Strike Activity and Bertrand vs Cournot Competition[*]

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Abstract

We develop a model of wage determination with private information in a unionized imperfectly competitive industry. Under two different bargaining structures (firm-level vs industry-level), we investigate the effects of the degree of product differentiation and the type of market competition (Bertrand vs Cournot competition) on the negotiated wage and the strike activity. If the wage bargaining takes place at the industry-level, then both the wage outcome and the strike activity do not depend on the degree of product differentiation whatever the type of market competition. However, if the wage bargaining takes place at the firm-level, then wages and strikes are increasing with the degree of product differentiation, and the strike activity is smaller under Bertrand than under Cournot competition.

Keywords: Bertrand competition, Cournot competition, product differentiation, wage bargaining, strike activity.

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1 Introduction

Empirical literature suggests that industry-specific factors are key determinants of strike activity [see e.g. Tracy (1986)]. Key determinants are, among others, the type of industry, the industry size, the type of market competition, the industry concentration, and the size of the bargaining unit. Despite this evidence, the theoretical literature on wage bargaining in industries with market power has neglected the study of the relationship among the type of market competition, the level of bargaining and the strike activity.

The purpose of this paper is to study how institutional features such as the bargaining structure and how industry factors such as the product market competition will affect the outcome of wage negotiations in unionized duopolistic industries. Within an incomplete information framework, we develop a model of wage determination in a product differentiated duopoly. First, unions and firms negotiate over the wage level according to institutional features (industry-level vs firm-level bargaining). Second, firms compete either in quantities (Cournot competition) or in prices (Bertrand competition) on the product market. To describe the wage bargaining process, we adopt Rubinstein's (1982) alternating-offer bargaining model with two-sided incomplete information, which allows the occurrence of strikes at equilibrium.

Related contributions are Davidson (1988), Horn and Wolinsky (1988), and Dowrick (1989). When firms produce in related product markets, wage settlements create spillover effects (by altering the firms' relative competitive positions in the product market) that have implications for the outcome of negotiations. Davidson (1988) and Horn and Wolinsky (1988) have studied the impact of wage spillover effects on the interaction of union-firm bargaining and duopolistic quantity-setting. Around the same time, Dowrick (1989) has used a conjectural variation oligopoly model to study how product market power and profitability are related to wages. More recently, Dhillon and Petrakis (2001) have investigated, for the case of centralized bargaining in oligopolistic industries, the effects of the degree of product differentiation and the type of market competition (Bertrand vs Cournot competition) on the negotiated wage. But, all these previous studies have considered complete information frameworks so that strikes, which waste industry resources, cannot occur at equilibrium.[1]

So, we go beyond the analysis offered in Davidson (1988), Horn and Wolinsky (1988), Dowrick (1989) and Dhillon and Petrakis (2001), by developing a model that enables us to investigate for different bargaining structures and types of market competition how private information as well as spillover effects across payoff functions created by contract

[1] 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)].

settlements affect the wages, the level of employment and the strike activity. We show that, if the wage bargaining takes place at the industry-level, then both the wage outcome and the strike activity do not depend on the degree of product differentiation whatever the type of market competition. Indeed, since wage spillover effects are internalized at the industry-level, wage bargaining affects employment and profits only through the overall level of industry demand. As a consequence, the strike activity is the same under both Bertrand and Cournot competition and is independent of product differentiation.

However, if the wage bargaining takes place at the firm-level, we show that wages and strikes are increasing with the degree of product differentiation. Since firm-level bargaining does not internalize the wage spillover effects and these spillover effects are decreasing with the degree of product differentiation, the strike activity at the firm-level is increasing with product differentiation. Indeed, wage spillover effects create incentives to lower wages in order to gain a larger share of the product market and to induce more concessions and less conflicts or strikes in wage bargains. These incentives are reinforced the less differentiated the products or brands are. Moreover, the strike activity under Bertrand competition is smaller than under Cournot competition. This is due to the fact that wage spillover effects are greater under Bertrand competition.

Contrary to the complete information framework, the firm-level wage outcome under Bertrand competition will not necessarily be lower than the firm-level wage outcome under Cournot competition. Moreover, the firm-level wage outcome under Cournot competition will not necessarily be lower than the industry-level wage outcome under Cournot (or Bertrand) competition. However, if it is commonly known that the local union is much stronger than the local firm and the degree of product differentiation is small, then Bertrand competition will decrease the firm-level wage at equilibrium and industry-level bargaining will increase the wage at equilibrium.

