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ABSTRACT

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Profit Sharing and Strike Activity in Cournot Oligopoly

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Within an incomplete-information framework, we develop a model of wage determination in a unionized Cournot oligopoly. The assumption of incomplete information allows the possibility of strikes or lockouts, which waste industry potential resources, at equilibrium. Facing such deadweight loss, the government or the social planner may decide to adopt a policy, such as a profit-sharing scheme. Under two different bargaining structures (firm level vs. industry level), we investigate the effects of adopting profit sharing on the wage outcome and the strike activity. If the base-wage bargaining takes place at the industry level, then the introduction of a profit-sharing scheme increases the strike activity. But if the base-wage bargaining takes place at the firm level and the number of firms in the industry is greater than two, then the introduction of a profit-sharing scheme reduces the strike activity.

Keywords: Cournot oligopoly, wage bargaining, profit sharing, incomplete information, strike activity.

JEL classification: C78, J50.

1 Introduction

Wage bargaining is unquestionably the main feature of collective-bargaining contracts, but contracts also deal with issues related to the employment level or other forms of pay like workers' participation schemes. Theoretically, Weitzman (1985) has stressed the impact of profit-sharing schemes on the unemployment level, in the framework of macroeconomic models of an imperfectly competitive economy. He has shown that a profit-sharing system can increase the employment level if it lowers the base wage. But Weitzman's argumentation has been challenged on two points: (i) the problem of the implementation of profit-sharing schemes at the firm level (see Wadhwani, 1988), (ii) there is little empirical evidence that by introducing profit-sharing schemes firms are able to reduce the base wage and to increase the employment

Table 1: Profit sharing in France

	1986	1987	1988	1989	1990
No. of agreements in force	2160	2630	4600	7000	10700
No. of workers involved ($\times 10^3$)	590	730	980	1390	2000
% workers involved	4	5	7	10	14

Agriculture and public administration excluded. Source: Bloch (1992).

level (see Bhargava and Jenkinson, 1995; Cahuc and Dormont, 1992, 1997).

However, Weitzman's argumentation as well as the problem of its implementation have been analyzed assuming monopolistic competition on the product market. But other market structures, such as oligopolistic industries, also deserve some attention. Once we take into account the interdependence of firms in a unionized Cournot oligopoly, a profit-sharing scheme may be a strategic commitment, which permits a firm to increase its market share, its profits, and its workers' pay (see Bensaïd et al., 1990; Bensaïd and Gary-Bobo, 1991; Fung, 1989; Stewart, 1989).

During the eighties profit-sharing schemes became a major alternative form of compensation in the UK and even more so in France, with the government promoting profit sharing through tax incentives. In the UK, there were 145 profit-sharing agreements in 1987 and 2049 in 1991. During the same period the number of workers involved in profit-sharing agreements increased from 26,411 to 581,000 (see Bhargava and Jenkinson, 1995). In France, profit-sharing schemes have been multiplying quite substantially (see Table 1). In 1986, there were 2,160 profit-sharing agreements and 10,700 in 1990. In 1986, 590,000 workers were involved in profit-sharing schemes, and 2,000,000 in 1990.

However, empirical studies based on British or French data[1] suggest that the base wage does not decrease or even rises after the introduction of profit sharing (see Bhargava and Jenkinson, 1995, for the UK; Cahuc and Dormont, 1992, 1997, for France). In France, it is forbidden to substitute the profit share for the base wage. Also, empirical investigations made by Cahuc and Dormont (1992, 1997) seem to confirm that this prohibition is respected. But this add-on nature of profit sharing is inconsistent with Weitzman's line of argument. Therefore, other

1 Cahuc and Dormont's (1992, 1997) empirical studies are based on a French panel data consisting of manufacturing firms observed over the period 1986–1989, while Bhargava and Jenkinson's (1995) study is based on a comprehensive data set of UK companies that introduced profit-sharing schemes during the period 1978–1989.

motives for the introduction of profit sharing and its growth have to be advanced.

A first motive is that the introduction of profit sharing may increase worker productivity and firm profitability. For the French manufacturing industry, Cahuc and Dormont (1992) have observed a positive correlation between profit-sharing systems and firms' economic results in terms of productivity and growth. This is not too surprising since one main objective of the French legislation was to stimulate the productivity and competitivity of the manufacturing industry. Thereafter, Cahuc and Dormont (1997) studied the causality between profit sharing and productivity: the huge increase in profit-sharing agreements seems to improve the productivity of the French manufacturing industry. Bhargava and Jenkinson (1995) observed similar results for the UK (manufacturing, construction, and retailing sectors) during the eighties.

All these previous studies, empirical or theoretical, have considered complete-information frameworks. But once we consider incomplete-information bargaining models, a second motive why profit sharing is introduced may be put forward: profit sharing may reduce the strike activities like strikes and lockouts. Bargaining is interpreted as a process of exchange of offers and counteroffers necessitated by opposite preferences and by initial differences in information known to the negotiators separately. The assumption of incomplete information allows the possibility of strikes and lockouts, which waste industry resources, at equilibrium. Facing such deadweight loss of wasting resources, the government or the social planner may decide to adopt a policy. Is profit sharing an accurate policy for reducing the strike activity?

In France, wage negotiations are mainly conducted at the firm level. Since the mid-eighties, we have observed a huge increase of profit-sharing agreements in the French manufacturing industry, associated with a sharp decrease in the number of strikes and workdays not worked. In 1986, there were 1,041,400 workdays not worked and 693,700 in 1990 (see Tables 1 and 2). Similar facts have been observed for the UK (in 1987, there were 3,546,000 workdays not worked and 761,000 in 1991). All these stylized facts support the study of the impact of profit sharing on the relationship between the bargaining structure, the wage outcome, and the strike activity. So, we slightly modify our question as follows. Is profit sharing an accurate policy for reducing the strike activity whatever the bargaining structure?

