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WAGE BARGAINING IN INDUSTRIES WITH MARKET POWER

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ABSTRACT

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In this paper we develop a fully game-theoretic version of the right-to-manage model of firm-level bargaining where strategic interactions among firms are explicitly recognized. Our main aim is to investigate how equilibrium wages and employment react to changes in the labour and product markets, the business cycle and economic policy. We show that our comparative statics results hinge crucially on the strategic nature of the game, which in turn is determined by the relative bargaining power of unions and managers.

JEL classification: D4, J30, J51
Keywords: bargaining, wages, strategic complementarity, strategic substitutability

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NON-TECHNICAL SUMMARY

Most models of union-firm bargaining imply that product market conditions should influence labour market outcomes. These studies assume that product market imperfections lead to economic rents over which unions and firms bargain. Typically, however, they do not include explicit models of firms' oligopolistic behaviour. They assume away the existing strategic interactions among competing firms in the product market and, consequently, the strategic interactions among the unions associated to different firms. Since, in reality, the bargaining outcomes at competing firms are generally interrelated, it is interesting to examine how standard predictions of the effects of different product and labour market conditions on wages change when the strategic nature of the game is fully modelled.

The intention here is to analyse the simultaneous determination of the oligopoly problem and the union-employer bargaining problem. In particular, we develop a version of the *right-to-manage* model where strategic interactions among competing firms in an oligopolistic industry are explicitly recognised. The *right-to-manage* model of wage determination assumes that unions and employers bargain about wages while employment is decided by firms' managers unilaterally. Since layoffs are generally left to managerial discretion, the wage bargain takes the risk of layoff into account.

We show in the context of our model, that managers at competing firms have conflicting interests concerning wages: Each employer wants its rival to raise wages in order to undercut him; that is, an increase in the wage of a rival firm raises the desirability of a wage cut in his own firm. This is so, since as the rival firm increases its wage, it becomes easier to steal market share and, additionally, by reducing the own wage, the extra share becomes more valuable as price-cost margins increase. Hence, using the standard game theoretic terminology, we find that wages are strategic substitutes for employers.

On the contrary, unions' interests are not in conflict: When the wage of workers in rival firms rises, the union can press further for wage increases in its own firm. The reason is that a higher wage in a rival firm improves the competitive standing of its own firm, decreasing the probability of layoffs for a given wage increase. Hence, unions are more likely to press for wage increases at the bargaining table when their fellows at competing firms enjoy higher wages. In this sense, we can characterize wages as being strategic complements for unions.

Given the different strategic nature of wages for unions and employers, the overall nature of equilibrium wages in the bargaining processes depends naturally on which party has higher relative bargaining power. This has important consequences for the effects of labour and product market conditions on equilibrium wages and employment levels.

Consider for instance the effect on wages of an increase in unemployment benefits. According to the standard theory of wage bargaining, equilibrium wages will increase as more generous benefits reduce the cost of becoming unemployed. This is just the direct effect. There is an additional strategic effect, however, stemming from the reaction of a firm's employer and union to changes in wages prevailing at rival firms. If unions are sufficiently strong, strategic complementarity implies that the strategic effect will add further pressure towards higher wages. If the employers are the strong party at the bargaining table, strategic substitutability will prevail and so it will tend to reduce wages. Hence, when firms' opinions prevail it could be the case that the strategic effect offsets the direct effect, implying that, contrary to conventional wisdom, an increase in unemployment benefits could lead to a reduction in wages.

Thus a first result of the paper is that the predictions of models which miss strategic interactions could be overturned when the latter are properly considered. For example, increased productivity in one firm may lead to lower, not higher, wages in that firm, etc.

Second, an interesting feature of the model is that it leads to multiplicity of equilibria. In particular, when unions are sufficiently powerful and the overall game is one of strategic complements, there is a high-wage and a low-wage equilibrium, raising the possibility of coordination problems and opening the door to government intervention in order to implement the most efficient equilibrium. This also implies that, according to the predictions of the model, there could be considerable variation across economies in equilibrium wages and employment without a large variation in the underlying determinants of wages, reflecting the fact that different economies can settle at different equilibria.

Finally, extensions of the model provide new results on several issues. For example, unions' bargaining power needs to reach a certain threshold to ensure that an increase in product market competition leads to lower wages. Indeed, an increase in product market competition makes managers less eager to undercut rivals' wages since the probability of layoff rises. Thus, only if unions are powerful and their viewpoint is dominant, will wages fall as competition rises. A strong prediction of the model is that only in industries with powerful unions will wages and concentration ratios be positively correlated.

1 Introduction

The fact that union power matters for the determination of wages and employment is by now well established, both theoretically and empirically.[1] In addition, there seems to be solid support for the presence of market power in product markets.[2] But the precise interaction between oligopoly in the product market and trade union effects in the labor market requires further analysis. Basically, standard models of wage bargaining in industries with market power have assumed away any strategic interaction among competing firms in the product market, and thus any strategic interaction among the unions associated to different firms.[3] However, we believe that the bargaining outcomes at competing firms are generally interrelated, and that this challenges many conclusions of the existing literature.

In this paper we account for these strategic effects by developing a fully game-theoretic model of wage bargaining in oligopoly.[4] In particular, this is a model of firm-level bargaining in a duopolistic industry, where competing firms are all unionized. Unions and managers bargain over wages while employment is decided by firms' managers unilaterally. That is, we develop a version of the *right-to-manage* model of firm-level bargaining where strategic interactions among competing firms are explicitly recognized.[5]

We show that unions are more likely to press for wage increases at the bargaining table when their fellows at competing firms enjoy higher wages. The reason is that each union recognizes that higher wages at rival firms lead to a more favorable competitive standing in the product market for its own firm and, therefore, a lower risk of layoffs for a given wage increase. More generally we analyze how

[1] See Krueger and Summers (1988), Layard, *et al.* (1991), Nickell (1990), Silvestre (1993) and references therein.

[2] See Bils (1987), Hall (1988), and Bresnahan (1989), among others.

[3] These models assume monopolistic competition in the product market. Each firm acts as a "local monopolist" with respect to its demand curve, disregarding the wage and employment policies of its rivals and the impact of the latter on its own expected payoffs. (See Manning, 1987, Layard *et al.*, 1991, and Nickell *et al.*, 1992.)

[4] Dowrick (1989) examines union-oligopoly bargaining in a model where both collusive behaviour by firms in the product market and union coordination are captured by standard conjectural variations. Our paper departs drastically from this, as it assumes non-cooperative behaviour in both parties. This highlights the importance of strategic complementarity or sustitutability for actual bargaining outcomes. As shown below, we also enrich the union's utility function so that membership does not necessarily exceed employment.