Finally, the strike activity is smaller under Bertrand than under Cournot competition when bargaining is decentralized. So, Bertrand competition increases the disparity, in terms of strike activity, of both bargaining structures.

The paper is organized as follows. In Section 2, the model is presented. The Bertrand and Cournot games in the duopolistic market are solved assuming that the wages have already been determined. Section 3 describes the wage bargaining game and solves this game for the industry-level bargaining system. It also analyses the relationship between the industry-level bargaining structure, the degree of product differentiation, and the strike activity. Section 4 is devoted to the wage bargaining game for the firm-level bargaining system and analyses again the relationship between the firm-level bargaining structure, the degree of product differentiation, and the strike activity. Finally, Section 5 concludes.

2 Description of the Duopolistic Market

We consider a duopolistic industry producing each firm one brand of a differentiated product. Let firm i produce brand i in quantity q_i. There is no entry or threat of entry, and both firms are either price setters (Bertrand competition) or quantity setters (Cournot competition). The inverse demand function for the brand i of the differentiated product is given by

$$p_i(q_i;q_j) = a - q_i - b \cdot q_j,\ i;j = 1;2 \text{ and } i \neq j. \quad (1)$$

The parameter $b \in (0;1)$ represents the degree of substitutability between both brands. The higher the b, the higher is the degree of substitutability between i and j. When b tends to zero, each firm becomes almost a monopolist; when b tends to one, both brands are almost perfect substitutes. We assume that both firms are producing under constant returns to scale with labor as the sole input, i.e. $q_i = l_i$, where l_i is labor input. The total cost to firm i of producing quantity q_i is $q_i \cdot w_i$, where w_i is the wage in firm i.

Associated with each firm there is a continuum of identical workers who supply each one unit of labor with no disutility. We denote by $\overline{w}$ the expected income of a worker who loses his job. It may be interpreted as the unemployment benefit. In each firm the risk-neutral workers are represented in the wage bargaining process by a utilitarian union. The continuum of workers who supply labor to each firm is normalized to unity. Hence, local union i's utility is given by

$$U_i(w_i;\overline{w};l_i;(q_1;q_2)) = l_i \cdot w_i + (1 - l_i) \cdot \overline{w} \qquad i = 1;2. \quad (2)$$

The profit of firm i is given by $\Pi_i(w_i;l_i;(q_1;q_2)) = (a - q_i - bq_j) \cdot q_i - w_i \cdot q_i$.

Interactions between the product market, the degree of product differentiation and the bargaining level are analyzed according to the following game structure. In stage one, wages are negotiated at the firm-level or at the industry-level. In stage two, Bertrand or Cournot competition occurs. The model is solved backwards.

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

$$q_i^{\ast}(w_1;w_2) = \frac{a(2-b) - 2w_i + bw_j}{4 - b^2} \qquad i;j = 1;2,\ i \neq j. \quad (3)$$

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

Under Bertrand competition both firms compete by choosing simultaneously their prices to maximize profits. The unique Nash equilibrium of this stage game yields:

$$p_i^*(w_1;w_2) = \frac{a(1-b)(2+b)+2w_i+bw_j}{4-b^2} \qquad i;j=1;2,\ i \neq j. \tag{4}$$

and

$$q_i^*(w_1;w_2) = \frac{a(1-b)(2+b)-(2-b^2)w_i+bw_j}{(1-b^2)(4-b^2)} \qquad i;j=1;2,\ i \neq j. \tag{5}$$

In the first stage of the game, firms and unions negotiate the wage level foreseeing perfectly the effect of wages on firms' decisions concerning employment. To investigate the effects of the degree of product differentiation and the type of market competition (Bertrand vs Cournot competition) on the negotiated wage and the strike activity, 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 central union (CU) whose objective function is to maximize the sum of local unions' payoffs. This central union negotiates the industry wage level with the firms representative (CF), whose objective function is to maximize the sum of local firms' profits. The negotiation proceeds as in Rubinstein's (1982) alternating-offer bargaining model. The CF and the CU make alternatively wage offers, with CF making offers in odd-numbered periods and CU making offers in even-numbered periods. The negotiation ends when one of the negotiators accepts an offer. No limit is placed on the time that may be expended in bargaining and perpetual disagreement is a possible outcome. All local unions are assumed to be on strike in every period until an agreement is reached. Both CF and CU are assumed to be impatient: the CF and the CU have time preferences with constant discount rates $r_f > 0$ and $r_u > 0$, respectively. We assume that all unions have the same discount rate r_u and all firms have also the same discount rate r_f.