This paper is a first attempt to give a theoretical answer to this question. Within an incomplete-information framework, we develop a model of wage determination with profit sharing in a unionized Cournot oligopoly. We impose the following game structure. First, given a profit-sharing parameter fixed statutorily by the government, unions and

Table 2: Strikes and lockouts in France

	1986	1987	1988	1989	1990	1991	1992
Localized strikes[a]							
no. of strikes	1391	1391	1852	1743	1529	1318	1330
av. no. of workers ($\times 10^3$)[b]	21,8	18,6	27,2	20,3	18,5	18,8	16,3
no. of lost workdays ($\times 10^3$)	567,6	511,5	1094,0	800,2	528,0	497,3	359,1
Generalized strikes[c]							
no. of strikes	78	66	46	38	29	12	15
av. no. of workers ($\times 10^3$)	194,4	135,3	76,8	54,9	55,8	183,0	123,1
no. of lost workdays ($\times 10^3$)	473,8	457,5	147,6	104,1	165,7	168,2	131,3
Total							
no. of strikes	1469	1457	1898	1781	1558	1330	1345
no. of lost workdays ($\times 10^3$)	1041,4	969,0	1241,6	904,1	693,7	665,5	490,4

Agriculture and public administration excluded. Source: *ILO Yearbook 1995.*
[a] Call to strike concerns only one establishment
[b] Monthly average of workers involved in strikes in progress each month
[c] Call to strike extends to several enterprises

firms negotiate over the base-wage level according to institutional features (industry-level vs. firm-level bargaining). Secondly, firms compete à la Cournot on the product market. We adopt Rubinstein's (1982) alternating-offer bargaining model with two-sided incomplete information about the negotiators' impatience, for describing the base wage bargaining process. In Vannetelbosch (1997), the same model is studied, but without profit sharing. We have shown that firm-level wage outcome is not necessarily lower than industry-level wage outcome, while the strike activity is larger when bargaining takes place at the industry level.

In this paper, we go beyond the analysis offered in Vannetelbosch (1997) by investigating, for two different bargaining structures, how profit sharing as well as private information affects the base wage, the level of employment, and the strike activity. The main results of the paper are as follows. First, if the base-wage bargaining takes place at the industry level, then the introduction of a profit-sharing scheme increases the strike activity. But if the base-wage bargaining takes place at the firm level and the number of firms in the industry is greater than two, then the introduction of a profit-sharing scheme reduces the strike activity. The intuition behind these two results has to do with the internalization of the wage-spillover effects. Under profit sharing, the incentives to lower wages in order to gain a larger share of the product market are reinforced when the negotiation takes place at the firm level. Therefore, the introduction of profit sharing reduces the scope for strikes and lockouts if there is enough competition. But, once the negotiation is at the industry level, the wage-spillover effects are internalized. In this case, the introduction of profit sharing makes the wage objective of the union less obvious. Now, part of the union's payoff comes from the firm's profits. Hence, the union has more opportunities to hide its type, which is private information, in order to reach a more favorable agreement. Therefore, longer strikes and lockouts may be needed to screen the private informations. French experience seems to corroborate the model developed in the paper as well as an incomplete-information framework for investigating wage negotiations with profit sharing (see Tables 1 and 2).

Secondly, Vannetelbosch (1997) has shown that the introduction of incomplete information, in the absence of profit sharing, will not necessarily imply that the firm-level wage is lower than the industry-level wage. This result is still valid under profit sharing. Thirdly, without profit sharing, Vannetelbosch (1997) has shown that the strike activity is larger if the wage bargaining takes place at the industry level rather than at the firm level. Introducing a profit-sharing system increases the disparity, in terms of strike activity, of both bargaining structures.

The paper is organized as follows. In Sect. 2, the model is presented. The Cournot game in the oligopolistic market is solved assuming that the base wages have already been determined. Section 3 describes the base-wage-bargaining game and solves this game for the industry-level-bargaining system. It also analyzes the relationship between the industry-level-bargaining structure, the profit-sharing system, and the strike activity. Section 4 is devoted to the base-wage-bargaining game for the firm-level-bargaining system and analyzes the relationship between the firm-level-bargaining structure, the profit-sharing system, and the strike activity. Finally, Sect. 5 concludes.

2 Description of the Oligopolistic Market

We consider a market for a homogeneous commodity produced by $N \geq 2$ identical profit-maximizing firms, denoted $n = 1, \ldots, N$. Let q_n denote the quantities of the commodity produced by firm n. Let $P(Q) = a - Q$ be the market-clearing price when aggregate quantity on the market is $Q \equiv \sum_{n=1}^{N} q_n$. More precisely,

$$P(Q) = \begin{cases} a - Q & \text{if } Q < a, \\ 0 & \text{if } Q \geq a, \end{cases} \tag{1}$$

with $a > 0$. We assume that the firms are producing under constant returns to scale with labor as the sole input, i.e., $q_n = l_n$, where l_n is labor input. The total cost to firm n of producing quantity q_n is $q_n w_n$. The general price level is normalized to unity so that w_n is the real base wage in firm n.

