+}\underbrace{\left(\frac{d\theta}{dp}\right)}_{+} \lesseqgtr 0,$$

$$\frac{dn}{dp} = \underbrace{\left(\frac{\partial n}{\partial k}\right)}_{-}\underbrace{\left(\frac{dk}{dp}\right)}_{+} + \underbrace{\left(\frac{\partial n}{\partial \theta}\right)}_{+}\underbrace{\left(\frac{d\theta}{dp}\right)}_{+} 0 \lesseqgtr 0,$$

$$\frac{de}{dp} = \underbrace{\left(\frac{\partial e}{\partial k}\right)}_{+}\underbrace{\left(\frac{dk}{dp}\right)}_{+} + \underbrace{\left(\frac{\partial e}{\partial \theta}\right)}_{+}\underbrace{\left(\frac{d\theta}{dp}\right)}_{+} > 0,$$

As one would expect, an increase in productivity p raises labor market tightness θ. More firms enter the labor market and create vacancies because the productivity improvement leads to an increase in profit, thus resulting in an increase in θ.[6] Looking at the effect on input for workplace safety k, a decrease in $q(\theta)$ implies that it is harder for firms to meet a worker if the job is separated. This encourages them to increase the amount of input for workplace safety to reduce the indirect separation rate from active employment to non labor force participation through a channel of absenteeism. As its indirect separation rate is higher, the job is more likely to be vacant and then the firm has to search for an unemployed in the labor market with higher labor market tightness.

Alternatively, an increase in productivity p implies an increase in profit that firms would have earned without workers' absenteeism from work. An increase in the opportunity cost incurred by forcing the worker to be absent induces the firms to increase the amount of input for workplace safety k to prevent employed workers from being injured at the work sites, leading to lower rate of injury $\lambda(k)$. Combined with the above two effect, productivity improvement unambiguously exerts a positive impact on input of workplace safety k. The rate of injury is thus counter-cyclical. This result is inconsistent with the implications of the views from Arai and Thoursie (2005), Ruhm (2000) and Boone and van Ours (2006). However, this paper focuses attention on an alternative view from the determinant of workplace safety.

According to the steady state conditions, we recognize that an increase in productivity lowers the unemployment rate through channels of the increased amount of input for workplace safety k and higher labor market tightness θ. It implies that both the unemployment rate and the rate of injury at the work site are counter-cyclical. Again, this view was different from those from Arai and Thoursie (2005), Ruhm (2000) and Boone and van Ours (2006), but was supported by Ussif (2004) who showed that despite a steady increase in the number of employed workers, the number of work-related injuries had declined from 1970 to 1999 using time-series data from selected countries. That is,

[6] If $\beta = 1$; that is, there is no bargaining power over the wage determination for firms, firms do not have incentives to enter the labor market despite the fact that productivity improves, and therefore $d\theta/dp = 0$.

he implied a *positive* relationship between the unemployment rate and the rate of injury at the work site. Our implication is consistent partially of the data from some countries such as Italy, UK and Japan displayed in Figure 1.

Productivity improvement provides ambiguous effects on fractions of absent workers (a) and non labor force participants (n). An increase in the amount of input for workplace safety k reduces the flow of absent workers from e to a, but on the other hand, higher labor market tightness enlarges the employment size e, which thereby leads to an increasing flow of absent workers from from e to a, even though the rate of injury remains unchanged. The same intuition can be applied in a case of n.

The next exercise explores the effect of the healing rate α on labor market conditions. It illuminates differences of the rate of injury by occupational types.