[5] There is extensive evidence suggesting that indeed unions rarely bargain over employment and supporting the assumptions embedded in the right-to-manage model. See, for instance, Oswald and Turnbull (1985), Oswald (1987), Layard and Nickell (1990), and Layard *et al.* (1990, ch. 2).

unions' and managers' bargaining positions change with their relative bargaining powers, labor and product markets' features, and firms' characteristics.

Our main aim is to investigate how equilibrium wages and employment react to changes in various dimensions of the labor market (such as changes in quit rates, insiders' power, and bargaining procedures), the product market (e.g., firms' productivity, R&D effort, advertising expenditures, degree of product differentiation, and market concentration), the business cycle, and economic policy (e.g., unemployment rate, unemployment benefits, taxes, export subsidies, and import tariffs). We show that the results of our comparative statics analysis crucially depend on the strategic nature of the game; that is, on whether wages are strategic substitutes or complements,[6] which in turn, is determined by the relative power of unions and managers at the bargaining table. These strategic features have been ignored by the existing literature, whose results can be reinterpreted as a particular case of our analysis.

An interesting feature of our model is that it naturally leads to multiplicity of equilibria. When unions are sufficiently more powerful than managers at the bargaining table, these equilibria can be unambiguously ranked according to the level of their corresponding equilibrium wages. More precisely, there is a high-wage equilibrium and a low-wage equilibrium. This raises the possibility of coordination problems, and opens the door to government intervention in order to implement a particular equilibrium (presumably, the most efficient low-wage equilibrium).

The rest of the paper is organized as follows. Section 2 describes our duopoly model and solves for equilibrium wages and employment. Section 3 presents comparative statics results and develops intuitions for them. In section 4 we extend the model of the previous sections to: i) study the relationship between market power and wages and the role of competition policy to moderate wage inflation (section 4.1); ii) compare the outcomes of wage bargaining at the firm and industry levels (section 4.2); iii) determine the cyclical behavior of wages (section 4.3); and finally, iv) consider the implications on wage bargaining of alternative fiscal and strategic trade policies (sections 4.4 and 4.5, respectively). Section 5 draws some concluding remarks. Lastly, we extend our previous results to more general settings in an appendix.

[6] In the terminology of Bulow, Geanakoplos and Klemperer (1985).

2 The model

2.1 The basic set-up

This is a model of firm-level bargaining in a duopolistic industry where competing firms are all unionized and demand is *ex ante* uncertain. We assume for simplicity that there is a single union and a single manager per firm. Managers and unions are all risk-neutral, maximizing their own expected payoffs. At each firm, wages are bargained over *ex ante* taking as given the competitor's wage and their impact on the product market equilibrium outcomes. Employment levels, instead, are decided *ex post* by firms' managers only. They set employment (or, equivalently, production) simultaneously and non-cooperatively to compete for the demand for a good which may be differentiated according to brand name and/or quality.[7]

•**The product market:** There is a continuum of consumers, each with an inelastic demand for one unit of the good. The Q-th consumer has a valuation for a unit of firm j's product, $j = 1, 2$, equal to $f(Q, \theta) + v_j$, where θ is a demand shock distributed according to a uniform distribution on the interval $[\underline{\theta}, \overline{\theta}]$, $v_j \geq 0$ measures the consumers' willingness to pay for brand j (which we take to be positively related to firm j's R&D effort, and advertising and marketing expenditures), and $f(\cdot,\cdot)$ is assumed to be linear and equal to $\theta - Q$. Both the uniform distribution and the linear demand function are chosen for illustrative purposes[8]

Firms use only labor to produce, according to the production function $q_j = a_j N_j$, where q_j denotes firm j's output, N_j its labor force, and a_j its productivity. From the previous assumptions, firm j's *ex-post* profits are given by

$$\begin{aligned} \pi_j(q_j(\theta) \mid \theta) &= q_j(\theta)(\theta - Q + v_j) - w_j N_j \\ &= q_j(\theta)(\theta - Q - \tilde{w}_j), \; j = 1, 2 \end{aligned} \quad (1)$$

where w_j are firm j's wages, $\tilde{w}_j = (w_j/a_j) - v_j$, and $Q = q_1 + q_2$. *Ex-ante* expected profits Π_j are then equal to $E_\theta(\pi_j(q_j(\theta) \mid \theta))$ (where E_θ denotes the expectations operator with respect to θ). We assume that the firm j's manager payoff function coincides with firm j's profits (so that in this model there is no separation between ownership and control).

•**Union objectives:** We assume that layoffs take place by random assignment and that each firm's union maximizes the expected income of every

[7]Both this sequence of play and the implicit assumption that the parties bargain without knowing the bargaining outcome at the rival firm seem to be empirically supported (see Svejnar, 1986).

[8]Appendix 1 provides a generalization of our main results to more general demand and distribution functions.

member.[9] The objective function of the union associated with the j-th firm is then given by

$$U_j = s_j w_j + (1 - s_j) w^a,\ j = 1, 2 \tag{2}$$

where s_j is the probability of staying employed at the same firm in the following period (the *survival* probability), and w^a is the expected income of a worker who loses his job. More precisely, $w^a = \varphi b + (1-\varphi) w^c$, where φ is the probability of being unemployed, $b \geq 0$ are the unemployment benefits, and w^c is the competitive wage.[10] [11] We shall denote by M_j the number of employees who remain at firm j from the previous period after voluntary quits have taken place. Taking δ_j to be the quit rate, $M_j = (1 - \delta_j) N_{j,-1}$ where $N_{j,-1}$ is the previous-period employment at firm j. We assume that union j's membership equals those M_j employees or *insiders*. Thus the survival probability s_j is given by

$$s_j = \Pr\{N_j > M_j\} + \Pr\{N_j \leq M_j\}(E_\theta(N_j \mid N_j \leq M_j))/M_j,\ j = 1, 2 \tag{3}$$

•**Wage bargaining:** The manager and the union associated with firm j choose a wage w_j^* to solve the following program:

$$\begin{array}{c} \max_{w_j}\ \Omega_j = \Pi_j + \beta_j U_j \\ \textit{subject to } (i)\ \Pi_j \geq 0 \\ \textit{and } (ii)\ w_j \geq w^a \end{array} \tag{4}$$

where β_j denotes firm j's union bargaining power.[12] Restrictions (i) and (ii) above ensure that both managers and workers are willing to preserve firm j as a going concern: a manager would close down his firm rather than face negative expected profits, and no worker would accept a job offer paying less than w^a, by definition.