Associated with each firm there is a continuum of identical workers who each supply one unit of labor with no disutility. We denote by $\bar{w}$ the expected real income of a worker who loses his job. It may be interpreted as the unemployment benefit. The total real profit, π_n, in firm n is

$$\pi_n(w_n, l_n, (q_1, \ldots, q_N)) = \begin{cases} (a - \sum_{n=1}^{N} q_n)q_n - l_n w_n & \text{if } \sum_{n=1}^{N} q_n < a, \\ 0 & \text{if } \sum_{n=1}^{N} q_n \geq a. \end{cases} \quad (2)$$

In a profit-sharing scheme, firms promise to pay each worker a base wage and a share of real profits per capita, λ. We consider the following profit-sharing system: the government or social planner fixes at some predetermined value the profit-sharing parameter λ, letting firms and unions negotiate over the base wage. Profit sharing is assumed to be enforceable by law. The owners of the firms are assumed to be risk-neutral. Therefore, the utility level of firm n is given by

$$\Lambda_n(w_n, l_n, (q_1, \ldots, q_N)) = (1 - \lambda) \cdot \pi_n(w_n, l_n, (q_1, \ldots, q_N)) \ , \quad (3)$$

where λ is the share of the profit going to the workers.

In each firm the risk-neutral workers are represented in the base-wage-bargaining process by a utilitarian union. The continuum of workers who supply labor to each firm is normalized to unity. Hence, local union n's utility is given by

$$u_n(w_n, \bar{w}, l_n, (q_1, \ldots, q_N)) = l_n w_n + (1 - l_n)\bar{w} + \lambda \cdot \pi_n(w_n, l_n, (q_1, \ldots, q_N)) \ . \quad (4)$$

Interactions between the product market, the profit-sharing system, and the bargaining level are analyzed according to the following game structure. In stage one, wages are bargained at the firm level or at the industry level. In stage two, Cournot competition occurs: firms simultaneously choose their quantities to produce, which determines their levels of employment, the industry output, and the market-clearing price. The model is solved backwards.

In the last stage of the game, the wage levels have already been determined and the N firms compete by choosing simultaneously their outputs (and, hence, employment) to maximize profits with price adjusting to clear the market. Assuming an interior solution to the Cournot competition game, the unique Nash equilibrium of this stage game yields:

$$Q^*(w_1, \ldots, w_N) = \frac{Na - \sum_{n=1}^{N} w_n}{N+1} \; ; \tag{5}$$

$$q_n^*(w_1, \ldots, w_N) = \frac{a - (N+1)w_n + \sum_{k=1}^{N} w_k}{N+1}, \quad n = 1, \ldots, N \; . \tag{6}$$

The Nash-equilibrium output of a firm (and, hence, equilibrium level of employment) is decreasing with its own wage and the number of firms in the industry, while it is increasing with other firms' wages and total industry demand.

In the first stage of the game, firms and unions negotiate the base-wage level foreseeing perfectly the effect of wages on firms' decisions concerning employment. To investigate the effects of adopting profit sharing on the wage outcome and the strike activity in oligopolistic industries, we consider two bargaining structures: industry-level and firm-level wage settlements.

3 Industry-Level Wage Bargaining

At the industry level, workers are represented by a single union's representative, which we call the central union (CU). The CU's objective function is to maximize the sum of local unions' utilities. The CU negotiates the industry base-wage level with the employers' representative, which we call the central firm (CF). The CF's objective function is to maximize the sum of local firms' profits. A uniform base wage is set by industrial associations for all firms when the negotiation is centralized. These industrial associations (CU and CF) correctly anticipate the effect of wages on subsequent Cournot competition game.

3.1 The Bargaining Problem

There are two bargainers, also called players, CU and CF, who must agree on a base wage w from the set X. X is the set of feasible agreements: $X \equiv \{w \in \mathbf{R} \mid 0 \leq w \leq a\}$. The players either reach an agreement in the set X, or fail to reach agreement, in which case the disagreement event E occurs. The two bargainers have well-defined preferences over $X \cup \{E\}$. The von Neumann–Morgenstern utility of a local firm n for a base-wage agreement w is

$$\Lambda(w, l^*(w)) = (1-\lambda)[l^*(w) \cdot (a - w - Nl^*(w))] , \tag{7}$$

while that of a local union n is the total amount of money received by its members

$$\begin{aligned} u(w, \bar{w}, l^*(w)) = & \; l^*(w) \cdot w + (1 - l^*(w)) \cdot \bar{w} \\ & + \lambda \cdot [l^*(w) \cdot (a - w - Nl^*(w))] . \end{aligned} \tag{8}$$

If the two parties (CU and CF) fail to agree, then a local firm obtains a profit of zero and a local union receives $\bar{w}$, so that CF's and CU's disagreement points are, respectively, zero and $N\bar{w}$. The utility function of a local union is unique only up to a positive affine transformation. For the sake of presentation, we rewrite local union's utility function:

$$u(w, \bar{w}, l^*(w)) = l^*(w) \cdot [w - \bar{w}] + \lambda \cdot [l^*(w) \cdot (a - w - Nl^*(w))] , \tag{9}$$

such that the CU's disagreement point shifts from $N\bar{w}$ to zero. Therefore, the von Neumann–Morgenstern utility of the local union for the agreement w is

$$u(w, \bar{w}) = \frac{a-w}{N+1}(w - \bar{w}) + \lambda\left(\frac{a-w}{N+1}\right)^2 , \tag{10}$$

while that of a local firm is

$$\Lambda(w) = (1-\lambda)\left(\frac{a-w}{N+1}\right)^2 . \tag{11}$$

We assume that there is free disposal, so that the set of possible utility pairs CU–CF that can result from agreement is

$$\begin{aligned} Y \equiv \Bigg\{ \Bigg(& \left[0, N\frac{a-w}{N+1}\left((w - \bar{w}) + \lambda\left(\frac{a-w}{N+1}\right)\right)\right], \\ & \left[0, N(1-\lambda)\left(\frac{a-w}{N+1}\right)^2\right]\Bigg) \;\Bigg|\; w \in X \Bigg\} . \end{aligned}$$

This bargaining set Y is depicted in Fig. 1. It can be easily verified that it is a compact convex set, which contains the disagreement point $d = (0, 0)$ in its interior. Thus $\langle Y, d \rangle$ is a bargaining problem.

