# Strikes and Slowdown in a Theory of Relational Contracts*

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**Abstract**

We propose a model of strikes in a relational (or self-enforcing) contracts framework. The employer has private information about firm profitability, proposes a wage and a bonus, and can outsource part of the production, in each period. The union can either go on strike or reduce the workers's effort (*i.e.*, decide a slowdown or work-to-rule) as a response to a low wage or a low bonus. We construct perfect public equilibria in which strikes (or slowdown) appear randomly on the equilibrium path, during finite-duration spells triggered by the occurrence of a low-profitability state. Equilibria exhibit money-burning (*i.e.*, conflict) and wage-compression as in the recent literature on relational contracts; they are first-best inefficient. We discuss empirical implications of the model and applications to the public sector. Paris dustmen are taken as an illustration. An important advantage of our theory is that it allows for equilibrium regime changes, induced by changes in the environment. Following a drop in outsourcing costs, strikes may disappear and be replaced by other forms of conflict that are less easily observable. This has consequences for the empirical work on strikes.

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# 1 Introduction

The theory of strikes is apparently outdated. True, in the past 20 years, the number of days lost, due to strikes, has steadily decreased in the United States, and the UK record has been low in comparison with the European Union average; but strikes have not disappeared from continental Europe, their frequency has not decreased in India and Brazil, and it seems that the number of wildcat strikes is quickly growing in China.[1] With the advent of the public debt crisis and the spreading of budgetary austerity, strikes could soon become a very significant problem in the Public Sector of many developed and newly industrialized economies. So, this topic may become fashionable again.

Labor disputes typically occur in ongoing, long-run relationships between an employer and the workers' union. Many strikes seem to be the result of a conflict situation that has been built up by past responses of the employer to changes in the environment.[2] The present paper proposes a simple way of integrating strikes in a theory of relational (or implicit) contracts between an employer and a workers' union, based on an infinitely repeated game with imperfect monitoring.[3] In this framework, conflict is the unavoidable consequence of informational asymmetries. But the various avatars of conflict, that is, strikes, slowdown, low morale, dismissals, resignations, etc., are not by themselves essential ingredients of the theory. Strikes, for instance, would have a nonzero incidence only under certain parameter configurations, while conflict is still present, but takes another form. This is important for the empirical work on labor disputes, because many aspects of conflict are not recorded in the data and therefore, the impact of factors causing strikes, as well as the real causal impact of labor strife in general, are hard to identify. This is the reason why strikes are only the "tip of the iceberg": that is, the visible part of the firm-union cooperation enforcement problem.

Indeed, many internal conflicts never result in a strike that would be recorded by outside observers. Workers can use various forms of resistance and slowdown to obtain im-

[1] On deunionization in the UK and the US, see, *e.g.*, Acemoglu *et al.* (2001), on strikes in the UK, see, *e.g.*, Hale (2008). On China, see Lin and Ju (2011), Cai and Wang (2012). The ILO statistics show a recent growth of the number of days not worked due to strikes in Brazil, see also Perry and Wilson (2004).

[2] In the US, for instance, strikes are more likely the greater is uncompensated inflation over the previous contract period. See Vroman (1989).

[3] On this notion, see Fudenberg *et al.* (1994), Mailath and Samuelson (2006).

provements of working conditions and pay. Resistance phenomena are less easily observable, but are likely to cause inefficiencies as severe as strikes. For instance, Krueger and Mas (2004) and Mas (2006, 2008) have shown that disappointed workers can cause a deterioration in the quality of produced goods and significant drops in some indirect measures of effort in general, even if labor strife is not recorded by outside observers.

The proposed model explains the incidence of strikes, as well as the employer's outsourcing (or worker replacement) decisions. It also extends the theory to account for worker resistance, such as slowdown and "work-to-rule". In our model, strikes (and other forms of conflict) appear as random equilibrium phenomena. We show that high-effort and high-pay cooperative agreements between the union and the employer can be supported as Public Perfect Nash equilibria of a repeated game, if players are patient enough, but only at the cost of random reversions to inefficient sequences of actions, in which strikes and rigid wages, or slowdown and outsourcing may take place. In equilibrium, the union simply goes on strike when the proposed wage is too low and the real state of nature, being private information of the employer, is never revealed to the union. This type of union behavior is rational in a repeated interaction framework: it creates the necessary incentives for cooperation in good times. In the proposed model, strikes are not retrospective punishments inflicted on the employer when the real state of nature is disclosed, or partially revealed. In contrast, they are merely the response to a disappointing wage (or bonus) offer. Another result is that our model can explain changes of regime, in which strikes disappear. Our theory suggests that strikes vanish because they are replaced by other forms of conflict that are less easily observable. This happens when some structural parameters change, like, for instance, the cost of outsourcing.

The intuition for the key results can easily be summarized. There are good and bad states of nature, but the union never observes the state. For the sake of efficiency, if a bonus is paid, it must be paid to workers in good states, not in bad states. Now, if the union always cooperated, the firm would never pay the bonus, and would always claim that the state is bad. It follows that the union must punish the firm at some point, without knowing if the firm really "deserves" the punishment. It wouldn't be reasonable to carry out threats when the promised bonus is paid. Therefore, conflict will occur in the bad states, as a response to a low pay event. In addition, conflict happens *on the equilibrium path, i.e.,* threats are implemented during the course of play, but they appear at random times, being triggered by the drawing of a bad state of nature. Now, the exact form assumed by conflicts doesn't matter much: the only important thing is that some money is "burnt" during conflict phases. As a consequence, following some changes in the environment (for instance, a drop in outsourcing costs), strikes may disappear, but conflict will take on a different form.

*Relationship with the literature.* Since the mid 1980's, the theory of strikes has been based mainly on noncooperative models of bargaining under asymmetric information (see, *e.g.,* Kennan and Wilson (1989), (1993), Ausubel *et al.* (2001)).[4] These models provide a powerful way of rationalizing labor disputes, but they cannot be easily extended to study dynamics, while the observed number of days lost, due to strikes, is a time series exhibiting much randomness. To the best of our knowledge, the literature on *relational contracts* (or the theory of self-enforcing contracts) has not considered strikes explicitly.[5]

The modern theory of strikes has first been developed with the help of Contract Theory, in static form (see *e.g.*, Hayes (1984), and Card (1990)). Extensions of these ideas have been proposed by Cramton and Tracy (1992) and others, using games with incomplete information.[6] These models describe a 3-year contract-period. Bargaining over the wage rate takes place at the beginning of the time interval, and strikes are an inefficient delay, incurred before an agreement is signed. But these models typically lack a dynamic element. It is intuitively clear that past contractual wages play a rôle in current contract negotiations, and that the current wage matters for the next contract. Changing circumstances in the input and output markets, unexpected inflation, and all sorts of business-cycle phenomena can randomly force players to renegotiate, at any moment.[7]

To the best of our knowledge, Robinson (1999) is the only contribution that proposed a model of labor disputes cast in an infinite-horizon, repeated-game, asymmetric-information framework, before the present paper. There are important differences in our respective ways

[4] There are also extensions of Nash bargaining approaches, see, *e.g.*, Barrett and Pattanaik (1989).

[5] On self-enforcing, relational (or implicit) contracts, see *e.g.*, Bull (1987), Malcomson and MacLeod (1989, 1998), Levin (2003).

[6] Again, see Ausubel *et al.* (2001)). The ability of bargaining models to reproduce a number of empirical facts about strikes is discussed in the papers of Kennan and Wilson (1989), and Card (1990).

[7] For a discussion of "within-contract strikes", see Harrison and Stewart (1994).

of modelling the problem.[8]

Principal-Agent theory has been extended to repeated interaction settings to study worker moral hazard and efficiency wages (*e.g.*, Malcomson and Spinnewyn (1988), MacLeod and Malcomson (1989), (1998)), but this literature does not encompass strikes. The literature on subjective performance evaluation and self-enforcing contracts has then used the repeated game model to derive constraints on compensation systems (see *e.g.*, Baker *et al.* (1994)). MacLeod (2003) models conflict in a rather abstract way as a form of money burning, in a static model, and suggests interpretations in terms of possible employee behavior, such as work-to-rule. Levin (2003) obtains related results in a repeated game setting. In his analysis, conflict takes the form of worker resignation in termination contracts; he does not explore other forms of resource-consuming conflict. In these contexts, optimal contracts exhibit a property of *wage compression*: we obtain the same kind of property here.[9] It can be noted that the *stationary contracts* emphasized by Levin (2003) cannot be used in our model, because the rate at which value can be transfered from the Principal (Employer) to the Agent (Union) depends on the privately observed state of nature.

In the following, Section 2 sketches a case study of the municipal dustmen strikes, and discusses some empirical evidence, for illustrative purposes; Section 3 is devoted to a description of the model. Section 4 presents the construction of equilibria and their properties are discussed in Section 5. Presentation is, as much as possible, non-technical; rigorous statements and proofs of a number of Propositions are gathered in the Appendix.

[8] Robinson (1999) adapts Green and Porter's (1984) oligopoly model, and models strikes as retrospective punishments: in each period $t$, the union receives a noisy signal of period $(t-1)$'s true state of nature, and the union strikes for $T$ periods if it is sufficiently likely that the firm has lied about the state of nature in the past period. Our model, we believe, is more realistic: the true state of nature is never disclosed to the union; the union simply reacts to the employer's pay decisions: disappointing wages trigger reversion to an inefficient mode of play. Another important difference is the presence of the workers' effort variable. There is no effort (or slowdown) and no outsourcing (or partial lock-out) in Robinson (1999), who makes the simpler assumption that the employer can replace the work force entirely, at a fixed cost. There are a number of other questionable assumptions in Robinson's (1999) pionneering paper. For instance, he assumes that the employer is risk-averse and that the union is risk-neutral.

[9] Since the first version of the present paper was written (Gary-Bobo and Jaaidane (2006)), some new results have appeared in the literature on subjective performance evaluation. Fuchs (2007) extends previous contributions in a repeated game setting with private monitoring: he confirms that termination contracts and money burning are second-best optimal. Rui Zhao (2009) explicitly considers low effort spells as a substitute for termination contracts and interprets low effort as low worker morale.

## 2 Dustmen in the City of Paris: Sketch of a Case Study

We begin with a brief discussion of the history of labor disputes between municipal dustmen (*i.e.*, sanitation workers) and the city of Paris, France. This is the type of implicit-contract, long-run relationship between a firm and a union that we try to model below. Some original data on the strikes and wages of these workers, recently collected by the authors, will provide an empirical illustration and a motivation for the theoretical analysis.

The dustmen of Paris enjoy a civil servant status which guarantees life-time employment to all workers: once hired, dustmen cannot be fired, except for very serious causes. Due to strict seniority rules and because firing is essentially impossible, when it comes to personnel motivation, the city of Paris is placed in an uncomfortable position. A single powerful trade union, the CGT, negotiates with the town hall.[10] The town hall cannot lock dustmen out, or use replacement workers, but they can rely on outsourcing to private sector sanitation companies, using public procurement contracts. The only problem is that this process takes some time, to auction the contract and to build new garbage trucks. It can thus be costly to outsource a large number of tons of garbage in a short period of time. Exceptionally, the army has been used to clean up the streets during some famous strikes of the past.

Figure 1 plots the dustmen's number of strike days, per year, from 1968 to 2004. It seems that the series is non-stationary, with a regime switch in the early eighties. The recurrent strikes of the late 1960's and early 1970's had resulted in important pay raises, and many new recruits. A new Mayor, Mr Jacques Chirac (a prominent politician, who was later to become the President of the Republic), was elected in 1977. Mayor Chirac's election was greeted with very tough strikes in 1977 and 1978. Until 1977, the city of Paris had never had recourse to the private sector: Mayor Chirac and his team crossed the Rubicon, and started partial privatization of garbage collection in the early eighties. Figure 1 clearly shows the reduction in strike incidence, starting from this period. Strikes have almost disappeared in the nineties, during Jacques Chirac's second and third terms (with

[10] CGT stands for *Confédération générale du travail*. Note that, in France, union certification does not lead to union monopoly or exclusive representation in bargaining units, but the CGT is the dominant union in the case of dustmen.

the exception of 1990). He stayed in office from 1977 to 1995 and was replaced by a deputy mayor from the same party until 2001. Thus, the outsourcing-privatization policy has lasted long enough to become a well-established, credible mechanism. Its strategic effect on strikes seems obvious. A glance at Figure 2 shows the year to year change in the total number of dustmen, (as voted by the municipal council, and published in its official record). From 1978 to 2000, with the exception of 1982 and 1983, the total number of dustmen remained constant and then decreased. In the year 2001, a new mayor from the Socialist Party, with a public-sector friendly approach, took office. In any case, new recruits had to be hired to compensate for the implementation of the 35-hours week law, which had just been passed by the Socialist government. A resurgence of strikes seems to have been the result of this policy.

But there is an unobserved downside to Mayor Chirac's (apparently successful) policy, which is that, since incentives are weak in the civil service, the privatization and low-pay policies created the conditions of chronic low effort, and progressively demoralized the workers. We have many reasons to believe that the rate of absenteeism, which is abnormally high among municipal dustmen nowadays, in fact increased over time. Slowdown or work-to-rule spells became more frequent and are not recorded as strikes.[11] So, the drop in strike incidence that we observe in Fig. 1 after 1983 could be due to a change of regime (*i.e.*, a change in the implicit contract). We suggest below that these facts can be explained by a change in the form of conflict involved in (or used to support) the long-run equilibrium. In other words, the underpinning of the implicit contract between the town hall and the union has shifted from observable strikes to unobservable slowdown problems. In Appendix A, we provide further details on the Paris dustmen case, and show that drops in the discounted value of careers seem to cause strikes. The data on this case doesn't contradict the view that the discounted value of future wages and working conditions is the driving force behind the observed history of disputes.

To sum up, these empirical facts, taken together, suggest that they have been generated by a long-run relationship between the town hall and the dustmen's union. It seems

[11] Our inquiry has revealed that, to an extent which is difficult to measure or establish objectively, the quality of applicants for vacant public dustmen positions has also decreased in the recent years. For details on Paris dustmen, see Jaaidane and Gary-Bobo (2008).

that a finite-horizon, single-contract bargaining game with incomplete information cannot reproduce the facts as accurately as a model of repeated interaction, in which pay raises, strikes, slowdown, outsourcing and the business cycle combine to produce a seemingly random sequence of conflicts.

# 3 A Repeated Game Model of Slowdown and Strikes

We consider an infinitely repeated game with 2 players: the employer and the union. To fix ideas, the employer can be viewed as a public entity, the "town hall", and the union is that of dustmen and sanitation workers. The employer has a given task to accomplish: a given, constant number of tons of waste, say, has to be collected during each time period.

## 3.1 Basic Assumptions

During each period $t$, the Union and the Employer play a stage game $G$. In this game, the Union chooses a level of effort $e$ and a "duration" (or probability) of strike $s$ in the interval $[0, 1]$. Effort can be "high" or "low" (*i.e.*, effort belongs to the set $\{\underline{e}, \overline{e}\}$). The effort variable also measures the employee's disutility of work. Intuitively, in the absence of incentives, low effort $\underline{e}$ is the natural behavior of workers, but, following a good agreement, the worker's morale can be raised by the Union's officials, and high effort $\overline{e} > \underline{e}$ can be implemented. We therefore assume that the Union has enough command of its members to implement the effort and strike policy. This assumption is reasonable: it is well-known that some unofficial hierarchical organizations play a rôle in firms and public administrations. Unions, secret societies and even the maffia can act as delegated monitors. Unions do exist to exploit some market power on the labor markets, but also because they can overcome the *free-riding* problem in teams and increase efficiency.[12] The theories of *social norms* and *community enforcement* provide a justification for our assumption in game-theoretic terms.[13]

[12] This point has been widely discussed. See, for instance, Freeman and Medoff (1984).

[13] See, *e.g.*, Kandori (1992). These ideas have been applied to the study of various social phenomena: Merchant Guilds, by Greif, Milgrom and Weingast (1994); Private Judges in the Middle Age, by Milgrom, North and Weingast (1990), the intermediation and disciplinary role of the Sicilian Maffia, by Dixit (2007). On unionization, see the essay of Hogan (2001).

Our model emphasizes the union's role as a representative of workers.

Effort determines the total number of hours, $h(e)$, needed to complete the task. High effort $\overline{e}$ is associated with a small number of hours $\underline{h} = h(\overline{e})$, while low effort $\underline{e}$ corresponds to a large number of hours $\overline{h} = h(\underline{e}) > \underline{h}$. In contrast, strikes are complete work stoppages during which a fraction $s_t$ of output is lost. Our most important assumption is the following:

**Assumption 1**. $\overline{e}\underline{h} < \underline{e}\overline{h}$.

Assumption 1 says that the social cost of low effort is higher than that of high effort, as will become clear below.