A *perfect Bayesian equilibrium* (PBE) for our (two-stage Bayesian) game is, therefore, an array $\{(w_1^*, w_2^*); (q_1^*(\theta), q_2^*(\theta))\}$ such that

(i) for given θ and (w_1^*, w_2^*), $\{(q_1^*(\theta), q_2^*(\theta))\}$ is a Nash equilibrium for the product market subgame and,

[9] Suppose that the union's bargaining objectives are decided by voting using a simple majority rule. Then, the union's objective function is given by the preferences of its median member. But given that workers are all risk neutral and that layoffs are assigned randomly, the preferences of the latter coincide with the preferences of any other union member (see Layard *et al.*, 1991, ch. 2).

[10] Firm j's laid-off workers join the pool of unemployed which is assumed to be large enough so that the probability of being employed by firm i, $i \neq j$, in the current period is negligible. Hence, search considerations are ignored for simplicity.

[11] Unemployment may exist in this economy due to, for instance, matching frictions.

[12] Alternatively, we might have assumed Ω_j to be equal to $\Pi_j (U_j)^{\beta_j}$ (the Nash maximand), as it is standard in the related literature. However, there are no sound theoretical reasons to prefer one formulation to the other in this context and our assumption on Ω_j makes the algebra less cumbersome.

(ii) for all j, $w_j^* \in \arg\max\{\Omega_j(q_1^*(\theta), q_2^*(\theta)) \mid \Pi_j \geq 0$ and $w_j \geq w^a\}$.[13]

In order to ensure perfection we now proceed to solve the model by backward induction.

2.2 Product market competition

Given firms' wages and for given θ, managers set production (employment) levels to maximize *ex-post* profits, i.e. $q_j^*(\cdot) \in \arg\max \pi_j(q_j(\theta) \mid \theta)$ for all j. For simplicity, we restrict ourselves to parameter configurations where, in equilibrium and for all demand states θ, both firms are active in the product market.[14]

From the previous assumptions, it is a standard result that for those parameter configurations, there is a unique Nash equilibrium for the product market subgame where

$$\begin{aligned} q_j^*(\theta) &= (\theta - 2\tilde{w}_j + \tilde{w}_i)/3 \\ N_j^*(\theta) &= q_j^*(\theta)/a_j \\ \pi_j(q_j^*(\theta) \mid \theta) &= (q_j^*(\theta))^2 \end{aligned} \tag{5}$$

for all $\theta \in [\underline{\theta}, \overline{\theta}]$. Notice that firm j's output, employment and profits are increasing in θ (the state of demand), w_i (the competitor's wage), a_j (firm j's productivity), and v_j (consumers' willingness to pay for firm j's product); and decreasing in a_i (competitor's productivity), and v_i (consumers' willingness to pay for the competitor's product). In addition, $\pi_j(q_j^*(\theta) \mid \theta)$ is decreasing and convex in w_j (for all θ and j), and so is $\Pi_j = E_\theta[(q_j^*(\theta))^2]$. Hence, were wages decided by managers in isolation, they would be equal to w^a, the alternative income.[15] Furthermore, using (5) it is easy to check that

$$\frac{\partial^2 \Pi_j}{\partial w_j \partial w_i} \leq 0 \; for \; all \; i, j \tag{6}$$

So that from the managers' point of view wages are *strategic substitutes*; that is, an increase in the rival's wage raises the marginal desirability of a wage cut for the firm's manager. The reason is that as the rival increases his wage it becomes easier to steal his business, which in addition becomes more valuable as the price-cost margin also increases.

[13] That is, it is common knowledge that negotiations at the firm level satisfy equation (4), for all competing firms.

[14] We therefore ignore the strategic use of wage settlements in order to foreclose rivals in the product market (in this respect, see Kühn, 1994). From equation (5) below, it should be clear that it is enough to require $q(\underline{\theta}) \geq 0$, since $q(\cdot)$ is strictly increasing in θ. Numerical examples show that perfect Bayesian equilibria satifying this additional constraint do exist.

[15] This result holds in the absence of efficiency wage considerations, which could be introduced by making productivity, a_j, to depend on equilibrium wages.

2.3 Equilibrium wages

We concluded the previous subsection by studying the managers' incentives to set wages. Now, prior to any formal discussion of the bargaining equilibrium outcome, we shall overview the corresponding unions' incentives.

First, notice that the survival probability s_j given in equation (3) can also be written as

$$s_j = (\overline{\theta} - \theta_j^*)/\Delta + \int_{\underline{\theta}}^{\theta_j^*} (N_j^*(\theta)/M_j\Delta)d\theta \qquad (7)$$

where $\Delta = (\overline{\theta} - \underline{\theta})$ and θ_j^* is such that $N_j^*(\theta_j^*) = M_j$.[16] That is, for all $\theta \geq \theta_j^*$, firm j's insiders are fully employed. Otherwise, some of them get laid off. Substituting $N_j^*(\theta)$ from (5) into (7), we can show that s_j is unambigously decreasing in w_j. That is, the probability of being laid off increases with higher wages because a higher wage places the firm at a worse competitive posittion in the product market, leading to market share loses and employment cuts.

Taking equations (2), (5) and (7) together we have that U_j is concave in its own argument, w_j, and may increase or decrease in w_j depending on the relevant parameter range. Furthermore, wages are *strategic complements* from the point of view of unions. In fact,

$$\frac{\partial^2 U_j}{\partial w_j \partial w_i} = \frac{\partial s_j}{\partial w_i} + (w_j - w^a)\frac{\partial^2 s_j}{\partial w_j \partial w_i} \geq 0 \qquad (8)$$

The intuition is as follows: as w_i increases, firm j's competitive standing in the product market is improved, raising both its production and employment, which in turn increases s_j (i.e., $\partial s_j/\partial w_i \geq 0$). Moreover, the negative impact of a wage increase on the survival probability is also tempered as w_i rises (that is, $\partial^2 s_j/\partial w_j \partial w_i \geq 0$). To summarize, when w_i rises, the union associated to firm j can press further for an increase in w_j without fearing layoffs so much. Therefore, workers observed behavior of claiming wage increases to match their fellow workers' wages in competing firms is here shown to be a fully rational decision. We do not need to refer to any psychological or sociological argument (as it has been standard in the bargaining literature -see, for instance, Martin, 1992-).

Note that standard models of monopolistic competition *á la* Dixit-Stiglitz and wage bargaining fail to capture the strategic effects described above. Indeed, assuming monopolistic competition in our model of section 2.1, we have that $\partial^2 U_j/\partial w_j \partial w_i = \partial^2 \Pi_j/\partial w_j \partial w_i = 0$, for all $i \neq j$, $i, j = 1, 2$. This has important implications for the understanding of the determinants of equilibrium wages and unemployment (see sections 3 and 4).