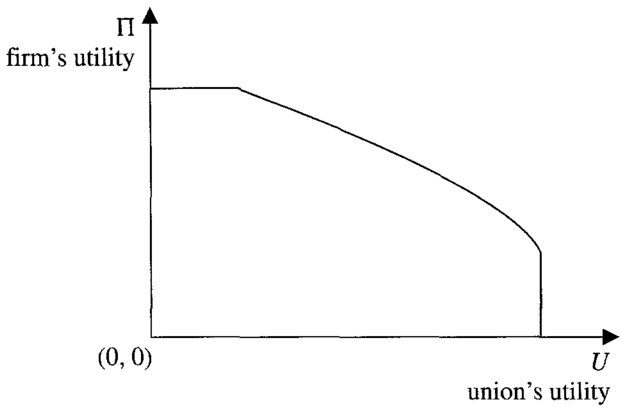

Fig. 1: The bargaining set

3.2 How Do the Agents Reach an Agreement

The negotiation is modeled as a noncooperative-bargaining game. The bargaining process is described by Rubinstein's (1982) alternating-offer bargaining model. The bargaining procedure is as follows. The bargainers can take actions only at periods in the infinite set $T \equiv \{1, 2, \ldots\}$. These bargainers make alternatively base-wage offers, with CU making offers in odd-numbered periods and CF making offers in even-numbered periods. The bargaining game starts in period 1 with CU proposing an agreement (an element of X). At period 2, CF either accepts the offer or proposes a counteroffer. The game ends when one of the bargainers accepts the opponent's previous offer. No limit is placed on the time that may be expended in bargaining: perpetual disagreement is a possible outcome of the game. An outcome in which agreement on w is reached at period t is denoted by (w, t).

It is assumed that CU is on strike in every period until an agreement is reached. Both players are assumed to be impatient. They have time preferences with constant discount factors. The subscripts "u" and "f" identify CU and CF, respectively. Payoffs in the wage bargaining are given by the von Neumann–Morgenstern utility functions U (for CU) and Π (for CF) defined[2] by $U(w, t) \equiv N \cdot \delta_{\mathrm{u}}^{t-2} \cdot u(w, \bar{w}, l^*(w))$ and $\Pi(w, t) \equiv N \cdot \delta_{\mathrm{f}}^{t-2} \cdot \Lambda(w, l^*(w))$ for every $(w, t) \in X \times T$, where $\delta_i \in (0, 1)$ is player i's discount factor, for $i = \mathrm{u}, \mathrm{f}$. Perpetual disagreement payoffs are equal to zero for both players. Given the homogeneity

2 The players' payoffs are discounted from period $t = 2$ since a base-wage agreement cannot be reached earlier.

of the players (N identical firms and N identical unions), we assume that all local unions have the same discount factor δ_u and all firms have also the same discount factor δ_f.

Let Δ be the length of the bargaining period. We focus on the case where the interval between offers and counteroffers is short, i.e., as the period length Δ shrinks to zero. We express the bargainers' discount factors in terms of discount rates, r_u and r_f, by the formula $\delta_i = \exp(-r_i \Delta)$, for $i = u, f$. Greater patience implies a lower discount rate and a higher discount factor: $r_u \geq r_f \iff \delta_u \leq \delta_f$. We denote by $G(r_u, r_f)$ the base-wage-bargaining game with complete information about the players' discount rates in which the period length Δ shrinks to zero.

3.3 Industry-Level Agreements under Complete Information

It can be shown that the bargaining game $G(r_u, r_f)$ possesses a unique limiting subgame-perfect equilibrium (SPE). Let $(U^*(r_u, r_f), \Pi^*(r_u, r_f))$ be the unique limiting SPE payoff vector of $G(r_u, r_f)$, which is obtained when the length Δ of a single bargaining period approaches zero. Binmore et al. (1986) have shown that the unique limiting SPE of Rubinstein's (1982) alternating-offer bargaining game approximates the Nash bargaining solution to the appropriately defined bargaining problem.[3] Their result can be extended to our base-wage-bargaining game: the unique limiting SPE of $G(r_u, r_f)$ approximates the asymmetric Nash bargaining solution to our bargaining problem $\langle Y, d \rangle$, where the parameter α (CU's bargaining power) is computed as follows:

$$\alpha = r_f / (r_u + r_f) \ . \tag{12}$$

Thus the predicted wage is

$$w_c^{SPE} = \arg\max_{w \in X} [N \cdot u(w, \bar{w})]^{\alpha} [N \cdot \Lambda(w)]^{1-\alpha} \ .$$

Simple computation gives us

$$w_c^{SPE} = \bar{w} + (a - \bar{w}) \frac{(N+1)\alpha - 2\lambda}{(N+1)2 - 2\lambda} \ , \tag{13}$$

3 However, Vannetelbosch (1998) has shown that we cannot use the asymmetric Nash bargaining solution as an approximation of Rubinstein's alternating-offer bargaining model once the players are boundedly rational ones.

where λ is the profit-sharing parameter and α is the CU's bargaining power. In other words, the more impatient the bargainer, the less powerful. Expression (13) tells us that, in complete information, the central base wage is a decreasing function of the profit-sharing parameter. Indeed, given the CU's bargaining power (α), increasing the profit-sharing parameter (λ) induces an increase in the CU's payoff which must be counterbalanced by a fall of the base wage. Thus the unique SPE payoff vector of $G(r_u, r_f)$ is

$$(U^*(r_u, r_f), \Pi^*(r_u, r_f)) = \left(\frac{N(2-\alpha)\alpha}{4(N+1-\lambda)}(a-\bar{w})^2, \frac{N(1-\lambda)(2-\alpha)^2}{4(N+1-\lambda)^2}(a-\bar{w})^2\right).$$

However, both the asymmetric Nash bargaining solution and Rubinstein's model predict efficient outcomes of the bargaining process (in particular, agreement is settled immediately). This is not the case once we introduce incomplete information into the wage-bargaining game, in which the first rounds of negotiation are used for information transmission between the two players.