In each period $t$, the employer chooses a real wage rate $w_t$, and simultaneously, chooses the level of outsourcing $x_t$. To be more precise, a fraction of the task $x_t$, in the interval $[0, 1]$, is outsourced. Accordingly, the fraction of the task fulfilled by the employees is $1 - x_t$. We now drop the time index $t$ to simplify notation. We also assume that outside options and (or) rules concerning the workers impose that the real wage rate $w$ cannot fall below a minimum $\underline{w}$, which is assumed constant for simplicity. To focus on the interesting cases, we assume the following.

**Assumption 2**. $0 < \underline{e} < \overline{e} \leq \underline{w}$.

Assumption 2 means that the minimum wage $\underline{w}$ is greater than the disutility of high effort. The cost of outsourcing is,

$$c_0(x) = \underline{w}.\underline{h}x + \beta\frac{x^2}{2}, \tag{1}$$

where $\beta > 0$ is a parameter. This formulation rests on the idea that subcontracting companies are efficient, since they pay the minimum wage $\underline{w}$ and obtain a high level of effort from their workers, *i.e.*, $h = \underline{h}$, but that there are additional outsourcing costs, represented by the quadratic term. This latter term captures the fact that outsourcing generates specific organizational costs. It is likely that subcontractors are in a better bargaining position to extract surplus from the employer when the extent of outsourcing is large. This quadratic term may also represent the "political costs" of replacing civil servants with private sector workers.[14]

Now, the employer faces changing circumstances, a changing state of the world, that we model as an *i.i.d* random cost parameter $\theta_t$— interpreted as a "cost of public funds" in the case of a public employer. This cost parameter is observed by the employer but not by the union and it is the source of asymmetric information in the model. For simplicity, $\theta_t$ takes only two values: $\underline{\theta}$, the "good state", with probability $\pi$, and a high value $\overline{\theta} > \underline{\theta}$, the "bad state", with probability $1 - \pi$. The cost of public funds summarizes a number of random phenomena: fluctuations of market shares, price changes in product and input markets, etc.

In the case of a public employer, cycles cause changes in tax revenues, changes in the interest rate on public debt, but there are also unexpected costs faced by the town hall, and changes in the priorities or in the political agenda of the ruling mayor's team, which change the tradeoffs that they face, in view of reelection. All these factors are subsumed in parameter $\theta_t$, which modifies the employer's resistance to the union's demands.

The stage game $G$ is a *static one-shot game* in which the union and the firm play simultaneously. The solution concept is the standard Bayesian-Nash equilibrium (because the union's information is incomplete). In this stage game $G$, the union chooses $(e, s)$, and the employer *simultaneously* chooses a state-dependent action denoted $(x_\theta, w_\theta)$, *i.e.*, the extent of outsourcing and the wage.[15]

We can now specify the players' payoffs in the stage game. The union's payoff in state $\theta$ is defined as follows,

$$u_\theta = (1 - s)(1 - x_\theta)(w_\theta - e)h(e). \tag{2}$$

The interpretation of this specification is easy. The worker's surplus per hour $(w_\theta - e)$ is multiplied by the required number of hours $h(e)$ and by the fraction of the task (the number of tons of waste) carried out by the union's workers in state $\theta$, that is $(1 - x_\theta)$. We assume that the workers receive a zero wage (and exert effort zero) during strikes. It follows that

[14] There are sectors and industries in which outsourcing may be very costly if production must be outsourced in the short run. The near impossibility of rapid outsourcing may be represented by a very high value of $\beta$.

[15] Formally, an action of the firm is a mapping $\theta \to (x_\theta, w_\theta)$, associating a pair $(x, w)$ to each state of nature.

the union's total surplus is multiplied by $(1-s)$, the proportion of non-strike days.

This assumption may seem strong at first glance. Suppose on the contrary that workers on strike receive a payment of $\alpha$ per hour, out of some *strike fund*. If strike pay is funded by the union workers themselves, the utility $u_\theta$ doesn't change, because the total amount of strike pay, that is, $\alpha s h(e)(1-x_\theta)$ has to be paid for through member contributions of exactly the same amount, and the two terms cancel out. If the workers receive support from a national federation, then, we have

$$u_\theta = (1-x_\theta)[(1-s)(w_\theta - e) + s\alpha]h(e),$$

where $\alpha$ is a net hourly wage from the strike fund. It can be shown that when the hourly strike pay is not too large, and more precisely, under the reasonable assumption that $\alpha < \underline{w} - \underline{e}$, the results are essentially the same as if $\alpha = 0$.[16] High values of strike pay are clearly not reasonable. This is why, knowing that we do not lose any important aspect of the theory, and to simplify the analysis, we assume that $\alpha = 0$.

The employer maximizes the (social) value of the task, denoted $v_0$, minus internal production costs, minus the cost of outsourced services. The fraction of the task performed by the union and the external providers taken together is

$$(1-s)(1-x) + x.$$

When the workers are on strike, the external provider produces a fraction $sx$ of the task. The remaining part of the task, $1 - x - (1-s)(1-x) = s(1-x)$, is not fulfilled. In the waste collection example, $s(1-x)$ is the fraction of the garbage that is collected neither by the public, nor by the private sector dustmen, and stays in the streets (forcing citizens, or the army, to do the job). The total cost of production $C_\theta$ is defined as follows.

$$C_\theta = \theta[w_\theta h(e)(1-s)(1-x_\theta) + c_0(x_\theta)], \tag{3}$$

where $c_0$ is the cost of outsourcing defined by (1) above. The employer's utility in state $\theta$ is denoted $v_\theta$, and defined as follows:

$$v_\theta = v_0(1 - s(1-x_\theta)) - C_\theta \tag{4}$$

[16] In particular, Propositions 1 and 2 below remain true. It can be shown that the rest of the results remains true, but the analysis becomes more complicated.

The social surplus is $R_\theta = u_\theta + v_\theta$, the sum of the players' utilities in a given period $t$. To simplify the presentation, we propose the following normalization of parameters.

**Assumption 3.** $1 = \underline{w} = \underline{h} = \overline{e} = \underline{\theta} < \overline{\theta}$.

The high level of effort is normalized to 1. The disutility of effort and the value of the minimum wage are also set equal to 1. As a consequence, under Assumption 2, we have $1 = \overline{e} > \underline{e}$. These assumptions are harmless, except $1 = \underline{\theta}$, because this ensures that one unit of money from the employer is worth exactly one unit for the union in the good state $\underline{\theta}$. It follows that surplus is perfectly transferable in the good state, while in the bad state, $\overline{\theta} > 1$ acts as a cost of public funds.[17]

Let now $\delta$ be the players' common discount factor. In the infinitely repeated game, denoted $G(\delta)$, the union's and employer's expected, discounted payoffs are respectively defined as follows:

$$U = (1-\delta)\sum_{t=0}^{\infty}\delta^t E(u_{t\theta}), \qquad V = (1-\delta)\sum_{t=0}^{\infty}\delta^t E(v_{t\theta}), \tag{5}$$

where the expectation $E(.)$ is taken with respect to state $\theta$'s distribution and $0 < \delta < 1$.

## 3.2 Noncooperative Nash equilibrium of the one-shot game

To solve the stage game $G$, we first analyze the employer's best reply to a given $(e, s)$. The employer's strategy is to offer a state-dependent wage and outsourcing level pair $(w_\theta, x_\theta)$. We therefore solve for a standard, static Bayesian-Nash equilibrium of $G$.

The employer's best reply to the union's choice of effort and level of striking $(e, s)$ is a wage $w_\theta^*$ and an outsourcing rate $x_\theta^*$, both depending on the state of nature $\theta$. It happens that the choice of the minimum wage $w_\theta^* = \underline{w}$ is always a best response, because there is no reason to pay a bonus in a one-shot, non-cooperative situation. The rate of outsourcing chosen by the employer is positive if $s$ is large and effort $e$ is low. Given the employer's best reply, the Union chooses the pair $(s^*, e^*)$ to maximize expected utility. Since the situation is a one-shot game, it is easy to show that the union's best choice is *no strikes*: $s^* = 0$ and

[17] Since $R_\theta$ doesn't depend on the wage $w_\theta$ when $\theta = 1$, the essential role of this latter assumption is to simplify the analysis. Note that a worker exerting high effort and paid the minimum wage has a zero rent, since $\underline{w} - \overline{e} = 0$.

*low effort:* $e^* = \underline{e}$. A positive amount of striking would just reduce the union's utility, since strike pay is not greater than the minimum wage. A high level of effort would decrease the required number of hours $h$ and therefore, reduce the utility (details are in the Appendix). As a consequence, we can state the following result.

**Proposition 1**. *The unique noncooperative Nash equilibrium of the one-shot game played by the employer and the Union involves zero strikes, low effort, a minimal wage and a positive amount of outsourcing.*

See the Appendix for a formal statement and a proof of this result.

The equilibrium of the one-shot game may be very inefficient. If $\overline{h}$ is large, and $\beta$ is small, it can be shown that the Nash equilibrium is a near collapse of the firm: cooperation is almost a necessary condition for the firm's mere existence. Outsourcing takes place in this Nash equilibrium because low effort causes the required number of hours to be too large. Since subcontractors are efficient, it is then cheaper to outsource at least a small part of the task. Even if $s = 0$, the firm saves $\theta \underline{w}(\overline{h} - \underline{h}) > 0$ per unit of $x$ in any state $\theta$ since effort is low. This gain is compared with the additional marginal cost term $\beta\theta x$. When effort is high and $s = 0$, the benefits of outsourcing vanish.

For future reference, the noncooperative equilibrium of the one-shot game $G$ is denoted $\sigma^* = (e^*, s^*, w^*_\theta, x^*_\theta)$; the expected utilities in this equilibrium are denoted $(u^*, v^*)$.

### 3.3 Short-run cooperative solutions

We now contrast non-cooperative behavior with cooperation. By definition, a cooperative solution of the one-shot game maximizes the expected value of the surplus $R_\theta$ with respect to $(e, s, w_\theta, x_\theta)$. To be more precise, the cooperative solution maximizes the expected surplus $ER_\theta$, taking into account the fact that the employer knows the state of nature while choosing $w$ and $x$. This form taken by cooperation can be described as follows: the union commits to a policy $(e, s)$, and the employer, in exchange, chooses $(w_\theta, x_\theta)$ once the cost of funds $\theta$ is known.

Let $\sigma^c = (e^c, s^c, w^c_\theta, x^c_\theta)$ denote the cooperative solution. We maximize $R_\theta$ with respect to $w_\theta$ and $x_\theta$ for each state $\theta$. Using the expressions (1)-(4) for $u_\theta$ and $v_\theta$, by means of a simple addition, we obtain,

$$\begin{aligned} R_\theta &= u_\theta + v_\theta \\ &= v_0(1-s+sx_\theta) + ((1-\theta)w_\theta - e)(1-s)(1-x_\theta)h(e) - \theta c_0(x_\theta). \end{aligned} \tag{6}$$

Then, it is easy to see that $R_1$ doesn't depend on $w_1$ since $\theta = 1$. It follows that in the good state, the cooperative wage, denoted $w_1^c$, is indeterminate. Intuitively, there will be an interval of possible efficient values of the wage in the good state. Define the cooperative bonus

$$b = w_1^c - \underline{w}. \tag{7}$$

This bonus is a socially costless transfer between the employer and the union in the good state.

Next, in the bad state, that is, if $\theta = \overline{\theta} > 1$, the surplus $R_\theta$ is a decreasing function of the wage $w_\theta$. It immediately follows that efficiency requires a minimal wage, *i.e.*, $w_{\overline{\theta}}^c = \underline{w}$. In other words, in the bad state, a pay raise is too costly: the union should accept austerity, in the name of efficiency. Under asymmetric information, this will of course be a source of conflict.

We can prove the following result, describing the cooperative solutions.

**Proposition 2**.
*If the marginal cost of outsourcing is large enough, a cooperative solution is characterized by high effort, no strikes, zero outsourcing and a state-dependent, flexible wage: the minimal wage should be paid when the state of nature is bad; a bonus should be paid when the state of nature is good. There is an interval of possible values of the bonus paid in good times.*

*For a formal statement and proof, see Appendix B.*

Under full cooperation, the union should accept a minimal wage in the bad state, and a high compensation in the good state. Intuitively, the wage $w_1^c$ must be high enough in "good times" to compensate workers for the effort, and for austerity in "bad times". The problem is that the state is privately observed by the firm.

# 4 Long-Run Interaction of the Union and the Firm

The long-run relationship between the firm and the union is described as an infinite repetition of the stage game $G$. In this game, the moves of players are public information, but moves are taken after players learn some private information.[18] In our model, the employer's *moves*, that is, the wage paid, $w_t$, and the rate of outsourcing, $x_t$, are observed by the union at every date $t$, and are therefore public information, but the state of nature $\theta_t$ is a private *i.i.d.* shock which is never disclosed. The union chooses effort $e_t$ and the rate of striking $s_t$ in every period $t$. These choices are publicly observed. Both players, the union and the employer, remember all past moves, and they can decide to change they behavior in period $t+1$ as a function of anything that happened in the publicly observable history of play, up to time $t$. In particular, this allows each player to punish the other for observed deviations (for not keeping a "promise") and to make punishments last for a certain number of periods (apply a "penal code"). For instance, the union may decide to exert low effort, or to strike during $T$ periods, if the employer has not paid a bonus $b$ at the end of a given period $t$. We require that the players' strategies be best responses to each other at the beginning of the game and following any publicly recorded history of the players' moves. In such a situation, the *Perfect Public Nash Equilibrium* is the appropriate equilibrum concept (see Appendix B for details and references on this notion). In the following, the term *equilibrium* must be understood as meaning Perfect Public Nash Equilibrium. In the case of our model, the results can be understood without paying too much attention to technical definitions. Game Theory predicts modes of of interaction that are intuitive, natural and reasonable.

We will first show that the repeated play of certain actions $\widehat{\sigma}$, involving strikes, is an equilibrium of the repeated game $G(\delta)$. This preliminary result shows that there potentially exists inefficient equilibria in which strikes are observed in every period — the result rationalizes the "social-conflict culture" that is sometimes observed. But, in many cases, these ways of playing the game are not particularly realistic predictions. In contrast, such inefficient modes of action are useful as descriptions of typical conflict phases, that will appear during the play of other, more efficient equilibria in which cooperation plays

[18] An instance of this class of games is Athey and Bagwell's (2001) model of repeated price-competition oligopoly, in which firm prices are public, but firm costs are subject to privately observed *i.i.d.* shocks.

a big role. In other words, the repeated play of actions $\widehat{\sigma}$, involving strikes, may be used as an appropriate punishment by the Union, during a limited number of periods, when the employer did not pay wages that are high enough at some point. More precisely, we will show that cooperative play $\sigma^c$ can be supported as part of an equilibrium when players are sufficiently patient, but at the cost of random reversions to $\widehat{\sigma}$, involving strikes. A further result is that cooperative play can also be supported by random reversions to the static, one-shot Nash equilibrium $\sigma^*$, during a finite number of periods. In this latter type of equilibria, strikes do not occur, but effort is low and outsourcing takes place. To sum up, slowdown and (or) strikes, and partial replacement of workers, are ways of supporting cooperation in a repeated-interaction, asymmetric-information context.

The advantage of a model with imperfectly informed players is that in such a model, threats are sometimes executed: strikes and slowdown do occur along the equilibrium path. If we were considering a perfect information, perfect monitoring model, threats would never be used by rational players: we would end up with a theory of strikes predicting that strikes never occur. This is a major reason explaining why incomplete information is an essential ingredient of our theory.

## 4.1 Equilibria with rigid wages and strikes

We start the analysis with an elementary result: the perpetual repetition of the stage-game Nash equilibrium, denoted with starred variables, $\sigma^* = (e^*, s^*, w^*, x^*)$ is obviously an equilibrium of the repeated game. The payoffs of the perpetual repetition of this one-shot equilibrium are denoted $(U^*, V^*)$. We have $U^* = u^*$ and $V^* = v^*$.[19] Define the associated total surplus $R^* = U^* + V^*$. Recall that $\sigma^*$ is characterized by a very inefficient way of playing: perpetual low effort, low wages, positive outsourcing and no strikes.