Managers' and unions' wage-setting incentives are thus in clear contradiction. Managers try to cut wages by as much as possible in order to improve the firms'

[16] θ_j^* is uniquely determined since for all j, $N_j(\theta)$ is strictly increasing for all θ and M_j constant.

operating margins and to win market share over their competitors. Unions, on the other hand, pursue to raise the earnings of their constituencies taking into account, however, the effect of their wage claims on employment. Moreover, the strategic nature of a wage-setting game between managers also differs from the strategic nature of the same game if played between unions. Wages are strategic substitutes for the former game while they are strategic complements for the latter.[17]

This confrontation between unions and managers at the firm level is resolved through the bargaining process, so that equilibrium wages solve the following first-order conditions,

$$\partial\Omega_j/\partial w_j = \partial\Pi_j/\partial w_j + \beta_j\partial U_j/\partial w_j = 0,\ j = 1, 2. \tag{9}$$

From equation (9) and since $\partial\Pi_j/\partial w_j < 0$ for all w_j, we have that, in equilibrium, $\partial U_j/\partial w_j$ must be positive, which means that equilibrium wages are always too low from the point of view of unions and too high form the perspective of managers. A direct implication of this is that, *ceteris paribus*, union activity (represented by $\beta_j \neq 0$ for all j) lowers firms' profitability in accordance with the existing evidence.[18]

Note that we can only ensure that the pair (w_1^*, w_2^*) solving the first-order conditions in (9) constitutes a proper (interior) equilibrium if β_j is not too low for all j. This is because, albeit U_j is concave in w_j, Π_j is convex. Therefore, to ensure the concavity of the objective function Ω_j at the proposed equilibrium values, we require $\beta_j \geq \overline{\beta_j}(w_1^*, w_2^*) = -[\partial^2\Pi_j/\partial w_j^2]/[\partial^2 U_j/\partial w_j^2] \geq 0$ for all j (where the second-order derivatives of Π_j and U_j are evaluated at (w_1^*, w_2^*)). Provided that this latter condition is satisfied and given the assumptions in section 2.1, there are parameter configurations for which a (subgame) perfect Bayesian equilibrium for our game $\{(w_1^*, w_2^*); (q_1^*(\theta), q_2^*(\theta))\}$ exists and is characterized by equations (5) and (7).[19]

Solving out the system of equations in (9), we have that $\partial\Omega_j/\partial w_j = 0$ is quadratic for all j. This implies that uniqueness of equilibrium is not guaranteed. Indeed, there are parameter ranges for which there are multiple equilibria (a maximum of two). Figure 2 below illustrates a numerical example where there are two equilibria for the overall bargaining game.[20]

Notice also that the sign of $\partial^2\Omega_j/\partial w_j\partial w_i$ and thus the (local) strategic nature of the bargaining game as a whole, also depends upon the exact magnitude of

[17]It can be easily shown that the strategic conflict between unions and managers at the firm level, namely that managers regard wages as strategic substitutes and unions as strategic complements, does not depend on whether managers set quantities or prices *ex post*.

[18]See Clark (1984), Ruback and Zimmerman (1984), Salinger (1984), Rose (1987), and Abowd (1989).

[19]If β_j is low enough for all j, then a corner equilibrium obtains where firms' wages equal w^a for all j.

[20]Numerical examples with multiple equilibria can be obtained from the authors upon request. See Appendix 2 for how to solve the model numerically.

β_i. If $\beta_i \geq \beta_i^*(w_1^*, w_2^*) = -|\partial^2\Pi_j/\partial w_j\partial w_i|/[\partial^2 U_j/\partial w_j\partial w_i]$ (where the cross-derivatives of Π_j and U_j are both evaluated at (w_1^*, w_2^*)), then $\partial^2\Omega_j/\partial w_j\partial w_i \geq 0$, and vice versa. That is, provided union bargaining power is sufficiently important, the bargaining game shows strategic complementarities among its decision variables. Otherwise, it is characterized by strategic substitutability. It can be easily shown that $\beta_j^*(w_1^*, w_2^*) \geq \overline{\beta_j}(w_1^*, w_2^*)$ for all j and irrespectively of (w_1^*, w_2^*), so that both the strategic substitutes and the strategic complements cases are relevant for our comparative statics analysis.[21] So, Figure 1, where the reaction functions are drawn, depicts a unique equilibrium at E showing local strategic substitutability. Figure 2, instead, shows an example of multiple equilibria, E_1 and E_2, with overall strategic complementarity.

[Insert Fig.1]

2.4 Coordination failures

For those parameter configurations under which the game shows *global* strategic complementarity and there are multiple equilibria, one of the two equilibria will have lower wages (*i.e.*, wages closer to the competitive wage) than the other. Therefore, it is possible to establish alternative rankings between the two equilibria according to the different objective functions of the players. Thus, managers would always prefer to coordinate on the low-wage equilibrium while unions may prefer the opposite (see the example in Figure 2).

[Insert Fig. 2]

On pure efficiency grounds the low-wage equilibrium is strictly superior to the high-wage equilibrium as it involves wages closer to the competitive wage. However, players may either fail to coordinate their actions on the low-wage equilibrium, or else, attempt voluntarily to coordinate on the high-wage equilibrium. The problem for a *benevolent* government is then how to induce players to coordinate on the low-wage equilibrium. This topic, however, is beyond the scope of the current paper but deserves further research.[22]

[21] Indeed, we have constructed numerical examples showing existence of equilibria for both kinds of scenarios, available upon request.

[22] The government may not be interested in efficiency only, but may have other interests. For example, it may care for its chances of re-election. In that case, if the *median* voter shares the same preferences as the unions, the government will try to induce coordination on the inefficient (high-wage) equilibrium.

3 Comparative statics

The goal of this section is to disentangle how equilibrium wages and employment react to changes in their basic determinants. However, given that we may face multiple equilibria for certain parameter configurations, our comparative statics analysis is only valid locally. The parameters of interest for this analysis are: w^a (the expected income of a worker who loses his job), β_1 and β_2 (the bargaining power of the unions associated to firms 1 and 2, respectively), M_1 and M_2 (firm 1's and firm 2's number of insiders), a_1 and a_2 (firms' labor productivity), and finally, v_1 and v_2 (the indices of brand and quality differentiation).