As the interval between offers and counteroffers is short and shrinks to zero, the alternating-offer model has a unique limiting subgame perfect equilibrium, which approximates the Nash bargaining solution to the bargaining problem (see Binmore et al., 1986). Let $U = U_1 + U_2$ and $\Pi = \Pi_1 + \Pi_2$. Thus the predicted wage is given by

$$w_c^{SPE} = \arg\max[U - U_0]^{\alpha} \cdot [\Pi - \Pi_0]^{1-\alpha} \tag{6}$$

where the lowerscript "c" means that wage bargaining is centralized (or industry-level), and where $U_0 = 2 \cdot \overline{w}$ and $\Pi_0 = 0$ are, respectively, the disagreement payoffs of the CU and the CF. The parameter $\alpha \in (0,1)$ is the CU bargaining power which is equal to $\frac{r_f}{r_u+r_f}$. In case of Cournot competition, simple computation gives us

$$w^{SPE}_{c,C} = \overline{w} + \frac{\alpha}{2}\cdot(a - \overline{w}) = \overline{w} + \frac{r_f(a-\overline{w})}{2(r_u + r_f)}. \tag{7}$$

Expression (7) tells us that, in complete information, the wage is increasing with the reservation wage $\overline{w}$ and with the CU bargaining power α, but it does not depend on the degree of product differentiation, $1-b$. Then, one can easily obtain the equilibrium employment level as well as the CU and CF equilibrium payoffs, which are denoted $U^*_{c,C}(\alpha)$ and $\Pi^*_{c,C}(\alpha)$, and are given by

$$U^*_{c,C}(\alpha) = \frac{\alpha(2-\alpha)}{2(2+b)}\cdot(a-\overline{w})^2, \quad \Pi^*_{c,C}(\alpha) = \frac{(2-\alpha)^2}{2(2+b)^2}\cdot(a-\overline{w})^2.$$

Both the CU and the CF equilibrium payoffs are increasing with the degree of product differentiation. That is, both are decreasing with b. The equilibrium employment in firm i is $(2-\alpha)(a-\overline{w})[2(2+b)]^{-1}$ and is also increasing with the differentiation.[2]

In case of Bertrand competition, simple computation gives us

$$w^{SPE}_{c,B} = \overline{w} + \frac{\alpha}{2}\cdot(a - \overline{w}) = \overline{w} + \frac{r_f(a-\overline{w})}{2(r_u + r_f)}. \tag{8}$$

Expression (8) is the same as Expression (7). When wage bargaining takes place at the firm-level, each union-firm pair expects to be able to alter its relative wage position in the industry. Therefore, wage spillover effects are created: each union-firm pair has an incentive to lower wages in order to increase its market share (or employment level) and the firm's profits, incentive which decreases with the degree of product differentiation. But, when wage bargaining takes place at the industry-level, these wage spillover effects are internalized and vanish. As a consequence, wage bargaining affects employment and profits only through the overall level of industry demand, and the wage outcome is the same under both Bertrand and Cournot competition. In case of complete information and centralized wage negotiations, a general discussion on when and why wages are identical under both Bertrand and Cournot competition can be found in Dhillon and Petrakis (2001).