The next step is to show that there exists equilibria of the repeated game with rigid wages, in which strikes occur during a positive fraction of each period $t$, and that are more efficient than $\sigma^*$. Let $\widehat{\sigma} = (\widehat{e}, \widehat{s}, \widehat{w}, \widehat{x})$ be a list of actions of the stage game such that, *(i)*, some striking occurs, $\widehat{s} \geq 0$; *(ii)*, but effort is high, $\widehat{e} = \overline{e} = 1$; *(iii)*, there is no recourse

[19] This is because $U^* = (1-\delta)\Sigma_{t=0}^{\infty}\delta^t E(u^*) = E(u^*) = u^*$, etc.

to outsourcing, $\widehat{x}_\theta = 0$ for all $\theta$; *(iv)*, wages are constant and set above the minimum: $\widehat{w}_\theta = \widehat{w}$ for all $\theta$ and $\widehat{w} > 1$. Let $\widehat{u}$ and $\widehat{v}$ denote the stage game payoffs of $\widehat{\sigma}$ for the union and the firm, respectively.[20] From this, we immediately derive the long-run payoffs of a perpetual repetition of $\widehat{\sigma}$, namely, $\widehat{U} = \widehat{u}$, and $\widehat{V} = \widehat{v}$. The associated total surplus is denoted $\widehat{R} = \widehat{U} + \widehat{V}$.

It is then possible to show that there exists admissible $(\widehat{s}, \widehat{w})$ such that $\widehat{R} > R^*$ with $\widehat{U} > U^*$ *and* $\widehat{V} > V^*$. This is a strict Pareto improvement over $\sigma^*$, involving strikes. Next, we show that permanently playing $\widehat{\sigma}$ is an equilibrium of the repeated game. Deviations from $\widehat{\sigma}$ are immediately detected and punished by a permanent reversion to $\sigma^*$, *i.e.*, trigger strategies support the Pareto improvement. We can summarize this standard result as follows.

**Proposition 3**. *If players are sufficiently patient, there exists actions $\widehat{\sigma}$ such that some strikes occur in every period, effort is high, outsourcing is zero and wages are rigid, and such that the perpetual repetition of $\widehat{\sigma}$ is an equilibrium.*

*For a formal statement and proof of Proposition 3, see Appendix B.*

This type of equilibrium entails a permanent, positive duration of strikes, no outsourcing, high effort and constant wages above the minimum. It is potentially very inefficient too, because efficient arrangements require no strikes and a state-contingent, flexible-wage policy. In this type of equilibrium, strikes may seem to be the cause of above-the-minimum wages. As shown by the proof of Proposition 3, in this type of equilibrium, there is an admissible set of equilibrium wages and equilibrium strike rates, constrained by the fact that $(\widehat{s}, \widehat{w})$ must be chosen so as to satisfy $\widehat{u} > u^*$ and $\widehat{v} > v^*$. These constraints ensure that sufficiently patient players can be punished by reverting to the very inefficient one-shot Nash equilibrium $\sigma^*$. But there are different ways of satisfying these constraints, corresponding to different ways of sharing the surplus between players. It follows that in a cross-section of identical firms, during phases in which $\widehat{\sigma}$ is played, there is no reason to observe an increasing relationship between strikes and wages. The observed correlation between between strikes and wages would be spurious. Each feasible pair $(\widehat{s}, \widehat{w})$ may be interpreted as a different "implicit"

[20]The stage game payoffs of $\widehat{\sigma}$ are easy to compute, we have, $\widehat{u} = (1 - \widehat{s})(\widehat{w} - \overline{e})$ and $\widehat{v} = E\widehat{v}_\theta = (1 - \widehat{s})(v_0 - \widehat{w}E(\theta))$.

or *self-enforcing* contract between players. The details of such a self-enforcing arrangement may largely be due to contingent circumstances, exogenous random factors that affected negotiations, etc. We now turn to a family of equilibria that are much more efficient than the rudimentary $\widehat{\sigma}$.

## 4.2 Long-run cooperative equilibria in which strikes are random events

We now construct an equilibrium involving the cooperative mode of play $\sigma^c$, as defined above. A precise definition of our equilibrium candidate, denoted $\widetilde{\sigma}$, is given first. Then, we show that the candidate is indeed an equilibrium of the repeated game, and analyze its properties.

### 4.2.1 Description of the equilibrium candidate

We must fully specify the strategies of the union and of the employer, how they "normally" play, how each player punishes the deviations of the other and how long the punishment lasts. Punishments lasting forever, as in the textbook version of trigger strategy equilibria are presumably a bad description of reality. Since information is asymmetric (*viz.*, the union never observes the real state of nature $\theta$) punishments will occur along the equilibrium path. As a consequence, the players will rely on finite-length punishment phases, to save on the social cost of punishments.

Another interesting feature of the strategic situation described here, that is also due to asymmetric information, is the fact that there exist two types of deviations of the employer: the *on-schedule* and *off-schedule deviations.*[21]

During the course of play, the employer should normally cooperate as much as possible, and therefore, play the cooperative actions $(w^c_\theta, x^c_\theta)$ defined above, with zero outsourcing, that is, $x^c_\theta = 0$ in both states $\theta$, and a state-dependent wage. A bonus $b$ should be paid in good times, on top of the minimum wage, that is, $w^c_1 = b + \underline{w}$ in good times and $w^c_{\underline{\theta}} = \underline{w}$ in bad times. The union doesn't observe the state but can easily detect if the employer pays a wage $w'$ different from the normal levels, either $w^c_1$ or $w^c_{\underline{\theta}}$. This, by definition, is an

[21] This terminology was introduced by Athey and Bagwell (2001).

*off-schedule* deviation.

But the employer can also pay $b + \underline{w}$ in the bad state and (or) pay $\underline{w}$ in the good state. The union cannot be sure that this is a deviation, since they do not observe the true $\theta$. This latter way of deviating is defined as *on-schedule.*

The union can punish the off-schedule deviations easily, but cannot punish on-schedule deviations in an appropriate way. They have several possibilities. If they *never* punish, in good times, the employer can save on the bonus payments without cost — never punishing is thus naive and dangerous. The outcome is bound to be very inefficient if they *always* punish — since then cooperation fails completely. It seems absurd to punish only when the bonus is paid. The last possibility is to punish the employer only when the bonus is not paid (when the employer claims that times are bad). Hence, strikes may appear when the employer claimed that times were bad (an therefore refused to grant a pay rise, or didn't pay the usual bonuses, etc.). We will show that there exists equilibria with punishment spells, lasting a limited number of periods, and such that, in good times, the union and the firm normally cooperate. We first exhibit candidate strategies, with an intuitive appeal, and then show that they indeed form an equilibrium when players are patient enough.

Our *equilibrium candidate* $\widetilde{\sigma}$ can now be decribed as follows:

(1) In the initial period, $t = 0$, the union cooperates and plays high effort and no strikes, that is, $(e^c, s^c) = (1, 0)$. There is no outsourcing. The employer pays the bonus $b$ if the state is actually good, *i.e.*, if $\theta = 1$, and pays the minimum wage if the state is actually bad, *i.e.*, if $\theta = \overline{\theta}$. To sum up, players initially play the cooperative actions $\sigma^c$.

(2a) They play $\sigma^c$ again in period $t + 1$ if the bonus was paid in period $t$.

(2b) But if the employer didn't pay the bonus in period $t$, then, a *punishment spell* starts from period $t + 1$ on. To punish the firm, the union plays $(\widehat{e}, \widehat{s})$, where some striking occurs, but effort is high, and the employer plays $(\widehat{w}, \widehat{x})$, where the wage is rigid and there is no outsourcing, during $T$ periods. Both players return to cooperation and play $\sigma^c$ again in period $t + 1 + T$, at the end of the punishment spell.

We now specify how off-schedule deviations are punished.

(3) If the union plays an off-schedule deviation $(e', s')$ in a period $t$ such that coopera-

tive actions $(e^c, s^c)$ are required, or if the union plays an off-schedule deviation $(e', s') \neq (\widehat{e}, \widehat{s})$ during a punishment spell, then, in period $t+1$, both players revert to the one-shot noncooperative equilibrium $\sigma^*$ during $T^*$ periods. They return to cooperative play $\sigma^c$ in period $t + T^* + 1$.

(4) If the employer plays an off-schedule deviation $(w', x')$, in a period $t$, such that cooperative actions $(w^c, x^c)$ are required, or if the employer plays $(w', x') \neq (\widehat{w}, \widehat{x})$ during a punishment spell, then, starting from period $t+1$, both players revert to the one-shot noncooperative equilibrium $\sigma^*$ in period $t+1$, during $T^*$ periods, after which they return to cooperation and play $\sigma^c$ in period $t + T^* + 1$.

Note that in our model, the union deviations can only be off-schedule. We must now check that there exists values of the bonus $b$, of the actions $\widehat{\sigma}$ and of the length of punishment spells $T$ and $T^*$, such that the candidate strategies $\widetilde{\sigma}$ just described satisfy all the incentive constraints that must be satisfied by an equilibrium.

Let $U$ and $V$ be the long-run expected utilities of the union and the employer, respectively, along any path of play induced by our candidate equilibrium $\widetilde{\sigma}$. Let $v^c_\theta$ (resp., $u^c_\theta$) denote the employer's one-period profit (resp., the union's one-period utility) of playing cooperatively in a period with state $\theta$. To simplify notation, we denote the employer's expected per-period profit by $v^c = E v^c_\theta$. Similarly, the union's expected per period utility under cooperation is $u^c = E u^c_\theta$. Using the linear, recursive equations defining the value functions (see Appendix B), we easily obtain the following result.

**Proposition 4**. *The employer's expected discounted profit (i.e., the value) of the candidate equilibrium strategies $\widetilde{\sigma}$ can be expressed as follows,*

$$V = q\widehat{v} + (1-q)v^c, \tag{8}$$

*where, by definition,*

$$q = \frac{(1-\pi)\delta(1-\delta^T)}{(1-\delta) + (1-\pi)\delta(1-\delta^T)}. \tag{9}$$

*To find the union's expected utility, it is sufficient to replace $V$ with $U$ and $v$ with $u$ in the above formulas to find the expression $U = q\widehat{u} + (1-q)u^c$.*

The expression for value is remarkably simple: it is just a weighted average of $\widehat{v}$ (the permanent-conflict payoff) and $v^c$ (the permanent-cooperation payoff). The weight of conflict, that is, $q$ can be interpreted as a measure of strike incidence. When players become very patient, *i.e.*, when $\delta$ goes to 1, then $q$ approaches a limit $q^* > 0$. Applying l'Hopital's rule, we find the following limit,

$$q^* = \frac{(1-\pi)T}{1+(1-\pi)T}. \tag{10}$$

We will show below that $q^*$ is the *incidence of strikes*, namely, the unconditional probability of conflict under strategies $\widetilde{\sigma}$.

It is clear that, to maximize surplus, the probability of conflict periods should be minimized. Thus, the length of punishment spells, $T$, should also be minimal. We study the consequences of choosing constrained efficient values of $T$ in Section 5 below.

#### 4.2.2 Incentive constraints: honesty and guts

We now consider the on-schedule deviations of the employer. In the good state, the employer should have no incentive to act as if the state was bad. In other words, the employer should be honest. This imposes, a constraint on the bonus $b$, denoted $IC_1$(or the *honesty* constraint). $IC_1$ says that the appropriately discounted value of the expected gains from cooperation must be greater than or equal to the temporary benefits of behaving as if the cost was high when it is in fact low. Honesty is guaranteed if the promised bonus is not too large.

The employer must also prefer to pay a low wage over concealing the bad news that the cost is high, to avoid the punishment phase. In other words, the employer should have the guts to face conflict. The employer incurs a cost while deviating in this way — because the union receives a high wage, but they avoid the punishment phase. This gives rise to another constraint on the bonus, denoted $IC_2$ (the "guts" constraint). In fact, the employer will not eschew conflict if the bonus is large enough, because the immediate benefits of facing conflict (*i.e.*, saving the bonus) are large enough.

We can state the following result.

**Proposition 5**.

*The employer will keep the promise to pay the bonus in good times ("honesty") and refuse to pay the bonus in bad times ("guts") if and only if the following constraints are satisfied,*

$$b \leq (v^c - \widehat{v})Q, \tag{$IC_1$}$$

$$(v^c - \widehat{v})Q \leq \overline{\theta} b, \tag{$IC_2$}$$

*where, by definition,*

$$Q = \frac{q}{1-\pi}. \tag{11}$$

The incentive compatible set of values of the bonus $b$ is clearly non-empty since, by assumption, $\overline{\theta} > \underline{\theta} = 1$. But individual rationality constraints must also hold. In other words, the one-period cooperative payoffs must be greater than the one-period punishment-spell payoffs for both players, that is, we require,

$$u^c > \widehat{u} \quad \text{and} \quad v^c > \widehat{v}. \tag{$IR$}$$

Next, we can prove that the intersection of $IC_1$, $IC_2$ and $IR$ is nonempty if $\overline{\theta}$ is large enough. If the bad state entails a sufficiently high cost $\overline{\theta}$, as compared to the good state, these crucial equilibrium constraints can be satisfied. We can state the following "wage compression" result.

**Proposition 6**.

*If* $\overline{\theta} - \underline{\theta} > 1/\pi q$, that is, if $\overline{\theta}$ *is large enough, there exists a nonempty interval* $(b^{\min}, b^{\max})$ *of values of the bonus* $b$*, such that* $IC_1$*,* $IC_2$ *and* $IR$ *hold simultaneously. On-schedule deviations are not profitable for bonus values in this interval.*

*For a complete statement and proof of Proposition 5, see Appendix B.*

When players become very impatient, that is, when $\delta \to 0$, then, it is possible to show that $Q \to 0$ and $b^{\max} \to 0$: the interval $[b^{\min}, b^{\max}]$ shrinks and vanishes. We therefore need patient players, but we also need $\overline{\theta}$, the "cost of funds" in the bad state, to be high enough. This requirement is reasonable.[22]

*Off-schedule deviations.* Finally, we must check that a number of incentive constraints are satisfied, due to the possibility of off-schedule deviations. If players are patient enough, these deviations can be deterred by reversions to the one-shot Nash equilibrium $\sigma^*$ during $T^*$ periods, in a very standard way. We skip the details of this discussion and state the following result.

**Proposition 7**. *If the punishment spells are long enough and if the players are patient enough, off-schedule deviations are unprofitable.*

## 4.3 Main results

Taken together, Propositions 1-7 show that our equilibrium candidate $\widetilde{\sigma}$ (defined above), is an equilibrium of the repeated game $G(\delta)$ for sufficiently patient players, when outsourcing is sufficiently costly and provided that we choose parameters in a suitable way. We then show that there also exist cooperative equilibria without strikes, but with "slowdown" (*i.e.*, low effort), and we discuss the relevance of these equilibria.

### 4.3.1 Existence of equilibria with cooperation and strikes

The following proposition summarizes our result.

**Theorem 1**. *For any length of the on-schedule punishment spell $T \geq 1$, if the union and the firm are sufficiently patient, if outsourcing is costly enough and if the cost of funds is high enough in the bad state, then, there exist an interval of bonus values, of the duration*

[22] It is easy to check that $q$ goes to 1, when $\delta$ tends towards 1 and $T$ goes to infinity. More precisely, $\lim_{\delta \to 1} \lim_{T \to \infty} q = 1$. Then, when punishment spells are very long and players are very patient, the threshold $\overline{\theta}_0$ approaches $1 + 1/\pi$. It follows from Proposition 6 that, when $T$ is large and players are patient, we require only $\overline{\theta} > 1 + 1/\pi$. If, in addition, $\pi$ is itself close to 1, this means that, inessence, we require $\overline{\theta} > 2$. Intuitively, with a sufficiently large $\overline{\theta}$, the inefficiencies induced by the rigid wage $\widehat{w}$ become nonnegligible (it would be very profitable to implement a state-dependent bonus), and this enlarges the set of feasible solutions, even if the duration of strikes $\widehat{s}$ is very small.