Let $\alpha = (w^a, \beta_1, \beta_2, M_1, M_2, a_1, a_2, v_1, v_2)$ be the vector of parameters of interest, and α_k denote any of its elements. Then, it is a standard comparative statics result that.

$$\begin{pmatrix} \partial w_1^*/\partial\alpha_k \\ \partial w_2^*/\partial\alpha_k \end{pmatrix} = -\begin{pmatrix} \partial^2\Omega_1/\partial w_1^2 & \partial^2\Omega_1/\partial w_1\partial w_2 \\ \partial^2\Omega_2/\partial w_1\partial w_2 & \partial^2\Omega_2/\partial w_1^2 \end{pmatrix}^{-1} \begin{pmatrix} \partial^2\Omega_1/\partial w_1\partial\alpha_k \\ \partial^2\Omega_2/\partial w_2\partial\alpha_k \end{pmatrix} \tag{10}$$

where all cross-derivatives in (10) are evaluated at equilibrium values. From (10) we have that for all $i \neq j$ and all k.

$$(\partial w_i^*/\partial\alpha_k) = \eta_1/\eta_2 \tag{11}$$

where

$$\eta_1 = \underbrace{(\partial^2\Omega_j/\partial w_j\partial w_i)(\partial^2\Omega_i/\partial w_i\partial\alpha_k)}_{strategic\ effect} - \underbrace{(\partial^2\Omega_i/\partial w_i^2)(\partial^2\Omega_j/\partial w_j\partial\alpha_k)}_{direct\ effect},$$

and

$$\eta_2 = (\partial^2\Omega_j/\partial w_j^2)(\partial^2\Omega_i/\partial w_i^2) - (\partial^2\Omega_j/\partial w_j\partial w_i)(\partial^2\Omega_i/\partial w_i\partial w_j).$$

Given our previous assumptions, the denominator of (10), η_2, is always positive so that our equilibrium is *stable*. Therefore, the sign of $(\partial w_i^*/\partial\alpha_k)$ equals the sign of η_1, the numerator of (10). A change in the k-th parameter of interest, α_k, has two kinds of effects on equilibrium wages: *direct effects*, captured by the second term in η_1, and *strategic effects*, represented by the first term in η_1. The direct effects lead to shifts of the firms' reaction functions, while the strategic effects lead to movements along the reaction functions. Notice again that traditional monopolistic competition models omit these latter strategic effects by implicitly assuming that $\partial^2\Omega_j/\partial w_j\partial w_i = 0$ for all $i \neq j$.

From (10) and (11) it is clear that to derive our comparative statics exercises we need to go into the signs of the cross-derivatives $\partial^2\Omega_j/\partial w_j\partial\alpha_k$ and, therefore, into the signs of $\partial^2 U_j/\partial w_j\partial\alpha_k$ and $\partial^2\Pi_j/\partial w_j\partial\alpha_k$, for all j, k. The latter expressions represent the change in the bargaining attitudes of unions and managers, respectively, when α_k rises. Table 1 summarizes these signs.

[Insert Table 1]

Most results in Table 1 are self-explanatory. For instance, an increase in w^a (due to either an increase in the unemployment benefit, b, in the competitive wage, w^c, or else to a fall in the probability of unemployment, φ) raises the union's marginal utility from a wage increase (i.e., $\partial^2 U_j/\partial w_j \partial w^a \geq 0$), as laid-off workers benefit from an increase in their expected income (decreasing the cost of becoming unemployed at the margin). Consequently, raising w^a leads to a higher firm j's wage, w_j, for a given value of w_i, $i \neq j$. This is also the case when we let the number of firm j's insiders, M_j, shrink (because of an increase in the quit rate, δ_j, or a fall in previous period employment, $N_{j,-1}$). A fall in M_j raises the survival probability, s_j, for any firm j's employee and for given wages and, more importantly, makes s_j less sensitive to an increase in w_j. Therefore, the union is more likely to press further in order to raise the wage bill of its own firm since layoffs become less of a threat for its membership.

Other results are, perhaps, less intuitive. For instance, an increase in firm j's productivity, a_j, has ambiguous effects. First, it affects the managers' incentives at the margin, but in an ambiguous fashion. On the one hand, cutting wages becomes more attractive in this case since it is easier to steal the rival's market share. However, as the firm gets more productive, wage increases become relatively less costly. Second, it also changes the union's marginal utility from a wage increase. This latter effect does not have a clear sign either. The reason is that an increase in a_j affects firm j's employment, and the survival probability, in two opposite ways. For a given level of output q_j an increase in a_j makes some workers redundant (thus reducing s_j) but, on the other hand, the higher a_j the more competitive is firm j in the product market, which raises q_j, N_j and s_j. The first of these two effects on a_j reduces the union's marginal utility from a wage increase, while the second effect tends to raise it.

If we analyze the effect on firm j's bargaining agents of an increase in firm i's productivity, the ambiguity still persists. Concerning the attitudes of firm j's manager, a rise in a_i makes him more accommodating at the bargaining table since a greater wage reduction would be necessary to steal market share from firm i (i.e., $\partial^2 \Pi_j/\partial w_j \partial a_i \geq 0$). However, the union associated to firm j restrains its wage claims at the same time, as s_j becomes more sensitive to wage increases (i.e., $\partial^2 U_j/\partial w_j \partial a_i \leq 0$).

As in the previous case, an increase in firm i's brand quality, v_i, makes firm j's manager less willing to undercut rival's wages as its offer becomes relatively less valuable for consumers, and hence his ability to steal firm i's market share is reduced (that is, $\partial^2 \Pi_j/\partial w_j \partial v_i \geq 0$). However, it also reduces the union's incentives to press for wage increases ($\partial^2 U_j/\partial w_j \partial v_i \leq 0$) since it raises the sensitivity of s_j to w_j. Exactly the opposite holds when we consider the impact of an increase in v_j on the firm j's manager and union.

Therefore, we can distinguish between two different types of parameters.

Let α to be partitioned into two vectors $\alpha^1 = (w^a, \beta_1, \beta_2, M_1, M_2)$ and $\alpha^2 = (a_1, a_2, v_1, v_2)$. The parameters in α^1 are those for which the sign of $\partial^2\Omega_j/\partial w_j \partial\alpha_k$ is unambiguous, whilst it depends on the exact value of β_j for those parameters in α^2. Now, we are finally in a position to study the impact on equilibrium wages of changes in the parameters of interest. The next subsection studies analitically the comparative statics of equilibrium wages with respect to the parameters in α^1. Section 3.2 deals with the corresponding results for parameters in α^2, by means of numerical simulations.

3.1 Analytical results

From equation (11) and the results in Table 1, Propositions 1 and 2 below follow inmediately.

Proposition 1 *If the PBE (w_1^*, w_2^*) is such that $\beta_j \geq \beta_j^*(\cdot,\cdot)$, then firm j's equilibrium wage (employment) is monotonically increasing (decreasing) in w^a, β_j, and β_i, and monotonically decreasing (increasing) in M_j and M_i, $i \neq j$, $i, j = 1, 2$.*

Proposition 1 analyzes the bargaining outcome when wages are local strategic complements. In this case, firms j's equilibrium wage, w_j^*, is shown to rise with w^a (and, therefore, to rise with b and w^e and to fall with φ), and β_j, and to fall with M_j (or, alternatively, with an increase in δ_j and/or a fall in $N_{j,-1}$), as the standard monopolistic competition model would predict (see Layard *et al.*, 1991). But, w_j^* can also be shown to rise with the rival's union power, β_i, and to fall with the rival's number of insiders, M_i. The last two effects are exclusively strategic so that they cannot be captured by a model such as the monopolistic competition model which disregards strategic interactions among competing firms.