Proposition 2 *The comparative statics analysis provides the following characterizations: (1) The higher rate of healing α raises labor market tightness but has an ambiguous effect on the amount of input for workplace safety; that is,*

$$\frac{dk}{d\alpha} \lesseqgtr 0, \ \ \textit{and} \ \frac{d\theta}{d\alpha} > 0;$$

(2) an increase in the healing rate either raises or lowers the unemployment rate (u),

$$\frac{du}{d\alpha} = \underbrace{\left(\frac{\partial \widetilde{u}}{\partial k}\right)}_{-}\underbrace{\left(\frac{dk}{d\alpha}\right)}_{+/-} + \underbrace{\left(\frac{\partial \widetilde{u}}{\partial \theta}\right)}_{-}\underbrace{\left(\frac{d\theta}{d\alpha}\right)}_{+} \lesseqgtr 0,$$

As the healing rate is higher; that is, workers are not seriously injured and can return to work sooner, more firms enter the market and create vacancies because the loss that the firm would incur by own worker's absenteeism from work is relatively small. This result implies that jobs are more likely to be created in sectors in which workers' injuries are generally not so severe such as retail sales and service sectors. In contrast, firms are discouraged from creating jobs in sectors where work-related injury is usually severe such as construction, transportation and mining.

The higher healing rate has an ambiguous effect on the amount of input for workplace safety k. If injured workers can return to work sooner, work-related injury is a trivial issue; firms do not have an incentive to buy input k to prevent accidents from occurring at the work site. Alternatively, the higher healing rate raises the values of employment, $W(w)$ and $W_a(w)$. It means that the employment state is more attractive for unemployed than the unemployment state, thus lowering the reservation wage and thereby the wage. Firms faced by an increase in profit are then encouraged to purchase input for workplace safety. Furthermore, a decrease in $q(\theta)$ makes it harder for firms to meet an unemployed, so they raise k to reduce the indirect separation rate from active employment to non labor force participation through a channel of absenteeism. We conclude that the amount of input for workplace safety and the healing rate are not monotonically correlated, so firms do not necessarily practice to keep workplaces safe by purchasing k in sectors with the lower healing rate α.

5 Applications

This section presents the effects of two policy parameters: sickness and unemployment benefits. These impacts illuminate firms' incentives for determinants of job creation and the amount of input for workplace safety in response to policy changes. Here is with the emphasis on the impact of unemployment benefits on workplace safety. It appears that the linkage between unemployment benefits and workplace safety has not at least thus far been argued. This comparative statics exercise contributes to illuminating its linkage.

5.1 The Extended Model

An employed worker who is actively engaged in work instantaneously earns w as heretofore, but an employed worker who is absent from work because of work-related injury is recompensed for her/his loss by sickness benefits b. Additionally, an unemployed worker now receives unemployment insurance benefits z. Non labor force participants who cannot look for a job because of the treatment of work-related injury also receive the same amount of sickness benefits b. The value functions for a worker are modified by:

$$rW(w) = w + \lambda(k)[W_a(w) - W(w)] + \delta[U - W(w)],$$

$$rW_a(w) = b + \alpha[W(w) - W_a(w)] + \delta[U - W_a(w)],$$

$$rU = z + \theta q(\theta)[W(w) - U].$$

and

$$rN = b + \alpha[U - N]. \tag{16}$$

Because workers are risk-neutral, sickness and unemployment benefits are considered just as subsidies. The value functions for a firm remain the same: equations (6), (7) and (8). We assume for simplicity that firms do not take out disability insurance; that is, firms do not pay the insurance premium and therefore do not receive disability insurance benefits faced by absent workers who are injured at the work site.

Using these value functions and the free entry condition, the wage is solved according to the Nash bargaining rule:

$$w = \beta\left[p - k + \frac{r + \alpha + \lambda(k)}{r + \alpha}\phi\theta\right] + (1 - \beta)\left[\frac{(r + \alpha + \lambda(k))z - \lambda(k)b}{r + \alpha}\right]. \tag{17}$$

Be aware that this wage equation is reduced to equation (11) in a case of $b = z = 0$. An increase in input for workplace safety k lowers the wage unambiguously if $z > b$. An increase in k lowers $(p-k)$, leading to the lower wage. In addition, an increase in k lowers the likelihood that an employee is injured at the work site and raises the expected value of being employed relative to the value of being unemployed. The state of employment is more attractive, thus resulting in decreases in the reservation wage and thereby the wage. The wage depends negatively on sickness benefits b. As an absent worker is recompensed more generously, the employment state is more favorable than the unemployment state, thus leading to the lower reservation wage and thereby the wage. On the other hand, the wage increases with unemployment benefits z, which can be explained in an opposite way.