So, the wage in case of Bertrand competition is increasing with the reservation wage $\overline{w}$ and with the CU bargaining power α, but does not depend on the degree of product differentiation, $1-b$. Then, one can easily obtain the equilibrium employment level as

[2] An increase in the degree of product differentiation (a decrease in b) increases the market's firm size and reduces the intensity of competition. Since the market size effect dominates the competition effect, a firm's output increases with the differentiation in a Cournot industry.

well as the CU and CF equilibrium payoffs, which are denoted $U^*_{C,B}(\alpha)$ and $\Pi^*_{C,B}(\alpha)$, and are given by

$$U^*_{C,B}(\alpha) = \frac{\alpha(2-\alpha)}{2(1+b)(2-b)} \cdot (a - \overline{w})^2, \quad \Pi^*_{C,B}(\alpha) = \frac{(1-b)(2-\alpha)^2}{2(1+b)(2-b)^2} \cdot (a - \overline{w})^2 .$$

Notice that now, the CU equilibrium payoff and the equilibrium employment in firm i, which is equal to $(2-\alpha)(a-\overline{w})[2(2-b)(1+b)]^{-1}$, are decreasing with the degree of product differentiation if $b > \frac{1}{2}$, but are increasing otherwise.[3] However, the CF equilibrium payoff is still increasing with the differentiation whatever the parameter b.

Meanwhile the wage is the same under both Bertrand and Cournot competition, we observe that the employment level is smaller under Cournot competition. Indeed, under Cournot competition each firm expects the other firm to hold its output level constant. Hence, each firm would maintain a low output level since it is aware that a unilateral output expansion would result in a drop in the market price. In contrast, under Bertrand competition each firm assumes that the rival firm holds its price constant. Hence, output expansion will not result in a price reduction because the rival firm will adjust its output in a compensatory way to leave its market price unchanged. Therefore, more output is produced and a higher level of employment is obtained under the Bertrand market structure than under the Cournot one.

However, both the asymmetric Nash bargaining solution and the 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, in which the first rounds of negotiation are used for information transmission between the two negotiators.

The main feature of the negotiation is that both negotiators have private information. Each negotiator does not know the impatience (or discount rate) of the other party. It is common knowledge that the CF's discount rate is included in the set $[r^P_f; r^I_f]$, where $0 < r^P_f \leq r^I_f$, and that the CU's discount rate is included in the set $[r^P_u; r^I_u]$, where $0 < r^P_u \leq r^I_u$. The superscripts "I" and "P" identify the most impatient and most patient types, respectively. The types are independently drawn from the set $[r^P_i; r^I_i]$ according to the probability distribution p_i, for $i = u,f$. We allow for general distributions over discount rates. This uncertainty implies bounds on the CU bargaining power which are denoted by $\underline{\alpha} = r^P_f \cdot \left[r^I_u + r^P_f \right]$ and $\overline{\alpha} = r^I_f \cdot \left[r^P_u + r^I_f \right]$.

[3] Contrary to the Cournot case, under Bertrand competition an increase in the degree of product differentiation increases a firm's output only if $b < \frac{1}{2}$. Indeed, when $b > \frac{1}{2}$, the competition effect dominates the market size effect because a Betrand industry is more competitive than a Cournot industry.

Lemma 1 Consider the industry-level wage bargaining with incomplete information in which the distributions p_f and p_u are common knowledge, and in which the period length shrinks to zero. For any perfect Bayesian equilibria (PBE), the payoff of the CU belongs to $\left[U^*_{c,\cdot}(\underline{\alpha}); U^*_{c,\cdot}(\overline{\alpha})\right]$ and the payoff of the CF belongs to $\left[\pi^*_{c,\cdot}(\overline{\alpha}); \pi^*_{c,\cdot}(\underline{\alpha})\right]$.

This lemma follows from Watson's (1998) analysis of Rubinstein's alternating-offer bargaining model with two-sided incomplete information.[4] 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 his least patient type and the opponent were his most patient type. Furthermore, each player will be no better than he would be in equilibrium with the roles reversed".[5] From Lemma 1 we have that the PBE wage outcome in case of Cournot competition, $w^*_{c,C}(\underline{\alpha};\overline{\alpha})$, satisfies the following inequalities:

$$\overline{w} + \frac{r_f^P(a - \overline{w})}{2(r_u^I + r_f^P)} \le w^*_{c,C}(\underline{\alpha};\overline{\alpha}) \le \overline{w} + \frac{r_f^I(a - \overline{w})}{2(r_u^P + r_f^I)}. \quad (9)$$