*of strikes, and a length of the off-schedule punishment spells, such that, for values chosen in the intervals, the candidate strategies $\widetilde{\sigma}$ constitute an equilibrium of the repeated game $G(\delta)$.*

Remark that, in the statement of Theorem 1, the first three conditions involve the model's parameters $\delta$, $\beta$, $\overline{\theta}$, while the last three conditions bear on key variables of the family of strategies in which $\widetilde{\sigma}$ is picked, namely, the bonus $b$, the duration of strikes during conflict phases $\widehat{s}$ and the length of punishment for off-schedule deviations $T^*$. Remark that the result holds for any length $T \geq 1$ of the (on-schedule) punishment phase.[23]

The theorem describes conditions under which there exists an equilibrium characterized by cooperation under asymmetric information. There is an "ordinary course of business" in which the union and the employer cooperate, but finite-length, inefficient-conflict spells are triggered by the random occurrence of a high-cost state. During these conflict spells, the employees' wage $\widehat{w}$ is rigidly kept above its minimum, the employees' effort is still high and there is no outsourcing, but the duration of strikes $\widehat{s}$ is positive, *i.e.*, a nonzero fraction of output will be lost, due to work stoppages, during each of these periods. Cooperative phases are characterized by high wages, high effort on the part of employees, zero outsourcing and no strikes. The occurrence of strikes — as well as the low-effort spells — is entirely due to the presence of informational asymmetries.[24] Since the probability of a bad state is not zero, the probability of a punishment spell, and therefore the incidence of strikes, is not zero (see Section 5 below). Threats are necessarily carried out along the equilibrium path, from time to time, *i.e.*, conflict is a stochastic equilibrium phenomenon. The probability of conflict being necessarily nonzero, even if reversions to punishment spells are rare, the equilibrium with cooperation cannot be fully efficient, as will be seen below (in sub-section 4.4).

The $\widetilde{\sigma}$ equilibrium has some intuitively appealing properties. The workers start a conflict phase when they are unhappy with the pay in a given period. To the outside observer, the periods of conflict seem to be triggered by the occurrence of low pay or low bonuses. A conflict phase involves strikes, during a spell that may seem too long to be reasonable, to

[23] In addition, there is a technical condition on the rigid wage level $\widehat{w}$ , derived from the proof of Proposition 3. See the Appendix, for a completely formal statement of Theorem 1.

[24] The threat of a return to non-cooperative equilibrium $\sigma^*$ in which strike activity is zero, but outsourcing is positive, while effort and wages are low, plays a crucial role, but lies off the equilibrium path.

the outside observer.[25] Yet, the behavior of the union is rational: it is an equilibrium best response, following any publicly recorded history of cooperation and conflict. This analysis shows that the observed "culture" may be rationalized. For instance, the model shows that strikes can appear even if nothing has changed during the preceding period. Indeed, when $T \geq 2$, strikes occur in spite of the fact that the wage is constant during punishment spells. The outside observer may have the impression that he or she witnesses a kind of irrational folk custom, a specific and detrimental corporate culture. For instance, the French public-sector workers would go on strike because their culture tells them to do so. At the same time, note that conflict is in some sense "civilized", since it has limited consequences: when it occurs, effort remains high and there is no recourse to outsourcing. In the Paris dustmen case, these features of equilibrium play correspond to some observed facts.

The fact that our game-theoretic analysis does not pin down the values of some key variables exactly, and does not give equilibrium variables as functions of key model parameters may be disturbing. The model provides *bounds* on key (endogenous) variables (*i.e.*, the bonus $b$, the duration of strikes $\widehat{s}$, the length of punishment phases $T$) that depend on key (exogenous) parameters (*i.e.*, the rate of time preference $\delta$, the "cost of funds" $\overline{\theta}$, the probability of a good state $\pi$, etc.). The theory says that the key equilibrium variables must satify a set of inequalities: the incentive constraints discussed above. These variables are therefore determined by interdependent bounds, not by functional relationships. For instance, the bonus $b$ must belong to the interval $[b^{\min}, b^{\max}]$, and $b^{\max}$ depends on the key variable $\widehat{s}$, but also on parameter $\delta$. It follows that when parameters change, equilibrium variables can remain constant to a limited extent. But discrete changes in parameters will typically force an adjustment of equilibrium variables. The labor-contract model of MacLeod and Malcomson (1998) has properties of the same type. If we are ready to assume that players select equilibria with efficiency properties, then, some inequalities will be binding and as a consequence, we will find functional relationships between equilibrium variables and parameters. This will allow for a comparative statics exercise. In subsection 5.1 below, we assume that the length of punishment phases is minimal, and therefore constrained-

[25] Strikes recur if the punishment phase lasts for more than one period, *i.e.*, $T \geq 1$.

efficient. We then show that constraint $IC_1$ is binding, providing a nontrivial functional relationship between equilibrium values of $\widehat{s}$, $b$ and $T$.

To sum up, Theorem 1 rationalizes the incidence and recurrence of strikes, even when strikes seem absurd to the outside observer. But the result shows that strikes are useful only to the extent that they burn a certain quantum of money, to ensure that incentive constraints hold. Any device that would burn surplus in an appropriate way could in fact be used to discipline the employer. There are several instruments of that kind in the model: strikes, low effort, or rigid wages.[26] This explains why strikes are not essential in our analysis: the important thing is that the provision of incentives requires some "money burning".

#### 4.3.2 Equilibria with slowdown (and without strikes)

Low effort can be interpreted as a form of conflict, it corresponds to the well-known *slowdown* (*i.e.*, *go-slow*) or *work-to-rule* practices. Sabotage is another possible form of conflict (not modeled here).

Slowdown and strikes are in a certain sense substitutes as a way of "burning money". An equilibrium of the same type, in which strikes disappear but slowdown, outsourcing and low wages characterize punishment phases also exists. It is easy to construct an equilibrium of this sort in our model, using reversion to $\sigma^*$, instead of $\widehat{\sigma}$, when a bad state of nature is drawn. In the definition of the equilibrium candidate $\widetilde{\sigma}$, we replace $\widehat{\sigma} = (\widehat{e}, \widehat{s}, \widehat{w}, \widehat{x})$ with $\sigma^* = (e^*, s^*, w^*, x^*)$ everywhere and obtain a valid statement as follows.

**Theorem 2**. *In the definition of the candidate strategies $\widetilde{\sigma}$, replace everywhere $\widehat{\sigma} = (\widehat{e}, \widehat{s}, \widehat{w}, \widehat{x})$ with the one-shot Nash equilibrium $\sigma^* = (e^*, s^*, w^*, x^*)$. Then, under Assumptions 1-5, for all $T \geq 1$, if the union and the firm are sufficiently patient, if outsourcing is costly enough and if the lowest effort level is costly enough, then, there exist an interval of bonus values, of the duration of strikes, and a length of the off-schedule punishment spells, such that, for values chosen in the intervals, the candidate strategies $\widetilde{\sigma}$ constitute an equilibrium of the repeated game $G(\delta)$.*

*See Appendix B for a formal statement and a proof of Theorem 2.*

[26] We have shown that the very fact that wages do not vary with the state of nature involves a social cost.

Thus, there exists equilibria without strikes, but these equilibria exhibit some other form of inefficiency. In the above statement, the drop in effort, during on-schedule punishment phases, is a substitute for outright work stoppages. We could also extend the model a bit to construct equilibria with sabotage. There are several families of equilibria in this game, but they share a common feature: *(i)*, they all rely on a money-burning device, and *(ii)*, money is burnt along the equilibrium path (with a positive probability). We show this in the next subsection (Theorem 3).

Can we then say that the equilibrium with strikes is more relevant or more reasonable than the equilibrium with slowdown? If the observer doesn't know the details of the feasible money-burning technologies, the answer to this question is no. One of the messages of this paper is precisely that, because of incomplete information, the existence of a quantum of conflict is a feature of all equilibria, but that the precise form of this dose of conflict is not essential. Changes in the money-burning technologies may determine changes in the type of equilibrium. We claim below that a drop in the cost of outsourcing can trigger a shift from equilibria with strikes to equilibria with slowdown.

## 4.4 Money Burning: Inefficiency of Equilibria

Can we find a fully efficient equilibrium? In other words, does there exist equilibria such that the expected total average utility of the players is equal to the highest possible value of surplus, namely, such that $U + V = u^c + v^c$? For any given value of $\delta < 1$, the answer to this question is no. To prove this assertion, remark first that in our model, utility can be freely transfered only in the good state of nature, when $\theta = 1$. In this state, the slope of the utility possibility frontier is $-1$: any unit of value taken from the employer's pocket is worth exactly one unit to the union. The efficient frontier is defined by $x_\theta = 0$, $s = 0$, $e = 1$, and $w_{\overline{\theta}} = 1$. A fully efficient equilibrium cannot possess a path which drops below the efficient frontier with a positive probability. An efficient equilibrium path should therefore remain on the efficient frontier in all periods and $w_1$ is the only variable that can vary during fully efficient equilibrium play. This means that increases in the bonus $b = w_1 - 1$ are the only ways of punishing the firm. Thus, to preserve efficiency, the firm can be punished for on-schedule deviations only if the state is good, but the state is not observed by the union. Hence, whichever the union's decision rule to trigger punishments, the firm can always claim that the state is bad, *i.e.*, propose the minimum wage, and avoid any punishment. It follows that the only possible fully-efficient equilibria must be such that the wage is constantly equal to its minimum, or the bonus $b = 0$. The union's payoff in a fully efficient equilibrium candidate is therefore $(1 - \overline{e}) = 0$, but this is equal to the union's minmax in the game $G$.[27] Hence, if the candidate-equilibrium's union payoff is strictly above 0, there must exist one state at least in which $w_\theta > 1 = \underline{w}$. We can state the following result.

**Theorem 3**. *If the players are not perfectly patient, i.e., if $\delta < 1$, all equilibria of the repeated game such that the union's payoff is strictly positive are inefficient. In other words, if in a given equilibrium, the employer pays a wage higher than the minimum, i.e., $w_\theta > \underline{w}$, with a positive probability, then, equilibrium payoffs $(U, V)$ are located below the efficient frontier: $U + V < u^c + v^c$.*

Are some equilibria more efficient, for a given value of $\delta$, than the strategies that we studied? This is very likely. Note that in the type of game analyzed here, the complete characterization of second-best efficient equilibria is a hard problem. But intuitively, efficiency can be improved if the probability of reversion to non-cooperative or inefficient equilibria can be made smaller, to reduce the incidence of inefficient episodes. One way of doing this could be, for instance, to introduce memory, and let the union count the number of times the employer declared that (or behaved as if) times were bad. Radner's (1985) *review strategies* could be adapted to our pure adverse selection context.[28] To be more precise, in an equilibrium with *memory*, the union would for instance cooperate whatever happens during $r$ periods, the *review period*, and compute the frequency of high-wage and low-wage offers. Players would then revert to striking, or to low-effort equilibria, if the observed frequency of good states, during the review period, is lower than some threshold, indicating a likely deviation of the employer. We conjecture that it is possible to prove that such review strategies are equilibria for discount factors close enough to 1, as in Radner (1985). We would then approach

[27] Note that the union's minmax is obtained when the employer plays $x = 1$.

[28] Radner's (1985) paper is devoted to a pure moral hazard problem, but we know that hidden information problems can be rewritten as hidden action problems in the imperfect public monitoring case (see Fudenberg *et al.* (1994)).

efficiency for sufficiently patient players.

But what would be the economic interpretation of such a result? A discount factor close to 1 may mean a very frequent interaction between the union and the employer, and therefore frequent revisions of wages. This is not what is observed in practice. It follows that an equilibrium relying on a long memory and a review strategy, as described above, would require the union to wait for several years, before deciding on some action, strike or slowdown. This too doesn't seem very realistic. The short-memory strategies studied above are probably a more realistic description. A realistic equilibrium relies on simple strategies, based on publicly observed moves, with a short memory and short punishment spell. The statements of Theorems 1 and 2 above show that (on-schedule) punishment spells can be limited to one period (*i.e.*, $T = 1$) and the memory can be limited to 2 periods (*i.e.*, $T + 1$). Intuitively a short-memory, short-punishment equilibrium of the $\widetilde{\sigma}$ family has a form of robustness that is more appealing than some of the more sophisticated forms of behavior studied by game theorists. One obvious reason is that a $T = 1$ equilibrium is less demanding, in terms of commitment.

# 5 Interpretations

We now study some properties of the model and discuss their ability to shed light on relationships between facts.

## 5.1 Minimal length of the punishment phase

Our equilibrium candidate $\widetilde{\sigma}$ supports an expected discounted value of the surplus denoted $R = U + V$. Given the expressions of $U$ and $V$, we have,

$$R = (\widehat{u} + \widehat{v})q + (u^c + v^c)(1 - q). \tag{12}$$

Remark that $u^c$, $v^c$, $\widehat{u}$ and $\widehat{v}$ do not depend on $T$. If we now treat $T$ as a real number, we find that $q$ is an increasing function of $T$. Intuitively, long punishment spells increase the social losses due to conflict. Short conflict phases are more efficient. It follows from this that

$\partial R/\partial T < 0$ and the optimal value of $T$ is therefore the smallest value compatible with $IC_1$, $IC_2$ and $IR$.

Now, we go back to constraints $IC_1$, $IC_2$, and $IR$, defined above. Recall that $IC_1$ can be written,

$$b \leq (v^c - \widehat{v})Q, \tag{$IC_1$}$$

where $Q = Q(\delta, \pi, T)$ is a function of parameters defined by (9) and (11). Going back to (9), we find that $q$, and thus $Q$, are strictly increasing functions of $T$. As a consequence, for given values of $b$ and $(\widehat{s}, \widehat{w})$, constraint $IC_1$ will be binding at the smallest admissible real value of $T$, denoted $\widetilde{T}$. More precisely, to find the minimal punishment length $\widetilde{T}$, we must solve $IC_1$ in binding form, that is, solve the equation[29]

$$Q(\delta, \pi, \widetilde{T})(v^c - \widehat{v}) = b.$$

We can now summarize a number of findings in the following statement.

**Proposition 8**. *The real solution of the equation $Q(\delta, \pi, T)(v^c - \widehat{v}) = b$ with respect to $T$, denoted $\widetilde{T}$, is a differentiable function of $(\delta, \pi, v_0, b, \widehat{w}, \widehat{s})$. The following properties hold:*

$$\frac{\partial Q}{\partial T} > 0; \quad \frac{\partial \widetilde{T}}{\partial v_0} < 0; \quad \frac{\partial \widetilde{T}}{\partial b} > 0; \quad \frac{\partial \widetilde{T}}{\partial \widehat{s}} < 0; \quad \frac{\partial \widetilde{T}}{\partial \widehat{w}} < 0. \tag{13}$$

*The minimal admissible value of $(v^c - \widehat{v})$ is $b(1 - \delta\pi)/\delta$. When $\widehat{s}$ becomes so small that $(v^c - \widehat{v})$ approaches its minimal value, then $\widetilde{T}$ tends toward infinity.*

*For a detailed proof of Proposition 8, see Appendix B.*

The minimal value $\widetilde{T}$ is a function of $b$, $\widehat{w}$ and $\widehat{s}$. Let us now discuss the comparative statics properties of $\widetilde{T}$. For convenience, define $\eta = v^c - \widehat{v}$, the *one-period surplus of cooperation.* Now, the binding form of $IC_1$ can be written $Q\eta = b$. Since $Q$ is increasing in $T$, we see that $\widetilde{T}$ must be decreasing in $\eta$, and rigorous calculus confirms that $\partial\widetilde{T}/\partial\eta < 0$. An increase in the one-period gains from cooperation $\eta$ decreases the minimal length of the punishment phase — an easily understandable property — since the losses due to conflict

[29] Technically, the minimal value of $T$ is in fact an integer. We denote this integer by $T^{\min} = int(\widetilde{T}) + 1$, where $int(T)$ is the largest integer smaller than or equal to $\widetilde{T}$.

are higher. From this, we derive, $\partial\widetilde{T}/\partial v_0 < 0$. For the same reasons, an increase in the value of production $v_0$ reduces the length of punishment phases $\widetilde{T}$.

After some computations, we obtain, $\partial\widetilde{T}/\partial b > 0$. There is a tradeoff between the prevalence of conflict and the wage obtained by workers during cooperation phases. It must be that the fraction of time spent in a situation of conflict increases when the bonus $b$ is more generous. Increases in the bonus can only be sustained if the length of the minimal punishment phase is increased (other things being equal), because the employer's rewards from cooperation are reduced.

Another important tradeoff is between $\widehat{s}$ and $\widetilde{T}$. The chain rule yields, $\partial\widetilde{T}/\partial\widehat{s} < 0$. Longer strikes should therefore be associated with shorter punishment spells. This will generate a tradeoff between the duration and the incidence of strikes (we define incidence precisely below). In a cross-section of firms, we should observe that firms with longer strikes are also such that strikes are less prevalent.

Finally, we obtain , $\partial\widetilde{T}/\partial\widehat{w} < 0$. When the rigid wage rate paid to workers during punishment phases is higher, the length of these phases should be smaller.

## 5.2 Incidence of strikes

We now turn to the comparative statics of strike incidence, and study the ability of our model to reproduce a number of empirical observations. The empirical literature has discussed the behavior of strikes during the business cycle.[30] One of the main findings of this literature is, with qualifications, that strikes have a procyclical incidence. For instance, Vroman (1989) finds the latter property with US data between 1957 and 1984.[31] McConnell (1990) finds that strike incidence is highest in industries that are depressed relative to the rest of the economy but in regions with low unemployment. In France, the first difference in the log-aggregate number of days lost to strikes is positively correlated with the first difference in growth rates: the coefficient of correlation is 0.4 during the period 1977-2004. So, it seems that we have a pro-cyclical incidence of strikes at the aggregate level.