From equations (9) and (17), we obtain the value of a job being occupied and active $J(w(k), k)$. A firm chooses the optimal amount of input for workplace safety per job vacancy to maximize $J(w(k), k)$.

Similarly to Section 2, the nature of equilibrium is characterized by (i) the first-order condition, (ii) the free entry condition and (iii) the steady-state conditions. These conditions are the same as those derived in Section 2, but the wage form is different. The comparative statics studies show the characterizations of the equilibrium in response to the changes of policy parameters.

5.2 Comparative Statics Effects

We next explore the effects of policy parameters (sickness and unemployment benefits) on input for workplace safety and labor market tightness. According to the comparative statics analysis, we obtain the following results:

Proposition 3 *(a) sickness benefit*

$$\frac{dk}{db} \lesseqgtr 0 \quad \textit{and} \quad \frac{d\theta}{db} > 0,$$

and (b) unemployment benefit

$$\frac{dk}{dz} \gtreqless 0 \quad \textit{and} \quad \frac{d\theta}{dz} < 0.$$

The appendix section shows analytical details.

(a) Sickness Benefit

An increase in sickness benefits b encourages firms to enter the market because the wage is lower according to equation (17), thereby leading to higher θ.

An increase in labor market tightness changes a firm's behavior toward the choice of input for workplace safety. There are three effects on k to be considered. First, a decrease in $q(\theta)$ implies that it is more difficult for firms to meet an unemployed, so the firms raise k to reduce the indirect separation rate from active employment to non labor force participation through a channel of absenteeism. The second one is that an increase in b leads to an increase in the profit that firms would have earned without own worker's absenteeism owing to work-related injury. It induces the firms to purchase more input for workplace safety to reduce the risk of injury at the work site. Putting oppositely, as b increases more largely, the difference between the value for an active employed $W(w)$ and the value for an absent employed $W_a(w)$ is smaller, which implies that workers faced by larger b are more likely to accept the risk of injury. Therefore, firms are discouraged from buying k to keep workplaces safe.

Overall, the effect of sickness benefits on workplace safety is ambiguous. In a case that the first two effects are dominant over the last effect, sickness benefits exert a positive effect on the amount of workplace safety purchased by firms. One possible suggestion for policy implications from this exercise is to increase sickness benefits, inducing firms to pay more attention on workplace safety.

(b) Unemployment Benefit

The linkage between unemployment benefits and workplace safety is considered here. The intuitive explanations here are completely opposite to those for the effect of sickness benefits mentioned above. As seen in standard matching models, an increase in unemployment benefits z lowers labor market tightness θ. The intuition behind this result is that an increase in z raises the reservation wage of workers and thereby the wage, which encourages firms to exit.

The comparative statics study shows that input for workplace safety k is positively or negatively associated with unemployment benefits z. There are three different effects on k. First of all, a firm faced by lower θ recognizes that it is easier to meet an unemployed, which reduces an incentive for the firm to lower the indirect separation rate from active employment to non labor force participation through a channel of absenteeism. k is then lower. Secondly, an increase in z raises the wage and lowers the profit, so the opportunity cost of losing own worker because of work-related injury is lower, thereby reducing the amount of input for workplace safety. The final effect is opposite to the above two effects. An increase in z raises the value of unemployment, making the state of unemployment more favorable. To raise the expected value of employment for an active worker and an absent worker, firms are induced to increase the amount of input for workplace safety to reduce the likelihood that the active employed is injured at the work site and loses the wage.

If the final (positive) effect on k is dominant over the first two (negative) effects, the novel result is that the unemployment benefits have a positive effect on input for workplace safety, implying a decrease in the risk of being injured at the work site. It is possible that the unemployment benefits encourage firms to improve working conditions.