Notice that each wage satisfying these bounds can be the outcome by choosing appropriately the distribution over types. The lower (upper) bound is the 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) (and the CU bargaining power is $\underline{\alpha}$ ($\overline{\alpha}$)). Expression (9) implies bounds on the firm's employment level, as well as on the firm's output, at equilibrium. In case of Bertrand competition, the PBE wage outcome, $w^*_{c,B}(\underline{\alpha};\overline{\alpha})$, will also satisfy those inequalities:

$$\overline{w} + \frac{r_f^P(a - \overline{w})}{2(r_u^I + r_f^P)} \le w^*_{c,B}(\underline{\alpha};\overline{\alpha}) \le \overline{w} + \frac{r_f^I(a - \overline{w})}{2(r_u^P + r_f^I)}. \quad (10)$$

Lemma 1 and Expressions (9) and (10) also tell us that inefficient outcomes are possible, even as the period length shrinks to zero. The wage bargaining game may involve delay (strikes or lock-outs), but not perpetual disagreement, at equilibrium. Indeed, Watson

[4] Watson (1998) characterized the set of PBE payoffs which may arise in Rubinstein's alternating-offer bargaining game and constructed bounds (which are met) on the agreements that may be made. The bounds and the PBE payoffs set 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.

[5] Lemma 1 is not a direct corollary to Watson (1998) Theorem 1 because Watson's work focuses on linear preferences, but the analysis can be modified to handle the present case. Translating Watson (1998) Theorem 2 to our framework completes the characterization of the PBE payoffs. For any $\tilde{U} \in [U^*_{c,\cdot}(\underline{\alpha}); U^*_{c,\cdot}(\overline{\alpha})]$, $\tilde{\pi} \in [\pi^*_{c,\cdot}(\overline{\alpha}); \pi^*_{c,\cdot}(\underline{\alpha})]$, there exists distributions p_u and p_f, and a PBE such that the PBE payoffs are $\tilde{U}$ and $\tilde{\pi}$. In other words, whether or not all payoffs within the intervals given in Lemma 1 are possible depends on the distributions over types.

(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.

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: the strike incidence, the strike duration, and the number of work days 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 as the ones just mentioned.[6] Nevertheless, we propose to identify the strike activity (strikes or lock-outs) with the maximal delay in reaching a wage agreement. Following Watson (1998) Theorem 3, the larger is the difference between the upper bound and lower bound on the bargaining outcome, the larger is 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 wage outcome.[7] So, when bargaining takes place at the industry-level, the strike activity is given by the following expression under both types of market competition.

$$\Delta_{c,C} = \Delta_{c,B} = \frac{\bar{\alpha} - \underline{\alpha}}{2}(a - \overline{w}) = \frac{\left[r_f^I r_u^I - r_f^P r_u^P \right]}{2\left[r_f^P + r_u^I\right]\left[r_f^I + r_u^P\right]}(a - \overline{w}). \qquad (11)$$

Therefore, both $\Delta_{c,C}$ and $\Delta_{c,B}$ are increasing (decreasing) functions of r_u^I (r_u^P), are decreasing (increasing) functions of r_f^P (r_f^I), and are decreasing with the reservation wage $\overline{w}$. However, the strike activity does not depend on the degree of product differentiation because wage spillover effects are internalized when negotiations are centralized. The next proposition summarizes our results with respect to industry-level bargaining.

Proposition 1 *If the wage bargaining takes place at the industry-level, then the strike activity is the same in both Cournot and Bertrand markets, and is independent of the degree of product differentiation.*

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 wage level with the local firm representative (LF) whose objective function

[6] 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.

[7] Our measure of strike activity gives the scope each player has for screening his opponent by making wage proposals satisfying the expressions (9) or (10), and hence, for delaying the wage agreement. Only in average this measure is a good proxy of actual strike activity.

is to maximize its profit. All negotiations take place simultaneously and independently. That is, when negotiating the 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 the subsequent Bertrand or Cournot competition.