3.4 Industry-Level Agreements under Incomplete Information

The main feature of our base-wage-bargaining game is that players possess private information. They are uncertain about each others' discount rates. It is common knowledge between the players that player i's discount rate is included in the set $[r_i^P, r_i^I]$, where $0 < r_i^P \leq r_i^I < 1$, for $i = u, f$. The superscripts "I" and "P" identify the most impatient and most patient types, respectively. The players' types are independently drawn, with player i's discount rate drawn from the set $[r_i^P, r_i^I]$ according to the probability distribution p_i, for $i = u, f$. General distributions over discount rates are allowed. Letting $p = (p_u, p_f)$, we denote by $G(p)$ the wage-bargaining game of incomplete information in which the distribution p is common knowledge between the players (and in which the period length Δ shrinks to zero). Next we state some properties about the perfect Bayesian equilibria (PBE) of $G(p)$. The Lemma 1 follows from Watson's (1998) analysis.[4]

4 Watson (1998) studied Rubinstein's alternating-offer bargaining game with two-sided incomplete information. He characterized the set of PBE payoffs which may arise in the game and constructed bounds (which are met) on the agreements that may be made. The bounds and the PBE payoffs set

Lemma 1: Consider the wage-bargaining game $G(p)$. For any PBE of $G(p)$:

– the payoff of the CU (of type r_u) belongs to $[U^*(r_u^I, r_f^P), U^*(r_u^P, r_f^I)]$;

– the payoff of the CF (of type r_f) belongs to $[\Pi^*(r_u^P, r_f^I), \Pi^*(r_u^I, r_f^P)]$,

for $r_i \in [r_i^P, r_i^I]$, $i = \mathrm{u}, \mathrm{f}$.

Remember that $(U^*(r_u, r_f), \Pi^*(r_u, r_f))$ is the unique limiting SPE payoff vector of $G(r_u, r_f)$. Lemma 1 is not a direct corollary to Watson's (1998) theorem 1 because Watson's work focuses on linear preferences, however, the analysis can be modified to handle the present case. As Watson (1998) stated, Lemma 1 establishes that "each player will be no worse than he would be in equilibrium if it were common knowledge that he were the least patient type and the opponent were the most patient type. Furthermore, each player will be no better than he would be in equilibrium with the roles reversed." Finally, translating Watson's (1998) theorem 2 to our framework completes the characterization of the PBE payoffs. For any $\tilde{U} \in [U^*(r_u^I, r_f^P), U^*(r_u^P, r_f^I)]$, $\tilde{\Pi} \in [\Pi^*(r_u^P, r_f^I), \Pi^*(r_u^I, r_f^P)]$, there exists a distribution $p = (p_u, p_f)$ and a PBE of $G(p)$ such that the PBE payoff of the CU is $\tilde{U}$ and the PBE of the CF is $\tilde{\Pi}$. In other words, whether or not all payoffs within the intervals given in Lemma 1 are possible depends on the distribution p over types. Proposition 1 follows from Lemma 1.

Proposition 1: Under industry-level bargaining, the base-wage outcome, w_c^*, satisfies the following inequalities:

$$\begin{aligned} &\bar{w} + \frac{(N+1-2\lambda)r_f^P - 2\lambda r_u^I}{2(N+1-\lambda)(r_u^I + r_f^P)}(a - \bar{w}) \\ &\leq w_c^* \leq \bar{w} + \frac{(N+1-2\lambda)r_f^I - 2\lambda r_u^P}{2(N+1-\lambda)(r_u^P + r_f^I)}(a - \bar{w}) \ . \end{aligned} \tag{14}$$

In the alternating-offer bargaining game $G(p)$ with incomplete information, PBE implies bounds on the centralized base-wage outcome, w_c^*, which are given by expression (14). The argumentation above implies that each base wage satisfying these bounds can be the centralized

are determined by the range of incomplete information and are easy to compute because they correspond to the SPE payoffs of two bargaining games of complete information. These two games are defined by matching one player's most impatient type with the opponent's most patient type.

outcome by choosing appropriately the distribution p over types. Remember that general distributions over types are allowed. The lower (upper) bound is the base-wage outcome of the complete-information game, when it is common knowledge that the CU's type is r_u^I (r_u^P) and the CF's type is r_f^P (r_f^I). This lower (upper) bound is a decreasing function of CU's discount rate r_u^I (r_u^P), an increasing function of CF's discount rate r_f^P (r_f^I), an increasing function of the level of industry demand, parameterized by the intercept of the linear demand function, a decreasing function of the profit-sharing parameter λ, and an increasing function of the reservation wage $\bar{w}$. Expression (14) implies bounds on the firm's employment level l_c^*, as well as on the firm's output q_c^*, at equilibrium.

Lemma 1 and Proposition 1 tell us that inefficient outcomes are possible, even as the period length shrinks to zero. The wage-bargaining game may involve delay (strikes or lockouts), but not perpetual disagreement, at equilibrium. Indeed, Watson (1998) has constructed a bound on delay in equilibrium which shows that an agreement is reached in finite time and that delay time equals zero as incomplete information vanishes.

With complete information, the introduction of a profit-sharing scheme always decreases the wage level and increases the production output (and the employment level) as well as the consumer surplus. But when the players possess private information, the complete-information results do not necessarily hold. Corollary 1 gives us the necessary and sufficient condition to recover the complete-information results.