Consider, for example, an increase in β_i. This has a direct and positive effect on w_i for any given w_j (i.e., $\partial^2\Omega_i/\partial w_i \partial\beta_i \geq 0$). Firm j's reaction function remains unchanged, instead, since $\partial^2\Omega_j/\partial w_j \partial\beta_i = 0$. However, the initial increase in w_i due to a greater β_i, leads to a subsequent increase in w_j, as firms' wages are strategic complements. The final impact of an increase in β_i is, therefore, to raise both equilibrium wages w_i^* and w_j^*. Notice that the impact of β_i on w_j^* is purely strategic.

Furthermore, the impact on w_j^* of changes in w^a, β_j, and M_j, although qualitatively identical in the monopolistic competition and the oligopolistic models, may be quantitatively very different. For instance, consider the effect of an increase in w^a: it raises $\partial\Omega_j/\partial w_j$ making it more profitable for firm j to raise wages, but it also raises $\partial\Omega_i/\partial w_i$ and thus w_i^*. Since wages are strategic complements, firm j would react to an increase in w_i by increasing its own wage. This is precisely the strategic effect which is missing in models of monopolistic competition and which biases $\partial w_j^*/\partial w^a$ downwards in this latter kind of models. In Figure 3 below, an increase in w^a shifts firm i's reaction function to the right while it causes firm j's reaction function to shift upwards. Equilibrium wages move from E_0 to E_1. This movement involves both direct and strategic effects. The latter reinforce the inflationary effect on wages of the former, leading to overall larger wages in equilibrium.

[Insert Fig.3]

Proposition 2 *If the PBE (w_1^*, w_2^*) is such that $\beta_j < \beta_j^*(\cdot,\cdot)$ for all j, then firm j's equilibrium wage (employment) is monotonically increasing (decreasing) in β_j and M_i, but monotonically decreasing (increasing) in M_j and β_i, $i \neq j$, $i, j = 1, 2$.*

Proposition 2 focuses on the case where wages are strategic substitutes. Our basic comparative statics results are substantially modified with respect to the strategic complements case in Proposition 1. The equilibrium wage, w_j^*, still rises as firm j's union becomes more powerful in the bargaining process (as β_j rises) or as M_j shrinks, but it now falls with β_i, firm i's union power. This is because as β_i rises firm i's wage also rises which makes it more profitable for firm j to cut wages in order to win a greater share of the market. Since for these values of the $\beta's$ the bargaining outcome is dictated by firms' managers incentives, w_j^* must fall. A similar intuition also applies for falls in M_i. Also in contrast with the strategic complements case, the effect on equilibrium wages of an increase in w^a is, in principle, ambiguous. Of course, raising w^a has a positive direct effect on firms' wages since it strengthens the bargaining positions of unions by reducing each member's marginal loss from a lay-off. However, given strategic substitutability, as the rival's wage increases, it is more profitable to cut one's wage, which pushes equilibrium wages in the opposite direction.

3.2 Numerical computations

As regards the comparative statics results concerning the variables contained in vector α^2, we have to resort to numerical computations in order to sign those effects. In general, we have found that the results lack robustness with respect to the various parameter configurations which yield equilibria as well as the values of β. This outcome challenges comparative statics results found in models which ignore strategic interactions. Take, for instance, the standard effect of productivity changes on wages. In most models, this effect is found to be positive. However, in Figure 4, which corresponds to an strategic complements case, the numerator of (11), η_1, is computed across diferent values of the relative bargaining power of unions, β_j. the effect tends to be negative for low values of β_j, then positive for intermediate values and finally, negative again.[23] It is of course the change in sign of the strategic ($\partial^2\Omega_i/\partial w_i\partial\alpha_k$) and the direct effects ($\partial^2\Omega_j/\partial w_j\partial\alpha_k$) that gives rise to this lack of monotonicity. Similar effects are found for the remaining components of α^2, implying that changes in the firm's productivity or brand's quality and in their rivals' have effects which depend very much on β.

4 Extensions

4.1 Wages and product market concentration

Does competition policy affect equilibrium wages? Are wages positively or negatively related to the degree of concentration in the product market? How are the wage-setting incentives of managers and unions changed as the industry becomes more competitive? This section answers these questions in the light of our model.

Let us consider an n-firm version of our basic model where, in addition and for simplicity only, we suppose that all firms are identical. The first point to notice is that, as n increases and the market becomes more competitive, the wage-setting incentives of managers and unions change in opposite directions. While managers become less eager to undercut rivals' wages (i.e., $\partial^2\Pi_j/\partial w_j\partial n \geq 0$) and, therefore, more accommodating in the bargaining table, unions exert less pressure to raise wages (i.e., $\partial^2 U_j/\partial w_j\partial n \leq 0$). Thus, from the viewpoint of the former, wage reductions are relatively less profitable when the industry works with very small price-cost margins, that is, when the market is very competitive.[24] For unions, on the contrary, as n rises a wage increase becomes less valuable since it is less likely that member workers could enjoy the higher wage as the survival probability of any insider falls with n. Furthermore, the fall in the survival probability is larger for higher wages.

Therefore, the overall relationship between equilibrium wages and market concentration is, in principle, ambiguous. Our main interest is, however, in understanding the behavior of wages when unions do matter. Hence, suppose that union's bargaining power is such that (i) i.e., $\partial^2\Omega_j/\partial w_j\partial w_i \geq 0$ for all $i \neq j, i, j = 1, ..., n$, and (ii) i.e., $\partial^2\Omega_j/\partial w_j\partial n = \partial^2\Pi_j/\partial w_j\partial n + \beta_i\partial^2 U_j/\partial w_j\partial n \leq 0$. Then our n-firm bargaining game shows strategic complementarity and an in-

[23]This could provide an explanation for the actual lack of monotonicity in the productivity effect. Taking as a rough measure of the productivity effects the estimated "insider" weight in several economies (see Layard *et al.*, 1991, ch. 4, Table 4) we find that economies with low β, such as Japan or the US, have weights of 0.30, economies with medium sized weights, such as the Scandinavian countries, have weights of 0.03, whilst economies with high β, such as Spain or the UK, have weights between 0.10 and 0.15.