[30] Research on this topic has started a long time ago. See, for instance, on the US case, Hansen (1921), Rees (1952), Ashenfelter and Johnson (1969), Kennan (1986), Kennan and Wilson (1989), Card (1990).

[31] On the Canadian case, see Harrison and Stewart (1994). For a study of strikes in the UK (and further references), see *e.g.*, Devereux and Hart (2008).

### 5.2.1 Duration and incidence of strikes in the model

In our context, incidence is the unconditional probability of observing a strike during a given period, or the average fraction of time during which punishment strategies are observed, in equilibrium. It can be defined in a simple way as the probability, denoted $q^*$, that a period chosen at random belongs to a punishment phase. We thus define a lower bound, a notion of "minimal incidence". The duration of strikes is simply $\widehat{s}$.

**Proposition 9**.

The incidence of strikes is given by the expression,

$$q^* = \frac{(1-\pi)T}{1+(1-\pi)T}. \tag{14}$$

*For a proof of proposition 9, see Appendix B.*

### 5.2.2 Can the model explain procyclical strikes?

Suppose now that we have a sample of identical firms playing the same equilibrium and with states drawn independently: $q^*$ is then the probability of drawing a firm experiencing an inefficient conflict spell. But if random states are uncorrelated across firms, it is impossible to interpret the state of nature as a business-cycle fluctuation. At the macroeconomic level, we observe more strikes in the country during booms, whereas our model seems to predict that strikes are triggered by the occurrence of slumps. So, it seems that our model predicts a counter-cyclical incidence of strikes, but this would be a naive interpretation. Recall that, in our model, the state is by definition private information of the employers. On the contrary, it is reasonable to assume that a general state of boom or bust would be common knowledge.

Can we then use the model to interpret aggregate strike activity in a given country, using, say, ILO data? To derive a microeconomic foundation for the strike aggregates, we need *strategies that are contingent on the publicly observed macroeconomic state*, while the firm's state $\theta$ remains a privately observed, idiosyncratic shock. Suppose that unions are more demanding during booms: this means that they expect higher bonuses during booms. As a consequence, a given value of the bonus can trigger a strike during a boom, while it would be accepted without a murmur in a state of bust. Another possibility is that, when faced with a given wage or bonus, unions will go on strike with a smaller probability in a state of bust. If this is the case, more strikes will be triggered in firms that are relatively disadvantaged during booms, that is, in firms with a bad drawing of their private state $\theta$, while the economy is booming. Now, if the length $T$ of reversions to inefficient play is not too long, and if the publicly observed state of the macroeconomy is sufficiently persistent, a positive correlation of booms with the incidence of strikes will be generated. The same mechanism will also generate a lag of the aggregate strikes cycle. This is a relatively straightforward extension of our model, since strategies can be made dependent on the outcome of a public lottery in a simple way, but it requires lengthy computations to be worked out in details. With this type of extension, it seems clear that *strikes can be pro-cyclical in the aggregate, even if, in fact, they are always triggered by some disappointing event at the microeconomic level.*[32]

### 5.2.3 Paris dustmen redux

Finally, does the model provide us with an interpretation of the facts related to the Paris dustmen? In particular, can we explain the drop in strike activity that we observe on Fig. 1, from the mid-eighties until the early 2000s? We think that this sharp drop can be explained as a change of regime. An equilibrium in which strikes are used as a punishment device has disappeared and has been replaced by an equilibrium in which slowdown is used as a punishment. The number of observed days of strike fell to zero, while outsourcing appeared. This can be checked on Fig. 2, showing that the number of civil-service dustmen has also been decreasing from 1984 to 2000. This new equilibrium looks like the implementation of strategies in which the one-shot Nash equilibrium is used during inefficient punishment phases: unrecorded slowdown replaces observed work stoppages. This regime switching is the likely result of a sharp reduction in the value of $\beta$, the specific cost of outsourcing. A drop in $\beta$ captures the change of attitude of the town hall with respect to privatization of garbage-collection services. Indeed, we know that a change of policy regarding outsourcing took place in the late seventies, early eighties. In our model of strikes, a drop in $\beta$ is likely to destroy the established equilibrium regime described above by Theorem 1. To see this,

[32] Here, the unions' "disappointment" is relative to the publicly observed state of the economy.

we can easily compute the one-shot Nash equilibrium payoffs, namely,

$$\begin{aligned} u^* &= (1-x^*)(1-\underline{e})\overline{h}, \\ v^* &= v_0 - \underline{w}\overline{h}E\theta + E\theta(\overline{h}-1)x^*/2, \end{aligned}$$

where

$$x^* = \frac{\overline{h}-\underline{h}}{\beta}.$$

We then easily find,

$$\frac{\partial u^*}{\partial \beta} > 0, \qquad \text{and} \qquad \frac{\partial v^*}{\partial \beta} < 0.$$

If $v^*$ increases enough, as in the case of a sharp reduction in the cost of outsourcing, then $v^*$ hits $\widehat{v}$ from below and the prevailing equilibrium is no longer feasible.

Since $\widehat{v} = (1-\widehat{s})(v_0 - \widehat{w}E\theta)$, maintaining the old equilibrium requires $\widehat{s} \to 0$ or a drop in $\widehat{w}$ that may be infeasible. An equilibrium in which strikes disappear but slowdown, outsourcing and low wages characterize punishment phases is likely to replace the former arrangement. We have shown that it is easy to construct an equilibrium of this kind in our model, using reversion to $\sigma^*$ instead of $\widehat{\sigma}$ when a bad state of nature is drawn (see Theorem 2 above). In the latter equilibria, punishment phases are not easily observable, because slowdown phases are not recorded as strike days. We know from our case study of the Paris dustmen, and there is a lot of anecdotal evidence confirming these trends, that the recent period is one in which effort has been low (with for instance higher absenteeism) and worker resistance has been high (with many more work-to-rule or slowdown spells than before). Recent statistics of the French Ministry of Labour show that, if the number of outright strikes has been decreasing in the past thirty years, in contrast, nonstandard forms of conflict, slowdown and work-to-rule have been everywhere on the rise (*e.g.*, DARES (2009)). Strikes are far from being perfect indicators of social strife. A consequence of the inessential nature of strikes is that their causal effect on wages, as well as the causal impact of business-cycle indicators on strike incidence will be hard to identify, since other unobservable forms of labor strife can also have an impact on wages. There is a problem for the interpretation of empirical work if observable forms of conflict may be replaced with less easily observable or unrecorded forms.

### 5.2.4 Outsourcing and strikes

There is a rapidly growing literature on outsourcing. This theme is particularly important in International Economics.[33] There also exists a literature on outsourcing in the public sector, paying attention to the respective roles of efficiency considerations and political biases in the privatization of municipal services.[34] But the bulk of the literature is not focusing on the relationship of outsourcing with strikes, although it sometimes deals with the more general question of the impact of globalization on deunionization. In these matters, it seems that a consensus on causality has not yet emerged: is deunionization the origin of outsourcing or, on the contrary, are outsourcing decisions weakening the unions?[35] Yet, the latter point of view is likely to describe the "normal case".

Our result, based on the relational-contracts, repeated-game approach exposed above, is that changes in the transactions costs of outsourcing (that may encompass changes in the "political costs" of this type of decision) may explain changes in the form of social conflict within the firm. Then, we conjecture that *the aggregate number of days lost to strikes may exhibit a downward trend in several countries, not because social conflict is slowly disappearing, but because it becomes less easily observable.* To test this theory, further empirical research is needed. For instance, absenteeism could be on the rise, while strikes become less frequent.[36]

Our model is not particularly specific. The dustmen have been chosen as an illustration, but our theory is more general, and could be further generalized. Our approach clearly applies to private firms as well. We have proposed a theory of the firm encompassing social conflict, when the firm owners can use outsourcing to change the size of the surplus that must be shared with the workers. In the above theory, the firm nearly collapses (*i.e.*, the one-shot Nash equilibrium) if workers do not cooperate (and if outsourcing is cheap). Cooperation is vital. With repeated interaction, in spite of asymmetric information, long-run cooperation

[33] See, *e.g.*, Grossman and Helpman (2005).

[34] See, *e.g.*, Levin and Tadelis (2010); Elinder and Jordahl (2013).

[35] For instance, Lommerud *et al.* (2009) propose a model in which strong unions can deter outsourcing. In contrast, in an empirical study of French firms, Kramarz (2014) shows that firms facing strong unions are likely to use offshoring more intensively than firms facing weaker unions, since, with increased offshoring, the union and the firm bargain over a smaller rent.

[36] However, again, see the empirical studies of Alexandre Mas (2006, 2008).

is possible, but at the cost of some conflict outbursts.

# 6 Conclusion

We have modeled the long-run relationship between an employer and his workers' union as a mechanism design problem, in a repeated game with imperfect monitoring. The union doesn't observe the firm's profitability, drawn at random in every period. In this context, we have shown that cooperation can be sustained if players are sufficiently patient, in spite of informational asymmetries, at the cost of random reversions to inefficient ways of playing, during finite-duration spells, in which strikes, slowdown and outsourcing may appear. We focus on a class of Perfect Public Equilibria in which strikes are used to support equilibrium. Under cooperation, workers enjoy high wages (*i.e.*, positive bonuses), no outsourcing (and therefore more employment); the firm avoids strikes completely and productivity is higher, due to high worker effort. The equilibrium path is characterized by alternating phases of cooperative and inefficient play involving strikes. Transitions are caused by random external profitability shocks, which themselves cause low pay or a zero-bonus event. We showed that all the equilibria of our game are inefficient. Given incentive constraints, first-best efficiency can be reached only if wages are constantly equal to their minimum, implying a zero bonus, but the union's payoff is then equal to its minmax. In the class of equilibria that we studied, we have derived the minimal length of punishment spells. We have shown that under the incentive constraints implied by equilibrium, higher wages or larger bonuses should be positively correlated with longer strike durations — but longer strikes do not cause higher wages. Some empirical facts from the municipal garbage-collection industry were used to illustrate the theory and to show the interaction of outsourcing (or worker replacement) with wages and strikes in the long run. In particular, our model can explain why strikes may disappear as a consequence of a drop in outsourcing costs and be replaced by other, less easily observable forms of conflict such as slowdown (low effort). The proposed theory can be viewed as a synthesis of the theory of strikes with that of relational contracts.

# 7 Appendix A: Further Study of Paris Dustmen

A municipal dustman's lifetime career is somewhat rigidly organized. There is a rigid wage-scale divided in 10 grades. Seniority plays a major role in promotions: a dustman stays on each grade (or step) for two or three years (depending on the grade). Those who become foremen (*i.e.*, "head of sanitation team") start to climb up a different ladder. But the future of those who belong to the rank-and-file until the end of their careers is entirely described by the 10 grades, on the same scale. The pay corresponding to each grade varies over time, because each negotiation with the union can lead to alterations of the ladder's overall height, and to a lesser extent, of the difference between steps. The real value of each grade can also vary over time, because of pay raises decided by the country's central government and applied to all members of the civil service, including municipal workers, and because of inflation. Figure 3 shows the real value of the 10 grades of a dustman's career over time, with the real value of the minimum wage as a point of comparison (at the bottom). An additional, eleventh grade has been created in the nineties. Each wage-scale curve is roughly parallel to others.

The effects of Mayor Chirac's tough outsourcing policy can easily be measured. In 1977, the dustmen of Paris seemed to enjoy a generous rent; they earned substantially more than the national minimum wage: a first-grade beginner, which is typically an unskilled worker, would earn 25% more than an equivalent private-sector, minimum-wage worker. This rent is the result of the numerous strikes of the late sixties and early seventies (in particular, the well-known 1968 events). Another striking feature is that in the long run, the real values of the first grade and minimum wages converged. Public sector dustmen have lost the wage-premium they enjoyed 30 years ago. This seems to be the combined result of inflation, which eroded the real values, and of town hall resistance to the union's claims. The process of return to long-run "equilibrium" wages has been gradual. During some years, particularly the years 1984 to 1990, the real value of the lowest grades has decreased, and the real value of the highest grades has decreased from 1986 to 1989. But none of these curves does in fact describe the evolution of an individual worker's wage, because seniority triggers automatic grade promotions. Figure 4 plots a simulation of a typical career, showing the real wage of a dustman, hired in 1978, starting in the first grade, and promoted using the seniority rules that used to be in force. This dustman's wage has an increasing trend, with some fluctuations (such as the visible dip between 1987 and 1989); short periods of stagnation are followed by upward jumps, due to automatic grade promotions. Figure 4 also shows the real minimum wage as a point of comparison. It is likely that individual, seniority-induced raises have eased the town hall's austerity policy, by making the real-value erosion of wages less painful for workers.

Given the pay scale and promotion rules, it is possible to compute the real value of a dustman's career at each point in time: it is the present discounted value of a dustman's real wages over an entire career cycle, evaluated at a given moment using the promotion and pay rules in force. In other words, these discounted wage sums are computed each year for a first-grade new recruit, under the myopic assumption that current seniority rules will not change and that the real value of each grade will remain constant over the entire career. Figure 5 plots the series of real career values, based on the dustman's real take-home pay (in 2004 euros) and a discount rate of 3%. Figure 5 simultaneously shows a decreasing linear trend and the swings of the best-fit curve, using a fifth-degree polynomial.

Finally, we have tried some regressions involving the real value of a career and the number of strike days lost. The results obtained should of course be interpreted with caution, due to the small number of observations, and to possible endogeneity problems, but still, they are sufficiently suggestive to be presented here. Let $V_t$ be the value of a career in year $t$. Let $\Delta V_t = V_t - V_{t-1}$ be the first difference. Let $\Delta N_t$ be the yearly variation in the total workforce, and let $S_t$ be the number of days lost to strikes in year $t$. Are variations in $V_t$ in a certain way correlated with strikes $S_t$? The first column in Table 1 shows a linear regression of $V$ on $S$ which is not yielding a significant coefficient. But in the second column, a regression of $\Delta V_t$ on $S_t$ and $\Delta N_t$ yields a significant positive coefficient on strikes. Yet these results are somewhat disappointing. Define next the career-value increase $\Delta V_t^+ = \max\{0, \Delta V_t\}$. With this latter variable, we find an interesting regression. Column 4 in Table 1 reports the results of $\Delta V_t^+ = a + bS_t + c\Delta N_t + \varepsilon$, which yields a significant and positive $b$ and a negative $c$. Second, define value drops as $\Delta V_t^- = \min\{0, \Delta V_t\}$. We then run the regression $S_t = \alpha + \beta \Delta V_{t-1}^- + \gamma \Delta N_{t-1} + \varepsilon$ and find that $\beta$ is significant and negative, while $\gamma$ is significant and positive. The results of the latter regression are reported in column 5 of Table 1. Lagged value drops seem to "cause" strikes, while workforce reductions seem to harness strikes.

# 8 Appendix B: Proofs

## 8.1 Cooperative and Noncooperative Solutions of the Stage Game

**Formal Statement and Proof of Proposition 1**.

For simplicity, we assume that $\beta$ is large enough so as to ensure that $x_\theta^* < 1$. This guarantees that solutions for $x$ are interior.

**Assumption 4.** $\beta > \overline{h} - \underline{h}$,

**Proposition 1**. *The Nash equilibrium of* $G$, *denoted* $\sigma^* = (e^*, s^*, w_\theta^*, x_\theta^*)$, *is unique and we have,*

$$e^* = \underline{e}, \quad s^* = 0, \quad w_\theta^* = \underline{w}, \quad x_1^* = x_{\overline{\theta}}^* = (\overline{h} - \underline{h})/\beta. \tag{15}$$

*Proof of Proposition 1.*

*(a) The employer's best reply.* The employer's best reply to $(e, s)$ is a pair of functions, $(w_\theta^*(e, s), x_\theta^*(e, s))$. Given that $v_\theta$ is a non-increasing function of $w_\theta$, the choice of the minimum wage $w_\theta^* = \underline{w}$ is always a best response. It is the only best response if $x^* < 1$ and $s^* < 1$.