6 Concluding Remarks

This paper allows for firms' decisions on the amount of input for workplace safety, and trade-off between its cost and the risk of employed workers being absent from work because of work-related injuries.

By incorporating firms' decisions on the amount of input for workplace safety in a search and matching model, we investigated the relationship between unemployment and the incidence of work-related injury. Productivity improvement encourages firms' entry and then raises labor market tightness. More competitiveness to find an unemployed induces the firms to increase the amount of input for workplace safety to indirectly reduce the job separation rate. Additionally, productivity improvement raises profit, so the firms are induced to increase input for workplace safety to prevent a potential loss of the profit. Overall, the effect of productivity improvement is positive on the amount of input for workplace safety and in other words, negative on the risk of work-related injury. As for the impact on unemployment rate, firms' entry raises labor market tightness and thereby lowers the unemployment rate. The lower risk of injury at the work site enlarges active employment size but reduces absenteeism size. The flow rate to unemployment is thus larger from active employment but smaller from absenteeism. The comparative statics analysis documents that the latter effect is dominant over the former one, and therefore that an increase in the input for workplace safety lowers the unemployment rate. The overall effect of productivity improvement is negative on the unemployment rate through input for workplace safety and labor market tightness.

This exercise shows that both the risk of injury and the unemployment rate are counter-cyclical. This implication may not be supported according to some data findings. However, it is clearly observed this relationship from other data sources. For example, the risk of injury as well as the unemployment rate is counter-cyclical during the some period in Italy, United Kingdom and Japan.

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Appendices

Comparative Statics Effect (Section 3)

In this appendix, we use comparative statics analysis to explore the effects of productivity p on input for workplace safety k and labor market tightness θ, using the first-order condition (equation (12)) and the free entry condition (equation (13)). The comparative statics system is given by:

$$\begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} \frac{dk}{dp} \\ \frac{d\theta}{dp} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix},$$

where:

$$A_{11} = \lambda''(k)\left[\frac{\beta\phi\theta\delta}{r+\alpha} + (1-\beta)(p-k)\right] > 0$$

$$A_{12} = \frac{\beta\lambda'(k)\phi\delta}{r+\alpha} < 0,$$

$$A_{21} = 0 \text{ from the first-order condition,}$$

$$A_{22} = \left(\frac{r+\alpha+\delta}{r+\delta}\right)\left[\frac{q'(\theta)(p-w(k)-k)}{r+\alpha+\delta+\lambda(k)} - \frac{\beta q(\theta)(r+\alpha+\lambda(k))\phi}{(r+\alpha)(r+\alpha+\delta+\lambda(k))}\right] < 0,$$

$$B_{11} = -(1-\beta)\lambda'(k) > 0,$$

$$B_{12} = \frac{\beta\lambda'(k)\phi\theta\delta}{(r+\alpha)^2} - (1-\beta) < 0,$$

$$B_{21} = -\frac{q(\theta)(r+\alpha+\delta)(1-\beta)}{(r+\delta)(r+\alpha+\delta+\lambda(k))} < 0,$$

and

$$B_{22} = -\frac{q(\theta)\lambda(k)(p-w(k)-k)}{(r+\delta)(r+\alpha+\delta+\lambda(k))^2} - \frac{(r+\alpha+\delta)q(\theta)}{(r+\delta)(r+\alpha+\delta+\lambda(k))}\left(\frac{\beta\lambda(k)\phi\theta}{(r+\alpha)^2}\right) < 0$$

The Jacobian determinant is $\nabla_A \equiv A_{11}A_{22} - A_{12}A_{21} < 0$. Then we find:

$$\frac{dk}{dp} > 0, \text{ and } \frac{d\theta}{dp} > 0,$$

and

$$\frac{dk}{da} \gtrless 0, \text{ and } \frac{d\theta}{da} > 0.$$

Comparative Statics Effect (Section 4)