[24]Given our assumptions on the product market (section 2.1), it is a standard result that firms' price-cost margins fall as the number of firms operating in the market rises. (See, e.g., Tirole, 1988, ch. 5.)

crease in n leads to lower wages. It follows that in oligopolistic industries with powerful unions and where wages are bargained for at the firm level, wages and concentration ratios are positively correlated. Therefore, competition policy may play a very important role in moderating unions' wage claims and in restraining cost-push inflation.[25]

4.2 Industry-wide bargaining

It has been commonly argued that unions find it easier to coordinate their wage claims than firms' managers. Recall that in the context of our model, the managers at competing firms have opposed interests concerning wages: each manager wants its rival to raise wages in order to undercut him and so win over some additional market share. On the contrary, unions' interests need not be in conflict as they all benefit from simultaneous wage increases at their corresponding firms.[26] Assume, therefore, that even if bargaining was conducted at the industry level managers would fail to coordinate their strategies while unions would take into account the impact of their wage claims on other unions' welfare.[27] Firm j's objective function becomes $\tilde{\Omega}_j = \Pi_j + \beta_j(U_j + U_i)$, $i \neq j$. Firm j's equilibrium wage, w_j^{**}, would then solve

$$\partial\tilde{\Omega}_j/\partial w_j = \partial\Pi_j/\partial w_j + \beta_j(\partial U_j/\partial w_j + \partial U_i/\partial w_j) = 0, \quad j = 1, 2. \qquad (12)$$

From equations (9) and (12), and given that $\partial U_i/\partial w_j > 0$ for all w_j, we have that $\partial\tilde{\Omega}_j/\partial w_j > 0$ for $w_j = w_j^*$. Given that $\tilde{\Omega}_j$ is concave for the relevant β_j-range, it follows that $w_j^{**} \geq w_j^*$, the equilibrium wage for the firm-level bargaining model, for all j.

Alternatively, we could assume that managers' and unions' ability to cooperate among themselves is identical, so that industry wages are decided collectively among all of them. In this case, firm j's equilibrium wage, w_j^c, would maximize the joint payoff function $\Omega_1 + \Omega_2$ solving

$$\partial\Pi_j/\partial w_j + \partial\Pi_i/\partial w_j + \beta_j\partial U_j/\partial w_j + \beta_i\partial U_i/\partial w_j = 0, \quad j = 1, 2.$$

Since $\partial U_i/\partial w_j$ and $\partial\Pi_i/\partial w_j$ are both positive and β_j and β_i are such that $\Omega_1 + \Omega_2$ is locally concave, $w_j^c \geq w_j^*$ for all j. (Note that w_j^c and w_j^{**} cannot be easily compared without additional assumptions on the parameters of the model.)

[25]Suppose that (i) still holds but take $\partial^2\Omega_j/\partial w_j\partial n \geq 0$. Then, equilibrium wages are larger, the larger the number of firms in the market. The intuition is that as n increases the payoff associated with a wage cut (a marginal increase in firm efficiency) falls. A similar result is obtained by Martin (1993).

[26]In fact, a wage-setting game exclusively played by unions would share some of the features of a coordination game, namely strategic complementarity and cross-effects of the same sign (i.e., sign $\partial U_j/\partial w_i$ = sign $\partial U_i/\partial w_j$). Only the global concavity of U_j, which prevents the multiplicity of equilibria, makes it not to constitute a proper coordination game.

[27]This is identical to assuming that there is a single union per industry, whose members are the insiders of firms 1 and 2, and which bargains separately with each firm's manager.

In conclusion, we have shown that, for a broad set of assumptions on the way industry-level bargaining is conducted, equilibrium wages (employment) are higher (smaller) when bargaining is conducted at the industry level rather than at the firm level.

4.3 Wages and the business cycle

Suppose that in our basic model of section 2.1 we assume that demand is uniformly distributed on the interval $[\lambda\underline{\theta}, \lambda\overline{\theta}]$, where $\lambda > 0$. Demand *booms* would correspond to $\lambda > 1$ while demand *busts* to $\lambda < 1$. (Assume for simplicity that firms are all symmetric so that $\beta_j = \beta$ for all j.)[28]

An increase in λ makes it more profitable to undercut rival's wages in order to benefit from a bigger slice of the expanded market (that is, $\partial^2\Pi_j/\partial w_j\partial\lambda \leq 0$). Thus, firms' managers would exert a greater downward pressure on wages in booms, and would become less demanding on wage cuts in busts. On the other hand, as λ rises unions can demand greater wages without fearing the risk of layoffs so much. Consequently, they would demand higher wages in booms and would moderate their claims in busts (that is, $\partial^2U_j/\partial w_j\partial\lambda \geq 0$).

Thus the sign of $\partial^2\Omega_j/\partial w_j\partial\lambda$ depends on β. Let $\tilde{\beta}$ be such that $\partial^2\Omega_j/\partial w_j\partial\lambda >$ 0 (< 0) as $\beta > \tilde{\beta}$ ($\beta < \tilde{\beta}$). Straightforward algebraic manipulations lead us to conclude that $\tilde{\beta} < \beta^*$ so that strategic complementarity necessarily implies that $\partial^2\Omega_j/\partial w_j\partial\lambda \geq 0$. Therefore, from equation (11) above, equilibrium wages are monotonically increasing in λ for $\beta \geq \beta^*$. In other words, wages behave procyclically for industries with powerful unions.

However, consider an industry where $\beta \in (\overline{\beta}, \tilde{\beta})$, then wages are strategic substitutes and $\partial^2\Omega_j/\partial w_j\partial\lambda \leq 0$ for all j. Then, given symmetry and stability of equilibrium, and for all j,

$$sign(\partial w_j^*/\partial\lambda) = sign(\partial^2\Omega_j/\partial w_j\partial\lambda)(\partial^2\Omega_j/\partial w_j\partial w_i - \partial^2\Omega_j/\partial w_j^2) \leq 0$$

From equation (11) equilibrium wages fall as λ increases, so that wages are counter-cyclical for low-β industries. Therefore, it may be that in the aggregate real wages will show no cyclical behavior if, for instance, the weights of low-β and large-β industries are similar.[29]

[28] When $\lambda > 1$ (< 1), managers and unions correctly anticipate that *ex post* market demand will be larger (smaller) for any state θ.

[29] Nowadays conventional wisdom is that wages are, if anything, pro-cyclical (see Bernanke and Powell, 1986, for evidence at the industry level, and Bils, 1985, for evidence at the firm level using panel data). However the correlation between changes in real wages and output is most often statistically insignificant (Blanchard and Fischer, 1990, p. 19).

4.4 Taxes, subsidies and equilibrium wages

Let $t > 0 (< 0)$ be a government tax (subsidy) per unit of production. Firm j's *ex-post* profits after taxes are given by equation (1) above, where now $\overline{w}_j$ equals $(w_j/a_j - v_j + t)$ for all j. Unions' objectives are given by equation (2) above.