Corollary 1: The wage outcome with profit sharing, w_c^* ($\lambda \neq 0$), is always smaller than the wage outcome without profit sharing, w_c^* ($\lambda = 0$), if and only if there exists a profit share $\lambda \in (\lambda^*, 1]$ where

$$\lambda^* = \frac{(N+1)[r_f^I r_u^I - r_f^P r_u^P]}{(r_f^I + r_u^P)(r_f^P + 2r_u^I)} .$$

For a given profit-sharing parameter, this necessary and sufficient condition will be satisfied the smaller the number of firms in the industry and the smaller the uncertainty about the players' discount rates.

3.5 Strike Activity and Industry-Level Bargaining

In the literature on strikes (see, e.g., Cheung and Davidson, 1991; Kennan and Wilson, 1989), three different measures of strike activity are usually proposed: (1) the strike incidence, i.e., the number of strikes that occur during the negotiation, (2) the strike duration, i.e., the average length of strikes, (3) the number of workdays lost due to work stoppages. Since we allow for general distributions over types and we may encounter a multiplicity of PBE, we are unable to compute measures of strike activity such as those just mentioned.[5] Nevertheless, we propose to identify the strike activity (strikes or lockouts) with the maximal delay in reaching a wage agreement. Following Watson's (1998) theorem 3, the larger the difference between the upper bound and lower bound on the bargaining outcome, the larger the potential delay for obtaining an agreement. Therefore, the strike activity is given by the difference between the upper bound and the lower bound on the base-wage outcome.[6] When bargaining takes place at the industry level, the strike activity, $\Psi_c(\lambda)$, is given by the following expression:

$$\Psi_c(\lambda) = \frac{(N+1)[r_f^I r_u^I - r_f^P r_u^P]}{[r_f^P + r_u^I][r_f^I + r_u^P]2(N+1-\lambda)}(a - \bar{w}) \ . \qquad (15)$$

From Eq. (15) it is immediately clear that $\Psi_c\,(\lambda \neq 0) > \Psi_c\,(\lambda = 0)$. Therefore, we can state Proposition 2.

Proposition 2: If the base-wage bargaining takes place at the industry level, then the introduction of a profit-sharing scheme increases the strike activity.

The intuition behind Proposition 2 has to do with the time needed to screen or to learn each other's type. The introduction of profit sharing

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5 In order to compute an expected strike duration one would need to fix some parameters of the model such as the distribution over types (see, e.g., Cheung and Davidson, 1991; Kennan and Wilson, 1993) but it would imply a substantial loss of generality.

6 Our measure of strike activity gives the scope each player has for screening his opponent by making wage proposals, satisfying expression (14), and hence, for delaying the base-wage agreement. Only in average this measure is a good proxy of actual strike activity.

makes the wage objective of the CU less obvious. Indeed, the CU may still be interested in reaching high wages, but high wages reduce the share of the profits allocated to the CU. Hence, the CU has now more room to hide his type, which is private information, in order to reach a more favorable wage outcome. Therefore, the CF (who still claims lower wages) may need more time, during the negotiation, to screen the CU's type.

4 Firm-Level Wage Bargaining

At the firm level, workers are represented by a local-union representative (LU). The LU's objective function is to maximize the local union's utility. Inside each firm, the LU negotiates the local base-wage level with the local-firm representative (LF) whose objective function is to maximize its utility. All negotiations take place simultaneously and independently. That is, when negotiating the base-wage level, each LU–LF pair takes all other wage settlements in the industry as given. Moreover, these LU–LF pairs always correctly anticipate the effect of wages on subsequent Cournot competition game. The bargaining process is always described by Rubinstein's (1982) alternating-offer bargaining model (see Sect. 3). Payoffs in the wage bargaining are now given by the von Neumann–Morgenstern utility functions U_n (for LU n) and Π_n (for LF n) defined by $U_n(w_n, t) \equiv \delta_{\mathrm{u}}^{t-2} \cdot u_n(w_n, \bar{w}, l_n^*(w_1^*, ., w_n, .))$ and $\Pi_n(w_n, t) \equiv \delta_{\mathrm{f}}^{t-2} \cdot \Lambda_n(w_n, l_n^*(w_1^*, ., w_n, .))$ for every $(w_n, t) \in X \times T$, where $\delta_i \in (0, 1)$ is player i's discount factor, for $i = \mathrm{u}, \mathrm{f}$. Perpetual disagreement payoffs are equal to zero for both players. Remember that all unions have the same discount factor δ_{u} and all firms have also the same discount factor δ_{f}.

4.1 Firm-Level Agreements under Complete Information

Let $(U_n^*(r_{\mathrm{u}}, r_{\mathrm{f}}), \Pi_n^*(r_{\mathrm{u}}, r_{\mathrm{f}}))$ be the unique limiting SPE payoff vector at firm n of the decentralized-wage-bargaining game under complete information, which is obtained when the length Δ of a single bargaining period approaches zero. Therefore, with complete information, the decentralized wages are given by expression (16) where α is the LU's bargaining power and it is given by Eq. (12).

$$\begin{cases} w_{1\mathrm{d}}^{\mathrm{SPE}} = \arg\max_{w_1 \in X} [u_1(w_1, \bar{w}, l_1^*(w_1, \dots, w_N^*))]^{\alpha} \\ \qquad \cdot [\Lambda_1(w_1, l_1^*(w_1, \dots, w_N^*))]^{1-\alpha} , \\ \vdots \\ w_{n\mathrm{d}}^{\mathrm{SPE}} = \arg\max_{w_n \in X} [u_n(w_n, \bar{w}, l_n^*(w_1^*, .., w_n, .))]^{\alpha} \\ \qquad \cdot [\Lambda_n(w_n, l_n^*(w_1^*, .., w_n, .))]^{1-\alpha} , \\ \vdots \\ w_{N\mathrm{d}}^{\mathrm{SPE}} = \arg\max_{w_N \in X} [u_N(w_N, \bar{w}, l_N^*(w_1^*, \dots, w_N))]^{\alpha} \\ \qquad \cdot [\Lambda_N(w_N, l_N^*(w_1^*, \dots, w_N))]^{1-\alpha} , \end{cases} \tag{16}$$