The first-order condition (equation (12)) and the free entry condition (equation (13)) are:

$$\lambda'(k)[p-w(k)-k] + [w'(k)+1][r+\alpha+\delta+\lambda(k)] = 0,$$

and

$$\frac{q(\theta)(r+\alpha+\delta)[p-w(k)-k]}{(r+\delta)(r+\alpha+\delta+\lambda(k))} = \phi,$$

where

$$w = \beta\left[p-k+\frac{r+\alpha+\lambda(k)}{r+\alpha}\phi\theta\right] + (1-\beta)\left[\frac{(r+\alpha+\lambda(k))z-\lambda(k)b}{r+\alpha}\right].$$

We assume $(w'(k)+1)>0$ or $(1-\beta)+\frac{\beta\lambda'(k)}{r+\alpha}\phi\theta+(1-\beta)\frac{\lambda'(k)(z-b)}{r+\alpha}>0$; that is, the instantaneous profit $(p-w(k)-k)$ is decreasing in k. In addition, we assume $z>b$. It is then sufficient that the second-order condition ensures that the optimal capital level maximizes the value of a vacancy.

The comparative statics analysis is provided below to investigate the effects of the policy parameters:

$$\begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix} \begin{bmatrix} dk \\ d\theta \end{bmatrix} = \begin{bmatrix} D_{11} & D_{12} \\ D_{21} & D_{22} \end{bmatrix} \begin{bmatrix} db \\ dz \end{bmatrix},$$

where:

$$C_{11} = \frac{\beta\lambda''(k)\delta\phi\theta}{r+\alpha} + (1-\beta)\lambda''(k)\left[(p-k)+\frac{\delta z-(r+\alpha+\delta)b}{r+\alpha}\right] > 0,$$

assuming δz is larger than $(r+\alpha+\delta)b$,

$$C_{12} = \frac{\beta\lambda'(k)\delta\phi}{r+\alpha} < 0,$$

$$C_{21} = 0$$

from the first-order condition,

$$C_{22} = \left(\frac{r+\alpha+\delta}{r+\delta}\right)\left[\frac{q'(\theta)(p-w(k)-k)}{r+\alpha+\delta+\lambda(k)} - \frac{\beta q(\theta)(r+\alpha+\lambda(k))\phi}{(r+\alpha)(r+\alpha+\delta+\lambda(k))}\right] < 0,$$

$$D_{11} = \frac{(1-\beta)\lambda'(k)(r+\alpha+\delta)}{r+\alpha} < 0,$$

$$D_{12} = -\frac{(1-\beta)\lambda'(k)\delta}{r+\alpha} > 0,$$

$$D_{21} = -\frac{(1-\beta)q(\theta)(r+\alpha+\delta)\lambda(k)}{(r+\delta)(r+\alpha)(r+\alpha+\delta+\lambda(k))} < 0,$$

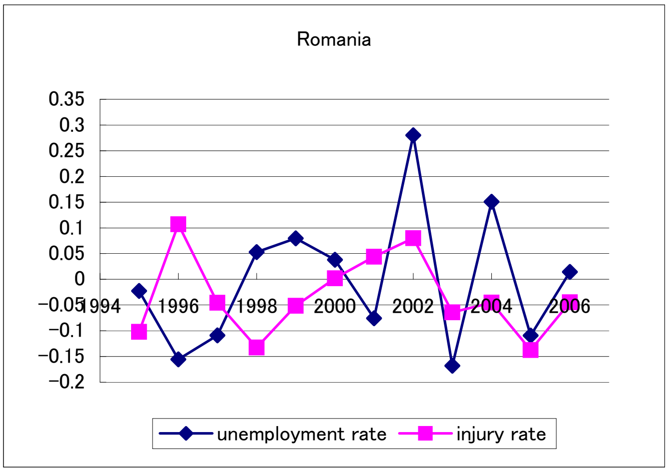
and

$$D_{22} = \frac{(1-\beta)q(\theta)(r+\alpha+\delta)(r+\alpha+\lambda(k))}{(r+\delta)(r+\alpha)(r+\alpha+\delta+\lambda(k))} > 0,$$