The best reply $x_\theta^*(e, s)$ is the value of $x_\theta$ which maximizes the employer's utility $v_\theta$. Using Assumption 3 and the result $w_\theta^* = \underline{w} = 1$, the first-order condition for an interior maximum can be written,

$$v_0 s + \theta h(e)(1 - s) - \theta \underline{h} - \theta \beta x_\theta^* = 0,$$

from which we immediately derive the best outsourcing response,

$$x_\theta^*(s, e) = \frac{1}{\theta\beta}\left(v_0 s + \theta h(e)(1 - s) - \theta \underline{h}\right), \tag{16}$$

provided that the expression is positive, and $x_\theta^*(s, e) = 0$ if $v_0 s + \theta h(e)(1 - s) < \theta \underline{h}$.

Since $v_\theta$ is a concave function of $x_\theta$, the above necessary condition is also sufficient.

*(b) The union's equilibrium strategy.* The Union chooses the pair $(s^*, e^*)$ so as to maximize the expected utility, that is,

$$Eu_\theta = (\underline{w} - e)h(e)(1 - s)(1 - Ex^*_\theta).$$

A best response maximizes $(\underline{w} - e)h(e)(1 - s)$, taking $Ex^*_\theta$ as given. Recall that $0 \leq Ex^*_\theta < 1$. It is straightforward that this implies *no strikes*: $s^* = 0$ and *low effort:* $e^* = \underline{e}$, since $(\underline{w} - \underline{e})\overline{h} > (\underline{w} - \overline{e})\underline{h} = 0$ (the latter condition being true under Assumptions 1-3). This proves Proposition 1. *Q.E.D.*

**Formal Statement and Proof of Proposition 2**.

By definition, a cooperative solution of the one-shot game $G$ maximizes $ER_\theta$ with respect to $(e, s, w_\theta, x_\theta)$, subject to the constraints: $e$ chosen in $\{\underline{e}, \overline{e}\}$, $0 \leq s \leq 1$, $1 \leq w_\theta \leq v_0$ and $0 \leq x_\theta \leq 1$. To state Proposition 2, we need just one additional technical assumption, namely, that the surplus associated with the task, that is, $v_0$, is large enough. The following assumption is rather innocuous.

**Assumption 5**. $v_0 > (\overline{\theta} - 1)\overline{h} + \underline{e}\overline{h}$.

We can now state the result describing the cooperative solutions.

**Proposition 2**.

*Under Assumptions 1-3 and 5, there exists a value $\beta_0 > 0$, such that if $\beta > \beta_0$, the cooperative solutions of $G$ are characterized by the following properties: $e^c = \overline{e}$, $s^c = 0$, $x^c_1 = x^c_{\underline{\theta}} = 0$, $w^c_{\underline{\theta}} = \underline{w} = 1$ and the bonus $b = w^c_1 - \underline{w}$ is nonnegative but indeterminate.*

*Proof of Proposition 2.*

We first compute the best cooperative amount of outsourcing, denoted $x^c_\theta(s, e)$. The first-order condition for surplus maximization with respect to $x^c_\theta$, in state $\theta$, can be written,

$$v_0 s + (e - (1 - \theta)w^c_\theta)h(1 - s) - \theta - \theta\beta x^c_\theta = 0,$$

which immediately yields,

$$x_\theta^c(e,s) = \frac{1}{\theta\beta}\left[v_0 s + (e-(1-\theta)w_\theta^c)h(1-s) - \theta\right]^+,$$

where for any $z$, we denote $[z]^+ = \max\{0, z\}$. Note that $R_\theta$ is concave with respect to $x_\theta$, so that necessary conditions for optimality are also sufficient. Again, we assume that $\beta$ is large enough to ensure that $x_\theta^c(s,e) \leq 1$.

To maximize the expected surplus $ER_\theta$ with respect to $s$, given $(w_\theta^c, x_\theta^c)$, we compute the derivative,

$$\frac{dER_\theta}{ds} = E\left(\frac{\partial R_\theta}{\partial s}\right) + E\left(\frac{\partial R_\theta}{\partial x_\theta}\frac{\partial x_\theta^c}{\partial s}\right) = E\left(\frac{\partial R_\theta}{\partial s}\right).$$

The right-hand side equality is due to the envelope theorem: if $x_\theta^c \equiv 0$ on some open neighborhood, then $\partial x_\theta^c/\partial s = 0$, and if $x_\theta^c > 0$, then, by definition, $\partial R_\theta/\partial x_\theta = 0$. Thus, using the definition of $R_\theta$, we have,

$$\frac{dER_\theta}{ds} = E\left((1-x_\theta^c)[(\theta-1)hw_\theta^c + eh - v_0]\right).$$

Given that $x_\theta^c < 1$, the above derivative is negative if $v_0$ is large enough, that is, if there is enough surplus. Under Assumption 4, we immediately obtain $s^c = 0$.

We now substitute the value of $s^c = 0$ in the expression for $x_\theta^c$ and we obtain,

$$x_1^c(e,0) = (1/\beta)\left[eh - 1\right]^+, \quad x_{\overline{\theta}}^c(e,0) = (1/\overline{\theta}\beta)\left[eh + (\overline{\theta}-1)h - \overline{\theta}\right]^+.$$

We must now determine the cooperative effort level $e^c$. High effort yields $h = \underline{h} = 1$, and we obtain, $x_{\overline{\theta}}^c(\overline{e},0) = (1/\overline{\theta}\beta)\left[\overline{e}-1\right]^+ = 0$, since $\overline{e} \leq 1$, and $x_1^c(\overline{e},0) = (1/\beta)\left[\overline{e}-1\right]^+ = 0$. From these results, we derive,

$$E(R_\theta \mid e = \overline{e}, s = 0) = v_0 - E[(\theta-1)w_\theta^c + \overline{e}].$$

If effort is low, we have $h = \overline{h} > 1$, and $x_\theta^c(\underline{e}, 0)$ can now be positive. Hence, we obtain,

$$E(R_\theta \mid e = \underline{e}, s = 0) = v_0 - E\{[1 - x_\theta^c(\underline{e},0)][(\theta-1)\overline{h}w_\theta^c + \underline{e}\overline{h}]\} - E[\theta g(x_\theta^c(\underline{e},0))].$$

Now, since $\theta g(x_\theta^c(.))$ is nonnegative, a sufficient condition for high effort $\overline{e}$ to be optimal is therefore,

$$E[(\theta-1)w_\theta^c + \overline{e}] < E\{[1 - x_\theta^c(\underline{e},0)][(\theta-1)\overline{h}w_\theta^c + \overline{h}\underline{e}]\}.$$

The left-hand side of this inequality doesn't depend on $\beta$. If $\beta$ is sufficiently high, $x_\theta^c$ is as small as desired and the inequality then holds, because, under Assumptions 1 and 2, $\underline{e}\overline{h} > \overline{e}$ and $\overline{h} > 1$. This proves the result.

*Q.E.D.*

## 8.2 Equilibria in the Repeated Game

### Public Strategies and Perfect Public Equilibria

The long-run relationship between the union and the employer is described as an infinite repetition of the stage game $G$, denoted $G(\delta)$. There is an element of incomplete information (or imperfect monitoring) due to the fact that the union does not observe the cost parameter $\theta_t$, drawn at each period $t$. Our model is a game of *repeated adverse selection*. The moves of players are public information, but moves are taken after players learn some private information.[37] In our model, the employer's *moves* $(w, x)$ are observed by the union, and are therefore public information, but the state of nature $\theta_t$ is a private *i.i.d.* shock which is never disclosed. An employer's *action* at time $t$ is by definition a *mapping* of the set of states $\{\underline{\theta}, \overline{\theta}\}$ into the set of possible moves $[\underline{w}, v_0] \times [0, 1]$. Employer *actions* are not observed by the union. This means that the workers can observe $w$ and $x$, but that they do not know how the firm chooses $w$ and $x$ as functions of the underlying state $\theta_t$. Since $\theta_t$ is never disclosed, $G(\delta)$ has no proper subgames, and it follows that the well-known concept of subgame perfect equilibrium cannot be used here. In such a situation, the *Perfect Public Nash Equilibrium* is the appropriate equilibrum concept. By definition, the Perfect Public Equilibrium is a Nash equilibrium in which players are restricted to play *public strategies*. By definition again, public strategies are rules of behavior, at each period $t$, that depend only on publicly observable histories of play. In other words, these strategies may depend only on things that both players have observed in the past. Public strategies therefore do not depend on past unobservable characteristics and actions of the players, they may only depend on past *moves*.

[37] An instance of this class of games is Athey and Bagwell's (2001) model of repeated price-competition oligopoly, in which firm prices are public, but firm costs are subject to privately observed *i.i.d.* shocks.

It happens that the restriction to public strategies is without loss of generality in our model. Given our assumptions, the union can only play public strategies since, by assumption, the Union has no private information in the model, and the union's moves are observable. The employer's strategy would not be *public* if it depended on some record of past values of the privately observed state $\theta$. In our context, it can be shown that the employer cannot improve his profit by means of non-public strategies: he or she always has a best reply which is a public strategy too. Therefore, in this context, there is no loss of generality in restricting the analysis to public strategies and public equilibria (see Mailath and Samuelson (2006)). A Perfect Public Equilibrium is defined as a pair of public strategies that, after any public history, specifies a Nash equilibrium for the repeated game.[38]

**Formal Statement and Proof of Proposition 3**

**Proposition 3**.

*Under Assumptions 1-5, there exists a $\delta_0 < 1$ and a $\beta_0 > 0$, such that, if $1 > \delta > \delta_0$ and $\beta > \beta_0$, the perpetual repetition of $\widehat{\sigma}$ is a Perfect Public Equilibrium path of $G(\delta)$.*

*Proof of Proposition 3.*

For convenience, denote the average value of $\theta$ by $\mu = E(\theta)$. Using the results obtained above, we have the one-shot Nash equilibrium payoffs,

$$u^* = Eu^*_\theta = (1 - \underline{e})\overline{h}(1 - x^*_1)$$

and

$$v^* = Ev^*_\theta = v_0 - \mu[\overline{h}(1 - x^*_1) + c_0(x^*_1)].$$

To prove the result, we set $\widehat{s} = 0$ in a first step and choose the value of $\widehat{w}$ so as to ensure $\widehat{u} > u^*$ *and* $\widehat{v} > v^*$. This imposes,

$$1 + (1 - \underline{e})\overline{h}(1 - x^*_1) < \widehat{w} < 1 + \overline{h}(1 - x^*_1) + c_0(x^*_1).$$

Computing the difference between the upper and the lower bounds, we easily show that this open interval for $\widehat{w}$ is nonempty if and only if,

$$(1 - x^*_1)(\underline{e}\overline{h} - 1) + \beta\frac{(x^*_1)^2}{2} > 0,$$

[38] On these questions, see Abreu *et al.* (1990), Fudenberg *et al.* (1994), Mailath and Samuelson (2006).

which is always true under Assumption 1. Now, given a feasible $\widehat{w}$, by continuity, we can always find a value $\widehat{s} > 0$ small enough to preserve $\widehat{u} > u^*$ and $\widehat{v} > v^*$. The minimal value of $\widehat{w}$, denoted $\widehat{w}^*$, is given by the following expression,

$$\widehat{w}^* = 1 + \frac{(1-\underline{e})\overline{h}(1-x_1^*)}{(1-\widehat{s})} > 1.$$

We conclude that there exist values $(\widehat{s}, \widehat{w}) >> (0, 1)$ such that, simultaneously, $\widehat{U} > U^*$ and $\widehat{V} > V^*$.

We must now show that the perpetual repetition of $\widehat{\sigma} = (\widehat{e}, \widehat{s}, \widehat{w}, \widehat{x})$ is a trigger strategy equilibrium of $G(\delta)$ if $\delta$ is high enough. But this is fairly standard. Consider the following trigger strategies: both players initially play $\widehat{\sigma}$ and any deviation is punished by a permanent reversion to $\sigma^*$. The equilibrium condition for the union is $\widehat{U} \geq (1-\delta)u' + \delta U^*$, where $u'$ is the expected payoff induced by the union's best one-shot deviation in the stage game, given that the employer plays $(\widehat{w}, \widehat{x})$. If $\widehat{U} > U^*$, there exists a $\delta_0 < 1$ such that the condition holds for any $\delta > \delta_0$. The reasoning is the same for the employer. There are no inference problems in this equilibrium because all deviations are perfectly detected by both players. We conclude that when players are sufficiently patient and $\beta$ is sufficiently large, the repetition of $\widehat{\sigma}$ is an equilibrium.

*Q.E.D.*

**Value Functions and Proposition 4.**

**Proof of Proposition 4.**

Let $V$ be the long-run expected utility of the employer along any path of play induced by our candidate equilibrium $\widetilde{\sigma}$. Let $V_1$ be the expected, discounted utility when the state is $\theta = 1$, and let $V_\theta$ be the expected, discounted utility when the state is $\overline{\theta} > 1$. Recalling that $\pi$ is the probability of a good state, we have,

$$V = \pi V_1 + (1-\pi)V_\theta. \tag{17}$$

If $\theta = 1$, then, $V_1$ satisfies the equation,

$$V_1 = (1-\delta)v_1^c + \delta V, \tag{18}$$

where $v_1^c$ is the one-period utility of the cooperative play $\sigma^c$ in state $\theta = 1$, and we denote $v_1^c = v_1(\sigma^c)$.

Next, if the true value of the state is $\overline{\theta}$, the employer pays the minimal wage and this triggers a punishment spell lasting $T$ periods, in the period immediately following a bad draw of $\theta$. During the punishment spell, $\widehat{\sigma}$ is played $T$ times; the per-period expected utility of the employer is $\widehat{v}$ in each of these periods, and this latter term must be weighted by the annuity factor:

$$\delta + \delta^2 + ... + \delta^T = \delta\frac{(1-\delta^T)}{1-\delta}.$$

Finally, the players return to cooperation at the end of the punishment phase. This has an expected, discounted value $\delta^{T+1}V$. It follows that $V_\theta$ satisfies the equation,

$$V_\theta = (1-\delta)v^c_{\overline{\theta}} + \delta(1-\delta^T)\widehat{v} + \delta^{T+1}V, \tag{19}$$

where $v^c_{\overline{\theta}} = v_{\overline{\theta}}(\sigma^c)$. To simplify notation, we denote the employer's expected per-period utility by $v^c = Ev^c_\theta$. Using the linear equations defining the value functions above, some algebra easily yields the solution,

$$V = q\widehat{v} + (1-q)v^c, \tag{20}$$

where $q$ is defined as follows,

$$q = \frac{(1-\pi)\delta(1-\delta^T)}{(1-\delta)+(1-\pi)\delta(1-\delta^T)}. \tag{21}$$

The union's expected utility and value functions have parallel definitions; it is sufficient to replace $V$ with $U$ and $v$ with $u$ in the above formulas to find $U$. *Q.E.D.*

**Incentives Constraints: Honesty and Guts**.

**Proof of Proposition 5.**

We consider the *on-schedule* deviations of the employer. In the good state, the employer should have no incentive to act as if the state was bad. In other words, the employer should be "honest". This imposes,

$$V_1 \geq (1-\delta)\widetilde{v}^c_1 + \delta(1-\delta^T)\widehat{v} + \delta^{T+1}V, \tag{$IC_1$}$$

where by definition, $\widetilde{v}^c_1$ is the one-shot payoff of playing $(w^c_{\overline{\theta}}, x^c_{\overline{\theta}})$ when $\theta = 1$. A punishment phase starts immediately after this deviation. Using expression (11), constraint $IC_1$ can be rewritten,

$$\delta(1-\delta^T)\,(V-\widehat{v}) \geq (1-\delta)(\widetilde{v}_1^c - v_1^c).$$

It is easy to check, using definitions, that $v_1^c = v_0 - 1 - b$ and $\widetilde{v}_1^c = v_0 - 1$. Hence, $b = \widetilde{v}_1^c - v_1^c$. Substituting the expression for $V$, as given by Proposition 4, and rearranging terms, we easily derive the following equivalent form of $IC_1$,

$$(v^c - \widehat{v})Q \geq b. \tag{$IC_1$}$$

where, to simplify notation, we denote,

$$Q = \frac{q}{1-\pi}. \tag{22}$$

The employer must also prefer to pay a low wage instead of concealing the bad news that the cost is high, to avoid the punishment phase. In other words, the employer should have the guts to face conflict. Formally, we must have,

$$V_\theta \geq (1-\delta)\widetilde{v}_{\overline{\theta}}^c + \delta V, \tag{$IC_2$}$$

where $\widetilde{v}_{\overline{\theta}}^c$ is the payoff of playing $(w_1^c, x_1^c)$ when $\theta > 1$. The employer incurs a cost while deviating in this way — because the union receives a high wage, but they avoid the punishment phase.