There is a unique solution to expression (16) given by

$$\begin{aligned} & w_{\mathrm{d}}^{\mathrm{SPE}} \\ & = \bar{w} + \frac{[\alpha(N+1) - 2\lambda N]}{2N(N+1-\lambda) - \alpha(N+1)(N-1)}(a - \bar{w}) = w_{1\mathrm{d}}^{\mathrm{SPE}} \\ & = \dots = w_{N\mathrm{d}}^{\mathrm{SPE}} \\ & = \bar{w} + \frac{(2\lambda N - N - 1)r_{\mathrm{f}} + 2\lambda N r_{\mathrm{u}}}{2(\lambda N - N^2 - N)r_{\mathrm{u}} + (2\lambda N - N^2 - 2N - 1)r_{\mathrm{f}}}(a - \bar{w}) . \end{aligned} \tag{17}$$

Therefore, the SPE payoff vector (at firm n) is

$$\begin{aligned} & (U_n^*(r_{\mathrm{u}}, r_{\mathrm{f}}), \Pi_n^*(r_{\mathrm{u}}, r_{\mathrm{f}})) \\ & = \frac{N(2-\alpha)(a-\bar{w})^2 \cdot [\alpha[N+1-\lambda N], (1-\lambda)N(2-\alpha)]}{[2N(N+1-\lambda) - \alpha(N+1)(N-1)]^2} . \end{aligned} \tag{18}$$

4.2 Firm-Level Agreements under Incomplete Information

Next we tackle the decentralized-wage-bargaining game with incomplete information about the players' discount rates. Given the symmetry of the model, we look for symmetric PBE, that is, an equilibrium in which $w_{1\mathrm{d}}^* = w_{2\mathrm{d}}^* = \dots = w_{N\mathrm{d}}^* = w_{\mathrm{d}}^*$.

Lemma 2: Assume each LU–LF pair n takes all other base-wage settlements in the industry as given during the bargaining at firm n. Then, for any symmetric PBE:

- the payoff of the LU n (of type r_u) belongs to $[U_n^*(r_u^I, r_f^P), U_n^*(r_u^P, r_f^I)]$;
- the payoff of the LF n (of type r_f) belongs to $[\Pi_n^*(r_u^P, r_f^I), \Pi_n^*(r_u^I, r_f^P)]$,

for $r_i \in [r_i^P, r_i^I]$, $i = \mathrm{u}, \mathrm{f}$.

Lemma 2 is the counterpart of Lemma 1 for the decentralized base-wage negotiation. Following Lemma 2 and the complete-information results we are able to state some properties about the decentralized wage outcomes.

Proposition 3: Under firm-level bargaining, the (symmetric) base-wage bargaining outcome, w_d^*, satisfies the following inequalities:

$$w_d^* \geq \bar{w} + \frac{[(2\lambda N - N - 1)r_f^P + 2\lambda N r_u^I](a - \bar{w})}{2(\lambda N - N^2 - N)r_u^I + (2\lambda N - N^2 - 2N - 1)r_f^P}, \quad (19)$$

$$w_d^* \leq \bar{w} + \frac{[(2\lambda N - N - 1)r_f^I + 2\lambda N r_u^P](a - \bar{w})}{2(\lambda N - N^2 - N)r_u^P + (2\lambda N - N^2 - 2N - 1)r_f^I}. \quad (20)$$

The lower (upper) bound is the base-wage outcome of the complete-information game, when it is common knowledge that LU's type is r_u^I (r_u^P) and LF's type is r_f^P (r_f^I). Again, as for the centralized case, each base wage satisfying these bounds can be the decentralized outcome by choosing appropriately the distribution p over types. This lower (upper) bound is a decreasing function of LU's discount rate r_u^I (r_u^P), an increasing function of LF's discount rate r_f^P (r_f^I), an increasing function of the level of industry demand, a decreasing function of the profit-sharing parameter λ, and an increasing function of the reservation wage $\bar{w}$. Note that, even as Δ approaches zero, the strike activity is possible in presence of incomplete information. Expressions (19) and (20) imply bounds on firm's employment level l_d^*, as well as on the firm's output q_d^*, at equilibrium.

With complete information, the introduction of a profit-sharing scheme always decreases the wage level and increases the production output (and the employment level) as well as the consumer surplus. But when the players possess private information, the complete-information results are not always valid. Corollary 2 gives us the necessary and sufficient condition to recover the complete-information results.

Corollary 2: The wage outcome with profit sharing, $w_{\mathrm{d}}^{*}\ (\lambda \neq 0)$, is always smaller than the wage outcome without profit sharing, $w_{\mathrm{d}}^{*}\ (\lambda = 0)$, if and only if there exists a profit share $\lambda \in (\lambda', 1]$ where

$$\lambda' = \frac{(N+1)[r_{\mathrm{f}}^{\mathrm{I}} r_{\mathrm{u}}^{\mathrm{I}} - r_{\mathrm{f}}^{\mathrm{P}} r_{\mathrm{u}}^{\mathrm{P}}]}{N(r_{\mathrm{f}}^{\mathrm{I}} + r_{\mathrm{u}}^{\mathrm{P}})(r_{\mathrm{f}}^{\mathrm{P}} + 2r_{\mathrm{u}}^{\mathrm{I}})} .$$

Hence, a sufficient condition is $\lambda > (N+1)[2N]^{-1}$. So, under incomplete information, if the government or social planner wants to decrease wages, by introducing a profit-sharing scheme between LU and LF, and hence, promoting employment, a simple way is to fix a profit-sharing coefficient λ greater than $(N+1)[2N]^{-1}$. But this last expression is decreasing with the number of firms in the industry and converges to $1/2$ as this number becomes large.