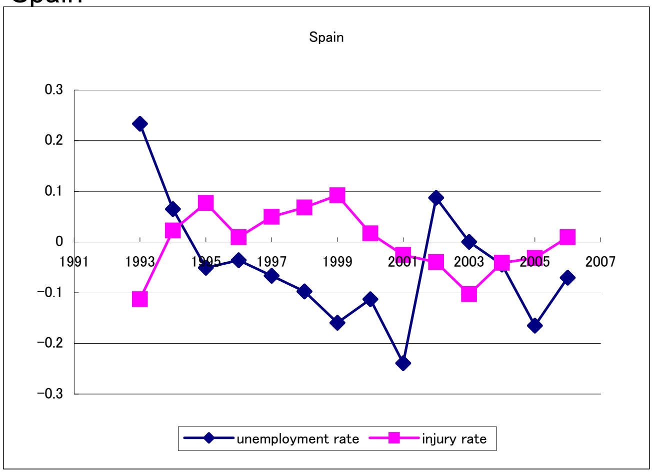
The Jacobian determinant is $\nabla_C \equiv C_{11}C_{22} - C_{12}C_{21} < 0$. We then obtain the implications described in proposition 3.

Figure 1: Poland

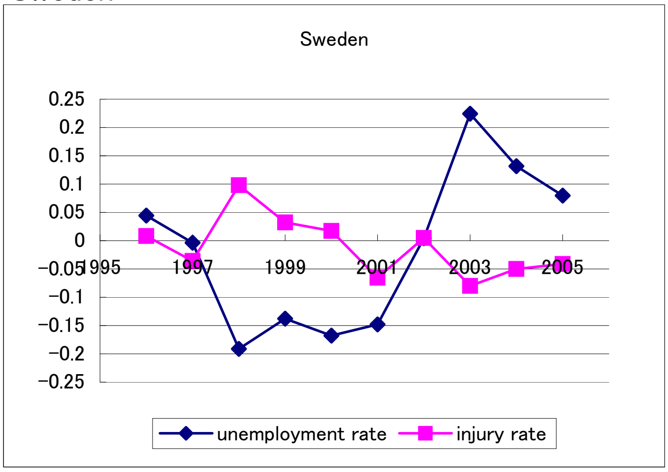
Romania