Using the expression for $V_\theta$, stated in the proof of Proposition 4, it is easy to check that $IC_2$ is equivalent to

$$v_{\overline{\theta}}^c - \widetilde{v}_{\overline{\theta}}^c \geq (v^c - \widehat{v})\frac{q}{1-\pi}.$$

It is easy to check, using definitions, that $v_{\overline{\theta}}^c = v_0 - \overline{\theta}$ and $\widetilde{v}_{\overline{\theta}}^c = v_0 - \overline{\theta}(1+b)$. Hence, $\widetilde{v}_{\overline{\theta}}^c - v_{\overline{\theta}}^c = \overline{\theta}b$. It follows that we can rewrite $IC_2$ as follows,

$$\overline{\theta}b \geq (v^c - \widehat{v})Q. \tag{$IC_2$}$$

This proves the result. *Q.E.D.*

**Proposition 6.**

*Under Assumptions 1-4, for all* $\delta$ in $(0,1)$ *and* $T \geq 1$, *there exists a threshold* $\overline{\theta}_0$, *defined as*

$$\overline{\theta}_0 = 1 + \frac{1}{\pi q}, \tag{23}$$

*and an upper bound on strike activity $s_0 > 0$, such that, for all $\overline{\theta} > \overline{\theta}_0$ and $\widehat{s} < s_0$, the values of the bonus $b$ picked in the nonempty interval $(b^{\min}, b^{\max})$ simultaneously satisfy the constraints $IC_1$, $IC_2$ and $IR$. In addition, we have,*

$$b^{\min} = \max\left\{\frac{QA}{\overline{\theta}+\pi Q}, \frac{(\widehat{w}-1)}{\pi}\right\},$$
$$b^{\max} = \min\left\{\frac{QA}{1+\pi Q}, \frac{\mu(\widehat{w}-1)}{\pi}\right\},$$

where $A = \widehat{s}v_0 + \mu\widehat{w}(1-\widehat{s}) - \mu$, $Q = q/(1-\pi)$ and $\mu = E(\theta)$.

**Proof of Proposition 6**.

In the proof of Proposition 5, it was shown that the incentive constraints $IC_1$ and $IC_2$, for "honesty" and "guts", respectively, can be rewritten as

$$v^c_{\overline{\theta}} - \widetilde{v}^c_{\overline{\theta}} \geq (v^c - \widehat{v})Q \geq \widetilde{v}^c_1 - v^c_1. \qquad (IC_{12})$$

where $Q = q/(1-\pi)$. Using the expressions for $\widehat{v}$, $v^c$, $\widetilde{v}^c_1$, $v^c_1$, $v^c_{\overline{\theta}}$ and $\widetilde{v}^c_{\overline{\theta}}$, and the definition of the bonus paid in the good state, $b = w^c_1 - 1$, we easily find that $IC_{12}$ is equivalent to $b \leq [A - \pi b]Q \leq \overline{\theta}b$, where by definition, $A = \widehat{s}v_0 + \mu\widehat{w}(1-\widehat{s}) - \mu$, and $\mu = E(\theta)$. We have $v^c - \widehat{v} = A - \pi b$. In addition, given that $\widehat{w} > 1$, and $\widehat{v} = v_0 - \mu\widehat{w} > 0$, it is easy to see that $A > 0$. The constraints $IC_{12}$ can finally be rearranged. $IC_1$ and $IC_2$ are equivalent to the following string of inequalities,

$$\frac{QA}{\overline{\theta}+\pi Q} \leq b \leq \frac{QA}{1+\pi Q}. \qquad (IC_{12})$$

To complete the proof, set $\widehat{s} = 0$. This implies $A = \mu(\widehat{w}-1)$. The analytical expressions for the terms $u^c$, $\widehat{u}$, $v^c$ and $\widehat{v}$ can easily be computed, and we find that $IR$ constraints are satisfied if the following holds

$$\frac{(\widehat{w}-1)}{\pi} < b < \frac{\mu(\widehat{w}-1)}{\pi}. \qquad (IR')$$

Since $\mu > 1$, $IR'$ is a nonempty interval for $b$. It is easy to check that if $\widehat{s} > 0$, $IR$ holds if $IR'$ holds.

It is easy to check that the interior of the intersection of the $IR'$ and $IC_{12}$ intervals, if nonempty, is the interval $(b^{\min}, b^{\max})$, defined as follows,

$$b^{\min} = (\widehat{w}-1)\max\left\{\frac{Q\mu}{\overline{\theta}+\pi Q}, \frac{1}{\pi}\right\};$$

$$b^{\max} = \mu(\widehat{w} - 1) \min \left\{ \frac{Q}{1 + \pi Q}, \frac{1}{\pi} \right\}.$$

Since $Q/(1 + \pi Q) < 1/\pi$, we trivially have,

$$b^{\max} = \frac{Q}{1 + \pi Q}(\widehat{w} - 1)\mu.$$

We now show that $Q\mu/(\overline{\theta} + \pi Q) < 1/\pi$ or equivalently, $\pi(\mu - 1)Q < \overline{\theta}$. Since $\mu - 1 = (1 - \pi)(\overline{\theta} - 1)$, we must in fact check that $\pi(1 - \pi)(\overline{\theta} - 1)Q < \overline{\theta}$, or equivalently, ensure that $(\overline{\theta} - 1)\pi q < \overline{\theta}$. But this is always true, since $q < 1$, $\pi < 1$. Thus, if $\widehat{s} = 0$, we have

$$b^{\min} = \frac{(\widehat{w} - 1)}{\pi}.$$

The interval $(b^{\min}, b^{\max})$ is nonempty if and only if $b^{\min} < b^{\max}$, that is, iff, $1 < (\mu - 1)\pi Q$, or equivalently,

$$1 < (\overline{\theta} - 1)\pi q,$$

since $\mu - 1 = (1 - \pi)(\overline{\theta} - 1)$ and $q = (1 - \pi)Q$. This is true if

$$\overline{\theta} > \overline{\theta}_0 = 1 + \frac{1}{\pi q}.$$

To finish the proof, we use continuity to show that the interval $(b^{\min}, b^{\max})$ must remain nonempty for small but positive $\widehat{s}$.

Remark that, using l'Hôpital's rule, we obtain

$$\lim_{\delta \to 1} Q = \frac{T}{1 + T(1 - \pi)}, \qquad \lim_{\delta \to 1} \left( \frac{Q}{1 + \pi Q} \right) = \frac{T}{1 + T},$$

and

$$\lim_{T \to +\infty} Q = \frac{\delta}{1 - \delta\pi}, \qquad \lim_{T \to +\infty} \left( \frac{Q}{1 + \pi Q} \right) = \delta.$$

The ratios $Q/(1 + \pi Q)$ and $Q/(\overline{\theta} + \pi Q)$ remain bounded when $T$ grows arbitrarily large and when $\delta \to 1$. Now, if $b$ is chosen in the open interval $(b^{\min}, b^{\max})$, by continuity, we can choose a sufficiently small $\widehat{s} > 0$ and still satisfy $IC_{12}$ and $IR$. This shows that if $\overline{\theta} > \overline{\theta}_0$, there exists a pair $(\widehat{s}, \widehat{w})$, with $\widehat{s} > 0$ and $\widehat{w} > 1$, such that $IC_{12}$ and $IR$ simultaneously hold. *Q.E.D.*

A formal statement of Proposition 7 is as follows.

**Proposition 7**. *There exists threshold values $\delta_0 < 1$ and $T_0 > 0$, such that for all $\delta > \delta_0$ and all $T^* > \max(T_0, T)$, the off-schedule deviations of both players are not profitable.*

The rigorous proof of Proposition 7 is long, but it is routine work to show that *off-schedule* deviations can be deterred by sufficiently long reversions to $\sigma^*$. We skip this proof here (details are available upon request).

**Formal statements and proofs of the Theorems**.

**Theorem 1**. *Under Assumptions 1-5, let $\widehat{w}$ belong to the nonempty interval $u^* + 1 < \widehat{w} < (v_0 - v^*)/\mu$. Then, for any length of the on-schedule punishment spell $T \geq 1$, there exist thresholds $\delta_0 < 1$, $\beta_0 > 0$, $\overline{\theta}_0 > 1$, $s_0 > 0$, an integer $T_0 > 0$ and a nonempty interval $[b^{\min}, b^{\max}]$ (defined above) with the property that, for all $(\delta, \beta, \overline{\theta}, T^*, \widehat{s}, b)$ such that*

$$
\begin{aligned}
\delta_0 \ < \ \delta \ < \ 1, & \quad \textit{players are sufficiently patient,} \\
\beta \ > \ \beta_0, & \quad \textit{outsourcing is costly enough,} \\
\overline{\theta} \ > \ \overline{\theta}_0, & \quad \textit{the cost of funds is high enough in the bad state,} \\
T^* \ > \ T_0, & \quad \textit{the specific punishment of off-schedule deviations is long enough,} \\
\widehat{s} \ < \ s_0, & \quad \textit{the chosen level of striking activity is not too high during punishment spells,} \\
b^{\min} \ < \ b \ < \ b^{\max}, & \quad \textit{and the bonus is chosen in the appropriate interval,}
\end{aligned}
$$

*the equilibrium candidate $\widetilde{\sigma}$ (defined above) is a Perfect Public Equilibrium of $G(\delta)$.*

The proof of Theorem 1 is an immediate consequence of Propositions 1-7 above, combined with the *one-deviation property* (see Mailath and Samuelson (2006)).

**Theorem 2**. *In the definition of the equilibrium candidate $\widetilde{\sigma}$, replace everywhere $\widehat{\sigma} = (\widehat{e}, \widehat{s}, \widehat{w}, \widehat{x})$ with $\sigma^* = (e^*, s^*, w^*, x^*)$. Then, under Assumptions 1-5, for all $T \geq 1$, there exist real numbers $\delta_0 < 1$, $\beta_0 > 0$, $\underline{e}_0 < 1$, an integer $T_0 > 0$ and a nonempty interval $(b^{\min}, b^{\max})$*

*with the property that, for all* $(\delta, \beta, \underline{e}, T^*, b)$ such that

$$\begin{aligned} \delta_0 &< \delta < 1, \quad \textit{players are sufficiently patient,} \\ \beta &> \beta_0, \quad \textit{outsourcing is costly enough,} \\ \underline{e}_0 &< \underline{e} < 1, \quad \textit{the lowest effort is costly enough,} \\ T^* &> T_0, \quad \textit{the specific punishment of off-schedule deviations is long enough,} \\ b^{\min} &< b < b^{\max}, \quad \textit{and the bonus is chosen in the appropriate interval,} \end{aligned}$$

*the equilibrium candidate* $\widetilde{\sigma}$ *is a Perfect Public Equilibrium of* $G(\delta)$.

**Proof of Theorem 2**.

The proof of Proposition 2 is easy if we use $u^*$ and $v^*$ instead of $\widehat{u}$ and $\widehat{v}$ in the definition of the value functions $U$ and $V$. We can write all incentive constraints in a parallel way, as in the derivation of Propositions 5-6. It is then easy to check that the honesty-and-guts constraints $IC_1$ and $IC_2$ can be written,

$$\frac{QA^*}{\overline{\theta} + \pi Q} \leq b \leq \frac{QA^*}{1 + \pi Q}, \tag{$IC_{12}$}$$

where, $A^* = \mu[\overline{h}(1 - x_1^*) + C(x_1^*) - 1]$. It is easy to check that $A^* > 0$ since $\overline{h} > 1$. In addition, we must have $u^c > u^*$ and $v^c > v^*$, that is, after some rearrangement of terms,

$$u^* = (1 - \underline{e})\overline{h}(1 - x_1^*) < \pi b < A^*. \tag{$IR$}$$

We then find that the bonus $b$ should be chosen in the open interval $(b^{\min}, b^{\max})$, with,

$$b^{\min} = \max\left\{\frac{u^*}{\pi}, \frac{QA^*}{\overline{\theta} + \pi Q}\right\}, \qquad \text{and} \qquad b^{\max} = \min\left\{\frac{A^*}{\pi}, \frac{QA^*}{1 + \pi Q}\right\}.$$

If $\underline{e}$ is sufficiently close to 1, then $b^{\min} = QA^*/(\overline{\theta} + \pi Q)$. It is easy to see that $b^{\max} = QA^*/(1 + \pi Q)$ since $\overline{\theta} > 1$. Thus, $b^{\min} < b^{\max}$ : the interval is nonempty.

*Q.E.D.*

**Proof of Proposition 8**.

Most of the results in the statement of Proposition 8 are obtained by straightforward calculus. If we now treat $T$ as a real number, we find

$$\frac{\partial Q}{\partial T} = -\frac{\delta^{T+1} \ln(\delta)}{[(1 - \delta) + (1 - \pi)\delta(1 - \delta^T)]^2} > 0.$$

It easily follows from this that $\partial q/\partial T > 0$ and $\partial R/\partial T < 0$. The optimal value of $T$ is therefore the smallest value compatible with $IC_{12}$ and $IR$. Let $\eta = v^c - \widehat{v}$. Easy algebra shows that the binding $IC_1$ constraint, *i.e.*, equation $Q\eta = b$, can be rewritten in the form $\delta^T = H$, where

$$H = \frac{\delta\eta - b(1 - \delta\pi)}{\delta\eta - b(\delta - \delta\pi)}.$$

It follows that the real solution of $Q(\delta, \pi, \widetilde{T})\eta = b$, denoted $\widetilde{T}$, is well-defined if $0 < H < 1$. It is easy to check that $H < 1$ if $\delta < 1$. We have $H > 0$ iff $\delta\eta - b(1-\delta\pi) > 0$, or equivalently, iff

$$\frac{\delta}{1 - \delta\pi}\eta > b.$$

But

$$\lim_{T\to\infty} Q = \frac{\delta}{1 - \delta\pi}.$$

It then follows that the above strict inequality is true, since $\eta = v^c - \widehat{v} > 0$, since $Q$ is a increasing function of $T$ and since $IC_1$ holds by definition. Hence, $H > 0$. It follows that we can write,

$$\widetilde{T} = \frac{\ln(H)}{\ln(\delta)} > 0.$$

Easy computations show that,

$$v^c = v_0 - E\theta - \pi b; \quad \text{and} \quad \widehat{v} = (1 - \widehat{s})(v_0 - \widehat{w}E\theta).$$

Thus,

$$\eta = \widehat{s}v_0 + [(1 - \widehat{s})\widehat{w} - 1]E\theta - \pi b, \quad \text{where} \quad E\theta = (1 - \pi)\overline{\theta} + \pi.$$

This easily yields the following partial derivatives,

$$\frac{\partial\eta}{\partial v_0} = \widehat{s}; \qquad \frac{\partial\eta}{\partial\widehat{s}} = v_0 - \widehat{w}E\theta; \qquad \frac{\partial\eta}{\partial\widehat{w}} = (1 - \widehat{s})E\theta; \qquad \frac{\partial\eta}{\partial b} = -\pi. \tag{24}$$

we have

Straightforward calculus now yields,

$$\frac{\partial\widetilde{T}}{\partial\eta} = \frac{(1 - \delta)b}{\ln(\delta)\delta H[\eta - b(1 - \pi)]^2} < 0.$$

After some computations, applying the chain rule, we also obtain,

$$\frac{d\widetilde{T}}{db} = \frac{\partial \widetilde{T}}{\partial \eta}\frac{\partial \eta}{\partial b} + \frac{1}{\ln(\delta)H}\frac{\partial H}{\partial b} = \frac{-(1-\delta)(\eta + b\pi)}{\ln(\delta)[\delta\eta - b(1-\delta\pi)][\eta - b(1-\pi)]} > 0;$$

$$\frac{\partial \widetilde{T}}{\partial \widehat{s}} = (v_0 - \widehat{w}E\theta)\frac{\partial \widetilde{T}}{\partial \eta} < 0.$$

$$\frac{\partial \widetilde{T}}{\partial v_0} = \widehat{s}\frac{\partial \widetilde{T}}{\partial \eta} < 0.$$

$$\frac{\partial \widetilde{T}}{\partial \widehat{w}} = (1-\widehat{s})E\theta\frac{\partial \widetilde{T}}{\partial \eta} < 0.$$

The minimal admissible value of $\eta$ is $b(1-\delta\pi)/\delta$. When $\eta$ approaches this minimal value, $\widetilde{T} \to +\infty$. Hence, when $\widehat{s}$ becomes so small that $\eta$ approaches its minimal value, then $\widetilde{T}$ tends toward infinity.