Under complete information, the firm-level equilibrium wages are given by

$$\begin{cases} w_{1d}^{SPE} = \arg\max [U_1 - \overline{w}]^{\alpha} [\Pi_1]^{1-\alpha} \\ w_{2d}^{SPE} = \arg\max [U_2 - \overline{w}]^{\alpha} [\Pi_2]^{1-\alpha} \end{cases} \tag{12}$$

where α is the LU's bargaining power and it is given by expression $\frac{r_f}{r_u + r_f}$, and where the lowerscript "d" means that negotiations are decentralized (or firm-level). In case of Cournot competition, simple computations give us

$$\begin{aligned} w_{d,C}^{SPE} &= \overline{w} + \frac{\alpha(2-b)}{4-b\alpha}(a-\overline{w}) = w_{1d,C}^{SPE} = w_{2d,C}^{SPE} \\ &= \overline{w} + \frac{r_f(2-b)}{4r_u + (4-b)r_f}(a-\overline{w}). \end{aligned} \tag{13}$$

Expression (13) tells us that, in complete information, the wage is increasing with the reservation wage $\overline{w}$, with the LU bargaining power α, and with the degree of product differentiation. Contrary to industry-level bargaining, firm-level bargaining does not internalize the wage spillover effects. Moreover, the smaller the degree of product differentiation (i.e. the larger b is) the larger the spillover effects are. As a consequence, we observe that the firm-level wage outcome is smaller than the industry-level one, and that it is decreasing with b. One can easily obtain the equilibrium employment level as well as the LU and LF equilibrium payoffs, which are denoted $U_{d,C}^{*}(\alpha)$ and $\Pi_{d,C}^{*}(\alpha)$, and are given by

$$\begin{aligned} U_{d,C}^{*}(\alpha) &= \frac{2\alpha(2-\alpha)(2-b)}{(4-b\alpha)^2(2+b)} \cdot (a-\overline{w})^2, \\ \Pi_{d,C}^{*}(\alpha) &= \frac{4(2-\alpha)^2}{(4-b\alpha)^2(2+b)^2} \cdot (a-\overline{w})^2. \end{aligned}$$

Both the LU and the LF equilibrium payoffs are increasing with the degree of product differentiation. The equilibrium employment in firm i is $2(2-\alpha)(a-\overline{w})[(4-b\alpha)(2+b)]^{-1}$ and is also increasing with the differentiation.

In case of Bertrand competition, simple computations give us

$$\begin{aligned} w_{d,B}^{SPE} &= \overline{w} + \frac{\alpha(1-b)(2+b)}{2(2-b^2)-b\alpha}(a-\overline{w}) = w_{1d,B}^{SPE} = w_{2d,B}^{SPE} \\ &= \overline{w} + \frac{r_f(1-b)(2+b)}{2(2-b^2)r_u + (2(2-b^2)-b)r_f}(a-\overline{w}). \end{aligned} \tag{14}$$

Expression (14) is now different than Expression (13): the wage level under Bertrand competition is smaller than under Cournot competition. This is due to the fact that wage spillover effects are greater under Bertrand competition. Indeed, a small decrease in a Bertrand firm's marginal cost (due to a wage decrease) makes it to win a substantial market share of its rival, while a Cournot firm would win only a small part of it. Therefore, a wage drop will increase more the output under Bertrand than under Cournot competition.

Nevertheless, the wage outcome is again increasing with the reservation wage $\bar{w}$, with the LU bargaining power α, and with the degree of product differentiation. One can easily obtain the equilibrium employment level as well as the LU and LF equilibrium payoffs, which are denoted $U^*_{d,B}(\alpha)$ and $\pi^*_{d,B}(\alpha)$, and are given by

$$
\begin{aligned}
U^*_{d,B}(\alpha) &= \frac{\alpha(2-\alpha)(2-b^2)(1-b)(2+b)}{(1+b)(2-b)(2(2-b^2)-b\alpha)^2}\cdot(a-\bar{w})^2, \\
\pi^*_{d,B}(\alpha) &= \frac{(1-b)(2-b^2)^2(2-\alpha)^2}{(1+b)(2-b)^2(2(2-b^2)-b\alpha)^2}\cdot(a-\bar{w})^2.
\end{aligned}
$$

The LF equilibrium payoff is increasing with the differentiation. However, the LU equilibrium payoff and the equilibrium employment in firm i, which is equal to $(2-\alpha)(2-b^2)(a-\bar{w})[(2(2-b^2)-b\alpha)(2-b)(1+b)]^{-1}$, are still decreasing with the degree of product differentiation if $b > \frac{1}{2}$, but are now undetermined otherwise.

We consider now the firm-level wage bargaining with private information about the discount rates. We look for symmetric PBE.