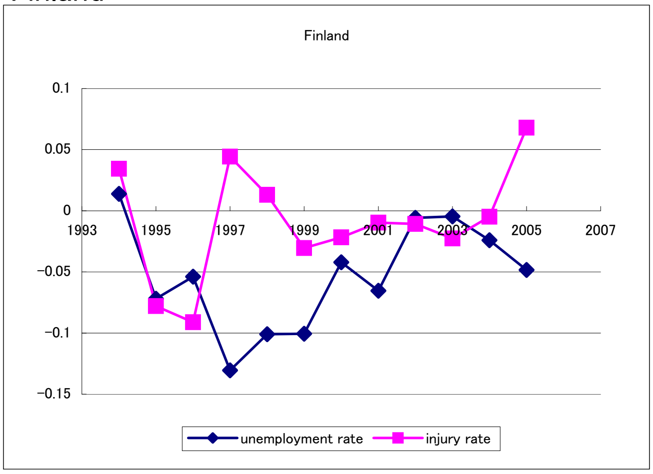
Spain



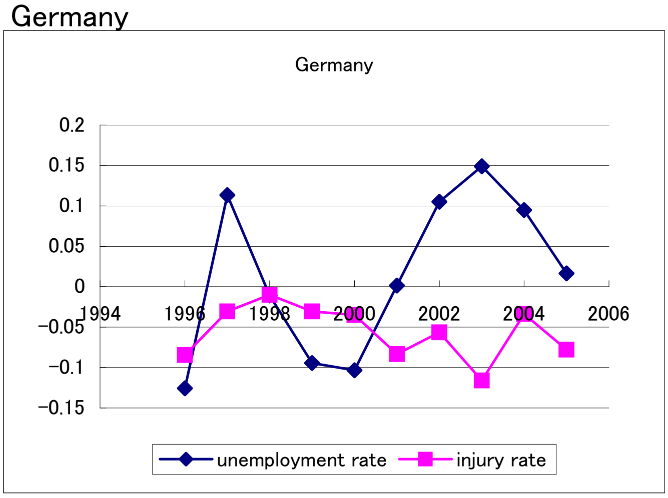
Sweden



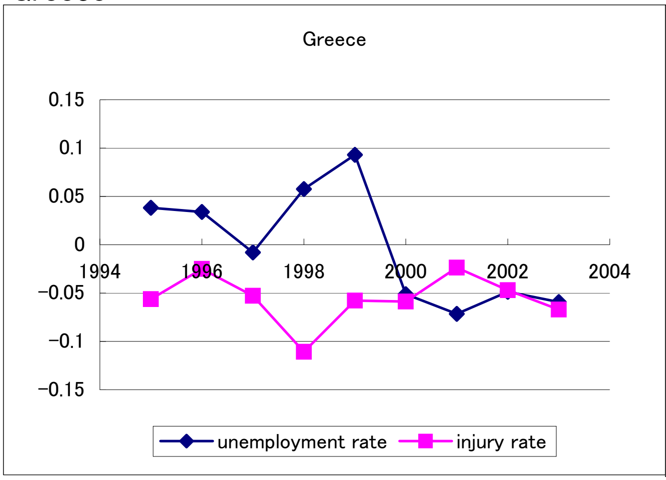
Finland



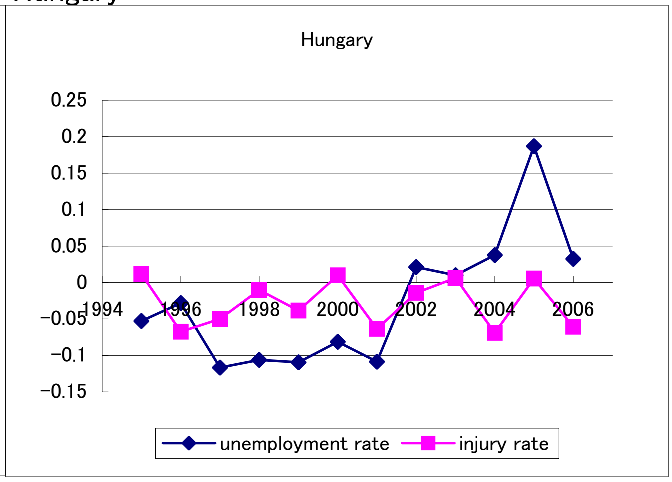
Germany



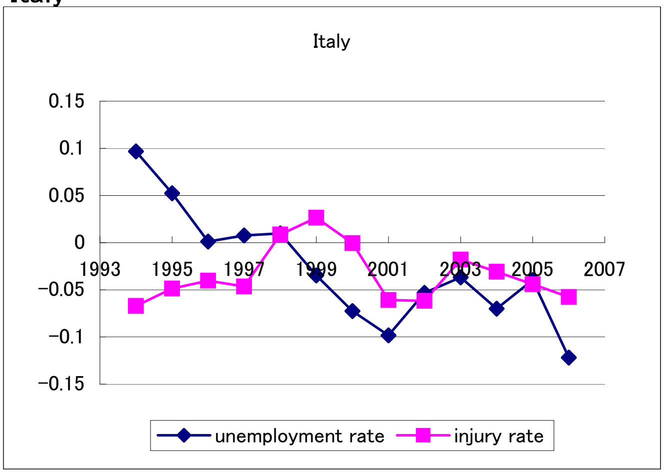