Finally, it can be checked that $\widetilde{T}$ is a decreasing function of $\delta$ and that $\widetilde{T}$ approaches a finite limit as $\delta \to 1$, namely,

$$\frac{\partial \widetilde{T}}{\partial \delta} < 0, \qquad \text{and} \qquad \lim_{\delta \to 1} \widetilde{T} = \frac{b}{\eta - b(1-\pi)}.$$

*Q.E.D.*

**Proof of Proposition 9**.

Given the length of punishment phases, and the probability of bad states $(1-\pi)$, we can express the probability of non-cooperation in period $t$ as follows:

$$1 - \Pr(\text{cooperation at } t) = \sum_{\tau=1}^{T}(1-\pi)\Pr(\text{cooperation at } t-\tau),$$

because the agents do not cooperate in period $t$ if a punishment phase has started $\tau$ periods before, with $\tau \leq T$. In equilibrium, a punishment phase starts if the players were cooperating in $t-\tau$ and if a bad state has been drawn (with probability $1-\pi$). Given the stationary nature of the model,

$$\Pr(\text{cooperation at } t) = \Pr(\text{cooperation at } t-\tau) = 1 - q^*.$$

From this, we immediately derive, $q^* = (1-\pi)(1-q^*)T$, that is,

$$q^* = \frac{(1-\pi)T}{1+(1-\pi)T}.$$

*Q.E.D.*

# 9 References


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**Fig . 1. Number of working days lost due to strikes**

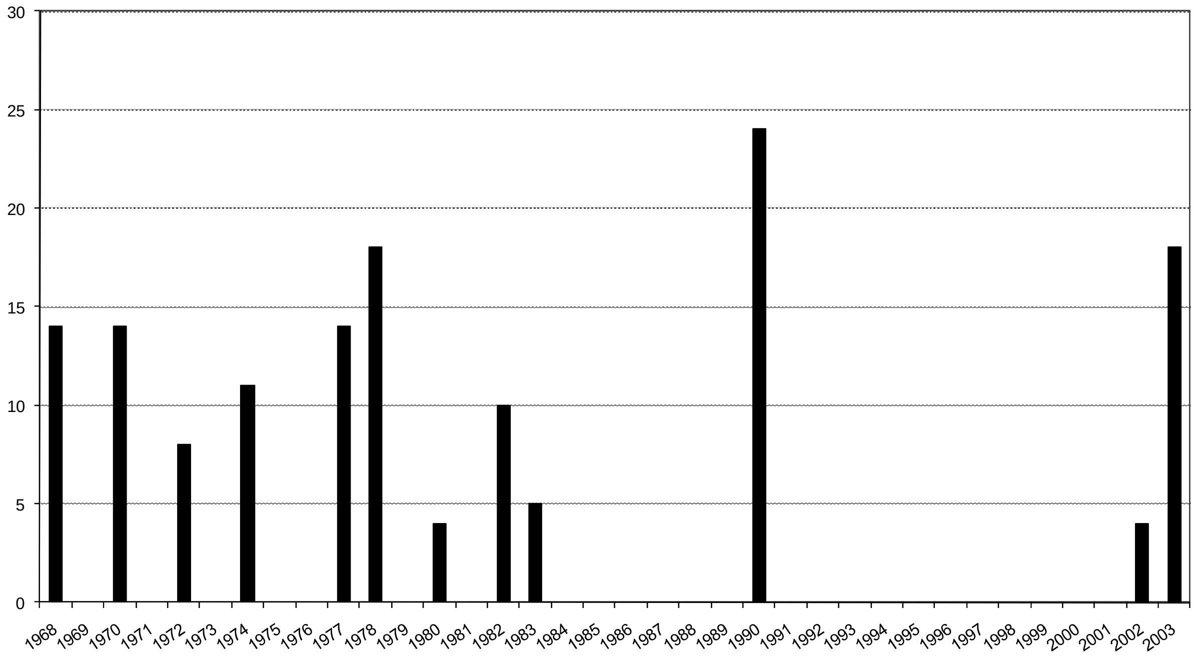
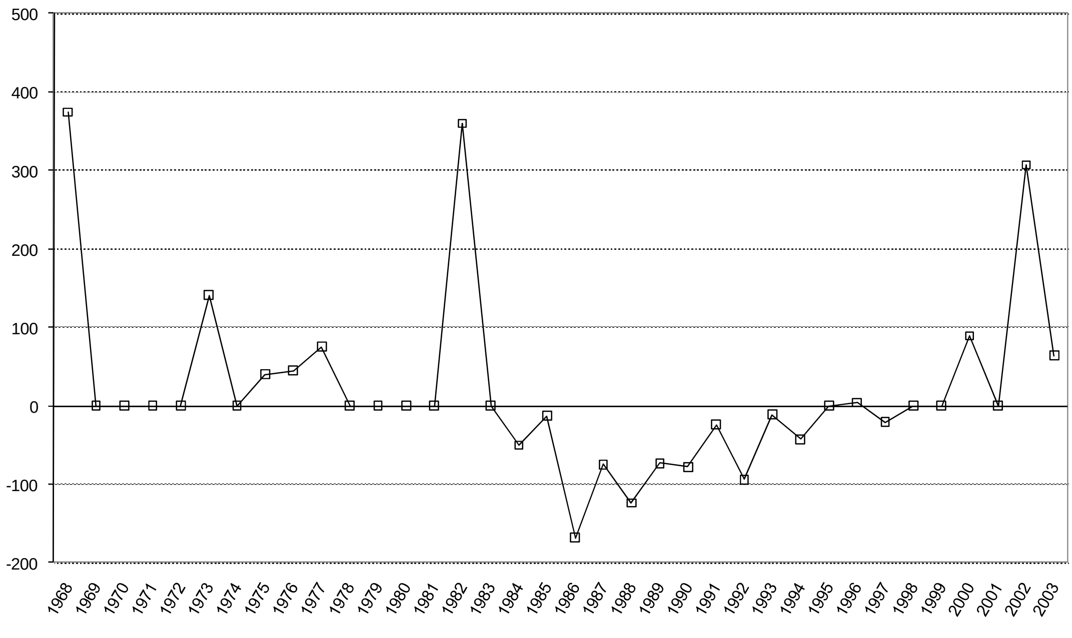



**Fig 2. Change in the number of dustmen with civil servant status**



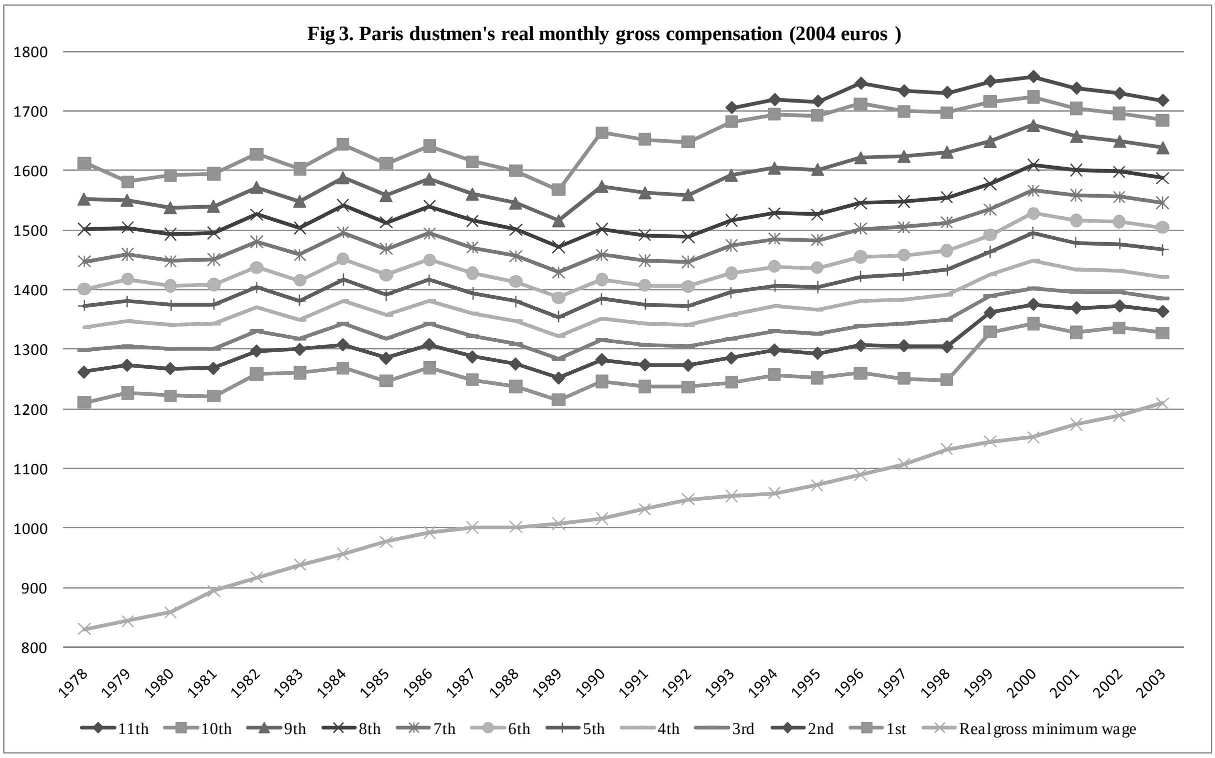


Fig 3. Paris dustmen's real monthly gross compensation (2004 euros )
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003
11th 10th 9th 8th 7th 6th 5th 4th 3rd 2nd 1st Real gross minimum wage

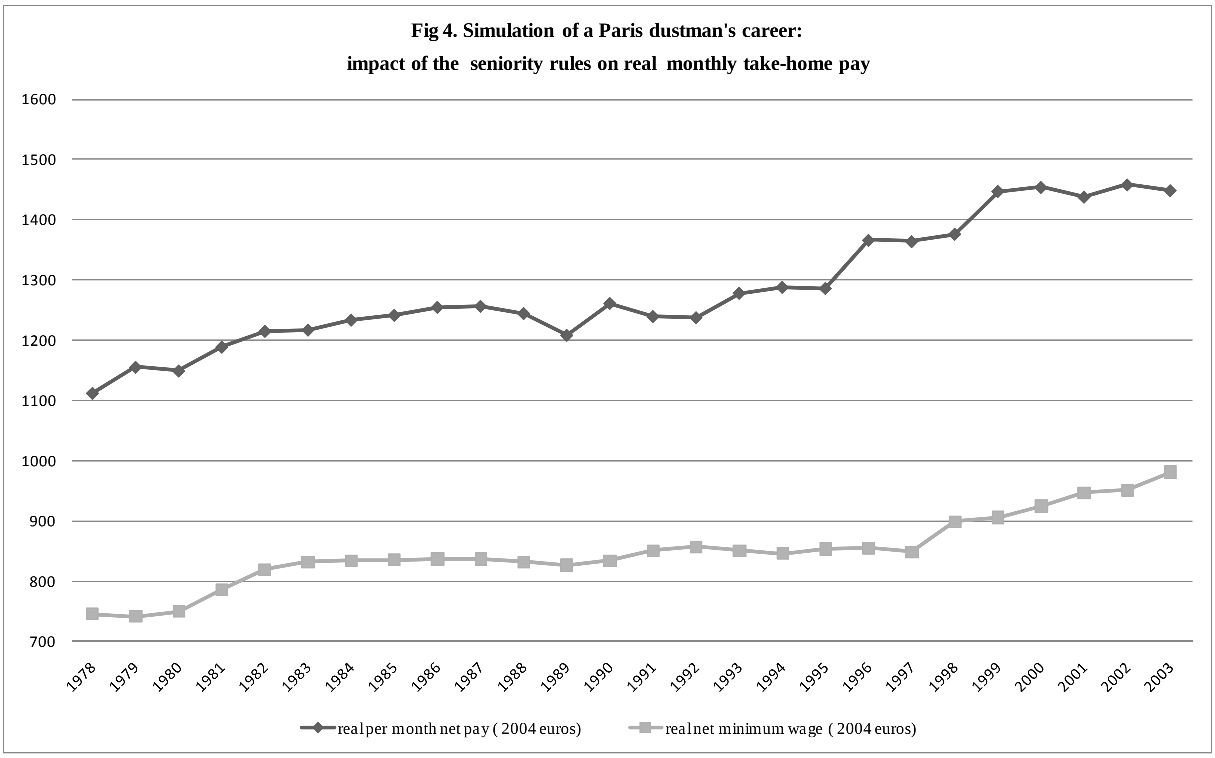


Fig 4. Simulation of a Paris dustman's career:
impact of the seniority rules on real monthly take-home pay
1600
1500
1400
1300
1200
1100
1000
900
800
700
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
real per month net pay ( 2004 euros)
real net minimum wage ( 2004 euros)

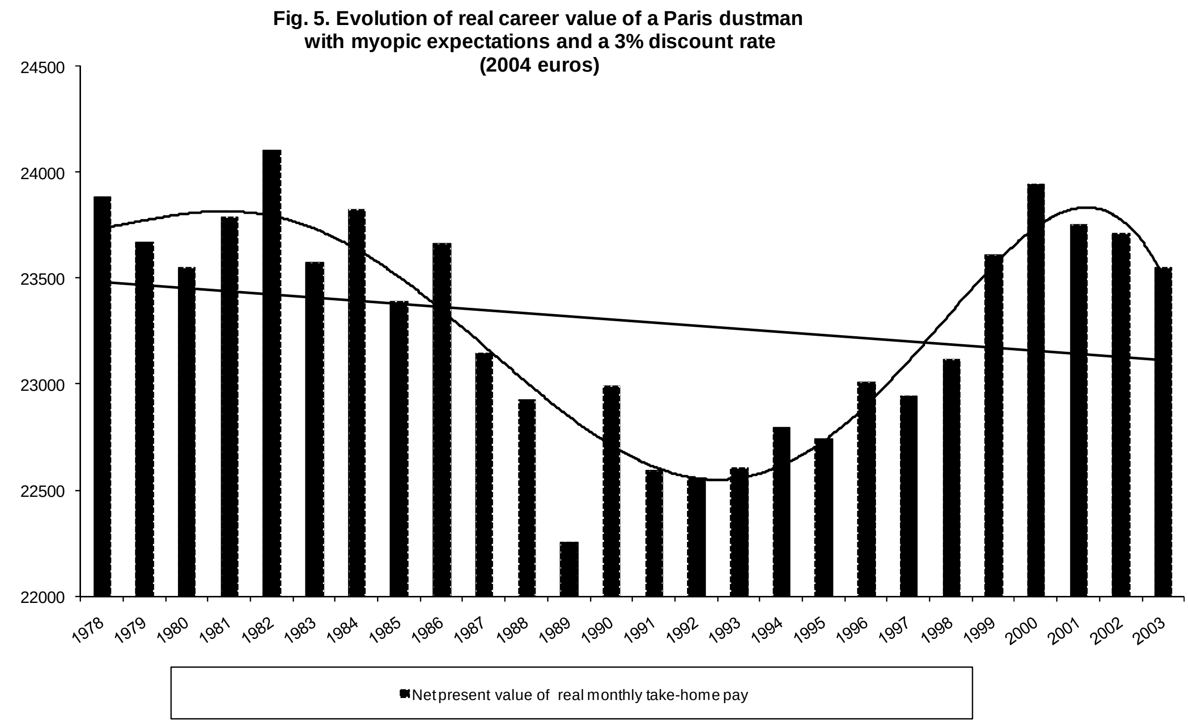


Fig. 5. Evolution of real career value of a Paris dustman
with myopic expectations and a 3% discount rate
(2004 euros)
24500
24000
23500
23000
22500
22000
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Net present value of real monthly take-home pay

Table 1. OLS regressions of career value and days lost due to strikes

| Dependent variable: | Career Value $V_t$ | Change in Value $\Delta V_t$ | Value Increases $\Delta V_t^+$ | Value Increases $\Delta V_t^+$ | Days lost to strikes $S_t$ | Days lost to strikes $S_t$ |
|---|---|---|---|---|---|---|
| constant | 22137.68*** | -69.11 | 85.34** | 76.10** | 1.127 | |
| | (111.68) | (70.16) | (37.59) | (36.50) | (1.37) | |
| Days lost to strikes $S_t$ | 17.81 | 22.34* | 14.59** | 18.03* | | |
| | (15.31) | (11.35) | (5.78) | (5.90) | | |
| Value drops lagged $\Delta V^-_{t-1}$ | | | | | -0.012** | -0.015*** |
| | | | | | (0.0058) | (0.0048) |
| Change in workforce $\Delta N_{t-1}$ | | -0.772 | | -0.544* | 0.023** | 0.024** |
| | | (0.61) | | (0.31) | (0.010) | (0.0102) |
| $R^2$ | 0.053 | 0.163 | 0.217 | 0.309 | 0.266 | |

Results have been obtained by OLS. Standard errors are in parentheses. Stars indicate significance at the 1% (***), 5% (**) and 10% (*) levels.