Lemma 2 Consider the firm-level wage negotiations with incomplete information in which the distributions p_f and p_u are common knowledge, and in which the period length shrinks to zero. Assume each LU-LF pair i takes the other wage settlement in the industry as given during the bargaining at firm i. Then, for any symmetric perfect Bayesian equilibria (PBE), the payoff of the LU belongs to $\left[U^*_{d,\cdot}(\underline{\alpha}); U^*_{d,\cdot}(\bar{\alpha})\right]$ and the payoff of the LF belongs to $\left[\pi^*_{d,\cdot}(\bar{\alpha}); \pi^*_{d,\cdot}(\underline{\alpha})\right]$.

Lemma 2 is the counterpart of Lemma 1 for the firm-level wage negotiations. Following Lemma 2 and the complete information results we are able to state some properties about the firm-level wage outcomes. In case of Cournot competition, the symmetric PBE wage outcome $w^*_{d,C}(\underline{\alpha};\bar{\alpha})$ will satisfy the following inequalities:

$$
\bar{w} + \frac{r_f^P(2-b)}{4r_u^l + (4-b)\,r_f^P}(a-\bar{w}) \leq w^*_{d,C}(\underline{\alpha};\bar{\alpha}) \leq \bar{w} + \frac{r_f^l(2-b)}{4r_u^P + (4-b)\,r_f^l}(a-\bar{w}). \qquad (15)
$$

Notice that each wage satisfying these bounds can be the outcome by choosing appropriately the distribution over types. The lower (upper) bound is the wage outcome of the complete information game, when it is common knowledge that the LU's type is r_u^l (r_u^P) and the LF's type is r_f^P (r_f^l) (and the LU bargaining power is $\underline{\alpha}$ ($\bar{\alpha}$)). In case of Bertrand competition, the symmetric PBE wage outcome, $w^*_{d,B}(\underline{\alpha};\bar{\alpha})$, will satisfy the following inequalities:

$$\bar{w} + \frac{r_f^P(1-b)(2+b)(a-\bar{w})}{2(2-b^2)r_u^I + (2(2-b^2)-b)\,r_f^P} \le w^*_{d,B}(\underline{\alpha};\bar{\alpha}) \le \bar{w} + \frac{r_f^I(1-b)(2+b)(a-\bar{w})}{2(2-b^2)r_u^P + (2(2-b^2)-b)\,r_f^I}. \quad (16)$$

In the model we developed of wage determination in a duopolistic industry, we can rank the wage outcomes as follows when there is complete information: $w^{SPE}_{d,B} < w^{SPE}_{d,C} < w^{SPE}_{c,B} = w^{SPE}_{c,B}$. But once the LU and the LF have private information, this ranking does not necessarily hold. The necessary and sufficient condition to recover the complete information result that the firm-level wage outcome under Bertrand competition is always strictly smaller than the firm-level wage outcome under Cournot competition is $4(\bar{\alpha}-\underline{\alpha})(2-b-b^2) < \underline{\alpha}(2-\bar{\alpha})b^3$. Finally, the necessary and sufficient condition to recover the complete information result that the firm-level wage outcome under Cournot competition is always strictly smaller than the industry-level wage outcome under Cournot (or Bertrand) competition is $(4-2b)\bar{\alpha} < (4-b\bar{\alpha})\underline{\alpha}$. The above conditions are satisfied the smaller the amount of private information $|\bar{\alpha}-\underline{\alpha}|$ and the degree of product differentiation $1-b$ are. Moreover, if it is commonly known that the local union is much stronger than the local firm and the degree of product differentiation is small (e.g. $\underline{\alpha} \ge .75$ and $b \ge .85$), then we get $w^*_{d,B}(\underline{\alpha};\bar{\alpha}) < w^*_{d,C}(\underline{\alpha};\bar{\alpha}) < w^*_{c,B}(\underline{\alpha};\bar{\alpha})$ and $w^*_{d,B}(\underline{\alpha};\bar{\alpha}) < w^*_{d,C}(\underline{\alpha};\bar{\alpha}) < w^*_{c,C}(\underline{\alpha};\bar{\alpha})$. The next proposition summarizes these results.