Greece



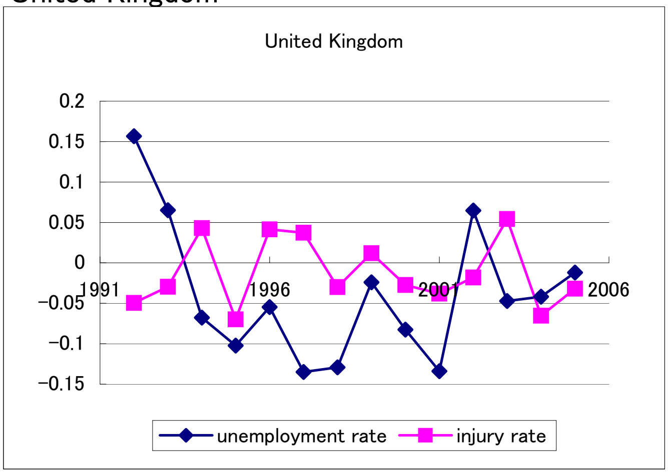
Hungary



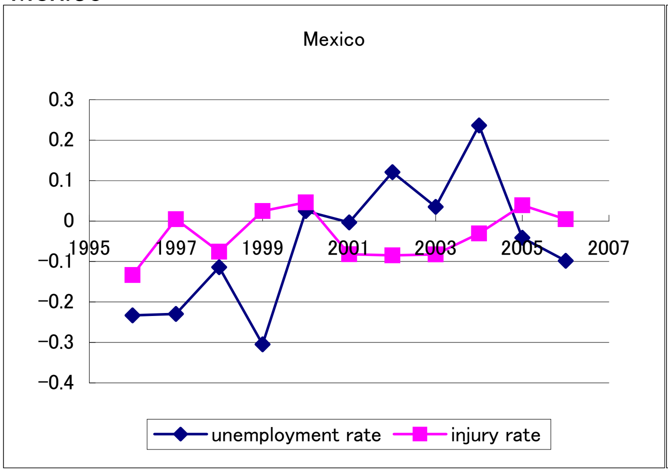
Italy



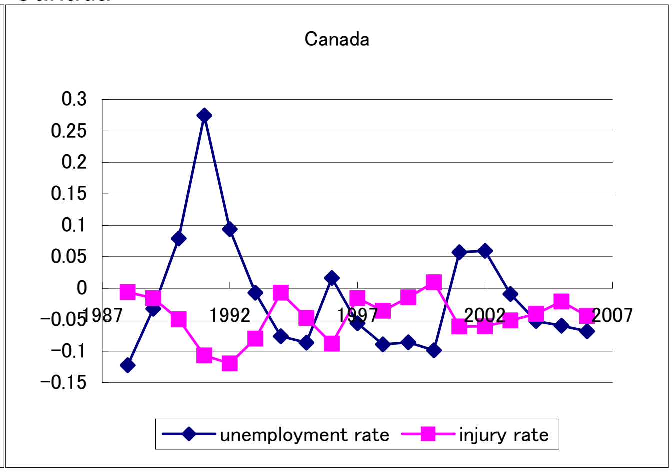
United Kingdom



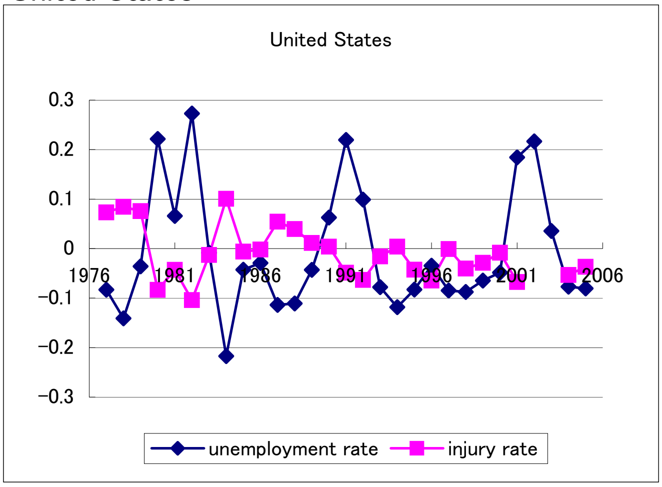
Mexico



Canada



United States



Japan