4.3 Strike Activity and Firm-Level Bargaining

Under our profit-sharing system, the strike activity when bargaining takes place at the firm level, $\Psi_{\mathrm{d}}(\lambda)$, is given by the following expression:

$$\Psi_{\mathrm{d}}(\lambda) = \left[\frac{[2N(N+1)(1+N-\lambda N)][r_{\mathrm{f}}^{\mathrm{I}} r_{\mathrm{u}}^{\mathrm{I}} - r_{\mathrm{f}}^{\mathrm{P}} r_{\mathrm{u}}^{\mathrm{P}}](a-\bar{w})}{(2\lambda N - N^2 - 2N - 1)r_{\mathrm{f}}^{\mathrm{P}} + (\lambda N - N^2 - N)2r_{\mathrm{u}}^{\mathrm{I}}}\right] \cdot \left[\frac{1}{(2\lambda N - N^2 - 2N - 1)r_{\mathrm{f}}^{\mathrm{I}} + (\lambda N - N^2 - N)2r_{\mathrm{u}}^{\mathrm{P}}}\right] . \qquad (21)$$

From Eq. (21) it is immediate that, if $N \geq 3$ then $\Psi_{\mathrm{d}}(\lambda \neq 0) < \Psi_{\mathrm{d}}(\lambda = 0)$. Therefore, we can state Proposition 4.

Proposition 4: If the base-wage bargaining takes place at the firm level and the number of firms in the industry is greater than two, then the introduction of a profit-sharing scheme reduces the strike activity.

Contrary to the industry-level wage bargaining, if the number of firms producing in the industry is greater than two, then a profit-sharing system reduces the strike activity under firm-level base-wage negotiations.

The intuition behind Proposition 4 has to do with the competition on the product market. Indeed, when the base-wage bargaining takes place at the firm level, each LU–LF pair expects to be able to alter its relative wage position in the industry. Therefore, it leads to wage-spillover effects: each LU–LF pair has an incentive to lower wages in order to increase its output level and the LF's profits, and to gain a larger share of the product market. This incentive is stronger once a profit-sharing scheme is introduced since now the LU also attaches some importance to the LF's profit. Therefore, it is not too surprising that, under incomplete information, the introduction of profit sharing reduces the scope for strikes and lockouts if there is enough competition (at least three firms competing in the industry) and wage bargaining takes place at the firm level.

4.4 Firm-Level vs. Industry-Level Bargaining

The wage-spillover effects are partially internalized by negotiating at the industry level, while they are not at the firm level. The degree of internalization differentiates the two bargaining structures in terms of the base-wage level and the strike activity. Vannetelbosch (1997) has shown that the introduction of incomplete information, in the absence of profit sharing, will not necessarily imply that the firm-level wage is lower than the industry-level wage. This result is still valid under profit sharing.

Without profit sharing, Vannetelbosch (1997) has shown that the strike activity is larger if the wage bargaining takes place at the industry level rather than at the firm level: $\Psi_c\,(\lambda=0) > \Psi_d\,(\lambda=0)$. Under profit sharing, comparing (15) with (21), we observe that $\Psi_c\,(\lambda\neq 0) > \Psi_c\,(\lambda=0) > \Psi_d\,(\lambda=0) > \Psi_d\,(\lambda\neq 0)$. Relating Proposition 2 to Proposition 4 tells us that a profit-sharing system increases the disparity, in terms of strike activity, of both bargaining structures.

5 Concluding Remarks

In recent years, profit-sharing schemes have become a major alternative form of compensation in France and in the UK. However, Bhargava and Jenkinson (1995) or Cahuc and Dormont (1992, 1997) have shown that the base wage does not decrease or even rises after the introduction of profit sharing. These empirical results are inconsistent with Weitzman's argument in favor of profit-sharing schemes for reducing the unemployment level. Therefore, other arguments for the introduction of profit sharing and its growth have to be considered.

One argument considered is that the introduction of profit sharing may increase worker productivity and firm profitability (see Cahuc and Dormont, 1992, 1997). In this paper, we have provided another argument why profit sharing is introduced: profit sharing may reduce the strike activity. We have developed a model of wage determination with incomplete information in a unionized Cournot oligopoly. The assumption of incomplete information allows the possibility of strikes or lockouts, which waste industry resources, at equilibrium. Facing such deadweight loss of wasted resources, the government or the social planner may decide to adopt a policy, like a profit-sharing scheme. Under two different bargaining structures (firm level vs. industry level), we have investigated the effects of adopting profit sharing on the wage outcome and the strike activity. If the base-wage bargaining takes place at the industry level, then the introduction of a profit-sharing scheme increases the strike activity. But if the base-wage bargaining takes place at the firm level and the number of firms in the industry is greater than two, then the introduction of a profit-sharing scheme reduces the strike activity.

Some extensions may be worthwhile. One possibility is to endogenize the introduction of profit sharing as well as the profit-share parameter. Such endogenization has been done by Sørensen (1992), but only for the duopoly case with complete information (strike activity is excluded) and with firm-level negotiations. A second extension is to incorporate the union's (or firm) decision on whether to call on a strike (lockout) or to hold out (see, e.g., Cramton and Tracy, 1992). Strikes data seem to have a significant impact on the wage–employment relationship for collective negotiations (see, e.g., Kennan and Wilson, 1989; Vannetelbosch, 1996). Hence, a third direction is to test empirically the relationships between strikes, wages, profit sharing, and bargaining structures.

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