Proposition 2 *In case of bargaining with private information in a duopolistic industry, the firm-level wage outcome under Bertrand competition will not necessarily be lower than the firm-level wage outcome under Cournot competition. Moreover, the firm-level wage outcome under Cournot competition will not necessarily be lower than the industry-level wage outcome under Cournot (or Bertrand) competition. However, if it is commonly known that the local union is much stronger than the local firm and the degree of product differentiation is small, then Bertrand competition will decrease the firm-level wage at equilibrium and industry-level bargaining will increase the wage at equilibrium.*

In case of Cournot competition, the strike activity when bargaining takes place at the firm-level, $\Psi_{d,C}$, is given by the following expression.

$$\Psi_{d,C} = \left[\frac{\bar{\alpha}}{4-b\bar{\alpha}} - \frac{\underline{\alpha}}{4-b\underline{\alpha}}\right](2-b)(a-\bar{w}), \quad (17)$$
$$= \frac{4(2-b)(r_f^I r_u^I - r_f^P r_u^P)}{(4r_u^P + (4-b)r_f^I)(4r_u^I + (4-b)r_f^P)}(a-\bar{w}).$$

In case of Bertrand competition, the strike activity when bargaining takes place at the firm-level, $\sigma_{d,B}$, is given by the following expression.

$$\sigma_{d,B} = \left[\frac{\bar{\alpha}}{2(2-b^2)-b\bar{\alpha}} - \frac{\underline{\alpha}}{2(2-b^2)-b\underline{\alpha}}\right](1-b)(2+b)(a-\overline{w}), \tag{18}$$
$$= \frac{2(2-b^2)(2+b)(1-b)(r_f^I r_u^I - r_f^P r_u^P)}{[2(2-b^2)r_u^P + (2(2-b^2)-b)r_f^I][2(2-b^2)r_u^I + (2(2-b^2)-b)r_f^P]}(a-\overline{w}).$$

Similarly to the industry-level case, we observe that, both $\sigma_{d,C}$ and $\sigma_{d,B}$ are increasing (decreasing) functions of r_u^I (r_u^P), are decreasing (increasing) functions of r_f^P (r_f^I), and are decreasing with the reservation wage $\overline{w}$. But now, the strike activity is increasing with the degree of product differentiation. Moreover, we observe that the strike activity is smaller under Bertrand than under Cournot competition. The intuition behind this result has to do with the competition on the product market. As already mentioned, when the 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; and, it leads to wage spillover effects. Each LU-LF pair has an incentive to lower wages in order to gain a larger share of the product market. This incentive is stronger once Bertrand competition takes place since now a wage decrease makes the LU-LF pair winning a quite large market share of its rival, while Cournot competition would give them only a small part of it. This explain why it is likely that more concessions and less conflicts in wage negotiations will occur under Bertrand competition. The next proposition summarizes our results with respect to firm-level bargaining.

Proposition 3 *If the wage bargaining takes place at the firm-level, then the strike activity is smaller in Bertrand than in Cournot markets, and is increasing with the degree of product differentiation.*

Under Cournot competition in a oligopolistic industry, 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, because spillover effects are internalized at the industry level. Comparing the expressions (11), (17), and (18), we observe that

$$\sigma_{d,B} < \sigma_{d,C} < \sigma_{c,B} = \sigma_{c,C}.$$

That is, the Bertrand competition increases the disparity, in terms of strike activity, of both bargaining structures.

5 Conclusion

Within an incomplete information framework, we have developed a model of wage determination in a unionized imperfectly competitive industry. Under two different bargaining structures (firm-level vs industry-level), we have investigated the effects of the degree of product differentiation and the type of market competition (Bertrand vs Cournot competition) on the negotiated wage and the strike activity. If the wage bargaining takes place at the industry-level, then both the wage outcome and the strike activity do not depend on the degree of product differentiation whatever the type of market competition. However, if the wage bargaining takes place at the firm-level, then wages and strikes are increasing with the degree of product differentiation.

Finally, our model suggests that, once private information matters, one should be cautious when making policy recommendations with respect to the impact of bargaining structures and types of market competition on wages and employment levels (see Proposition 2). Nonetheless, our model predicts that industries where firms compete à la Bertrand rather than à la Cournot will observe less strike activity when bargaining is decentralized.

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