Solving out the model as in the previous sections we have that: (i) firms' managers are less (more) eager to cut wages when government taxes (subsidies) are imposed on firms (i.e., $\partial^2 \Pi_j / \partial w_j \partial t \geq 0$); and (ii) unions willingness to obtain a wage increase falls (rises) as taxes (subsidies) on production are introduced (i.e., $\partial^2 U_j / \partial w_j \partial t \leq 0$).

From the point of view of managers a tax on production makes stealing market share (and thus wage cuts) less profitable since it reduces the profit margins per unit of output. On the other hand, unions realize that a tax on production reduces employment, and thus the survival probability s_j, for given wages, and also makes this probability more sensitive to wage increases. Therefore, they respond to a tax on production by moderating their wage claims (see (ii) above).

4.5 Open economy implications

Our model can be easily extended to deal with the analysis of strategic trade policy. In particular, we are interested in the effect of tariffs and subsidies on home wages. To do so, let firm 1 be a *home* firm facing competition form a *foreign* firm, firm 2, in the home market. An increase in home tariffs to the foreign firm's product is captured by a fall in v_2 in the context of our model, while an increase in the level subsidies to the home firm is equivalent to an increase in v_1. Therefore from section 3.2 we cannot report unambiguous results, in contrast with the *a priori* thinking that a rise in v_i would allow for a rise in w_j, via protection of concentrated industries (see Borjas and Ramey, 1993).

5 Conclusions

This paper has shown that the comparative statics analysis of equilibrium wages (or, more generally, of the degree of firms' efficiency) requires the explicit recognition of the strategic interactions that take place in the product market.

We have introduced those interactions in an otherwise standard right-to-manage model, where bargaining takes place at the firm level. We have shown that the effect on equilibrium wages of variables like union membership, product differentiation, or alternative wages depends on the strategic nature of the wage-setting process. More precisely, the impact of those variables has been shown to depend on whether wages in different firms are strategic complements or subsidies (i.e., whether increases in one firm's wage lead to an increase or a decrease in other firms' wages), the former case being more likely the higher is the bargaining power of unions at the different firms.

Our analysis has yielded three main sets of results. First, standard non-strategic models of wage setting -the most popular being the monopolistic competition model- miss important determinants of an oligopolistic firm's wages, by ignoring the impact of changes in the conditions at the firm's competitors. As a result, the predictions of those models are sometimes overturned when strategic interactions are considered. For example, increased productivity in one firm may lead to lower, not higher, wages in that firm.

Secondly, strategic wage bargaining may be an additional rationale for multiple equilibria, which has important consequences for economic policy. In our model, there can be considerable variation across economies in the equilibrium wage levels and hence in employment, without a large variation in the underlying determinants of wages, which simply reflects the fact that different economies settle at different equilibria.

Lastly, extensions of the model have provided new results on several issues. For example, unions' bargaining power needs to reach a certain threshold to ensure that a decrease in product market competition will lead to higher wages or that wages will be procyclical.

Finally, this paper could shed light on the specification of wage equations in empirical work. From the previous results it is clear that, once strategic interactions among competing firms are recognized, variables such as the competitors' productivity or their employees' bargaining power should enter the standard insider-outsider wage equations at the firm (or sectoral) level which are found in the literature.[30] Moreover, it becomes clear from the previous analysis that the standard measures of market power, like concentration ratios of the industry in which the firm operates, may be ill suited to capture the link between market power and wages.

6 Appendix 1

This section provides a generalization of Propositions 1 and 2 above to more general demand and distribution functions.

6.1 Mathematical preliminaries

A *lattice* is a partially ordered set $(A, \geq)$ in which any two elements have a supremum and an infimum in the set. A lattice is *complete* if every nonempty

[30]See Nickell and Wadhwani (1990), Nickell *et al.* (1992) and Bentolila and Dolado (1994), among others.

subset of A has a supremum and an infimum in A. For example, any product of compact intervals in the Euclidean space is a complete lattice.

Let A_j be the strategy space for player j, $j = 1, ..., n$. Let $A = \times A_j$. Let τ_j: $A \rightarrow R$ be the twice-continuosly differentiable payoff function, and $\rho \in \aleph$ a vector of parameters for this game. Then $G \equiv \{(A_j, \tau_j)_j; \aleph\}$ is a *smooth* n-player game.

Theorem 1 *(Topkis, 1978). Let τ_j. $A \times \aleph \rightarrow R$ be twice-continuously differentiable on some open interval. Then, τ_j satisfies the cardinal complementarity conditions if and only if: (i) τ_j is supermodular (i.e., $\partial^2\tau_j/\partial a_{jh}\partial a_{jk} \geq 0$ for all $k \neq h$, and $\partial^2\tau_j/\partial a_{jh}\partial a_{ik} \geq 0$ for all $j \neq i$ and for all k and h, where a_{jk} denotes the k action of player j; and (ii) τ_j has increasing differences (i.e., $\partial^2\tau_j/\partial a_{jh}\partial\rho_l \geq 0$ for all j, h, l).*

Definition 1 *G is a supermodular game if for all j: (i) A_j is a complete lattice; (ii) τ_j is twice-continuously differentiable; and (iii) τ_j satisfies the cardinal complementarity conditions.*

Theorem 2 *(Topkis, 1979). Let G be a supermodular game. Then, there exists a Nash equilibrium in pure strategies, which in addition is dominance solvable, for game G. Furthermore, the equilibrium strategies are non-decreasing functions of the elements of $\aleph$.*[31]

6.2 More general demand and distribution functions

Let $f(Q, \theta) = \theta + g(q)$ be a demand function, where $g(\cdot)$ satisfies that (i) $g'(\cdot) \leq 0$, and (ii) $g'(\cdot) + qg''(\cdot) \leq 0$ (so that the product market subgame shows strategic substitutability among its decision variables). Let $\Gamma(\theta)$ be a twice-continuously differentiable c.d.f. on the interval $[\underline{\theta}, \overline{\theta}]$, and $\gamma(\theta)$ ($= \partial\Gamma(\theta)/\partial\theta$, almost everywhere) its corresponding density function.

Let $W_j \equiv [w^a, \overline{w}] \subset R$, be the space of feasible wages for firm j, $j = 1, 2$, where $\overline{w}$ is arbitrarily large, and $W = \chi W_j$. Then W_j and W are complete sublattices.

From the previous assumptions, firm j's *ex-post* profits are given by

$$\Pi_j(q_j(\theta \mid \theta)) = q_j(\theta)(\theta + g(Q) - \tilde{w}_j), \quad j = 1, 2 \tag{13}$$

and the *ex-ante* expected profits equal $\Pi_j = E_\theta(\Pi_j(q_j(\theta \mid \theta))$. Notice that $\partial\Pi_j/\partial w_j = -q(\theta)/a_j < 0$ and $\partial^2\Pi_j/\partial w_j^2 = -\frac{1}{a_j}\frac{dq_j(\theta)}{dw_j} \geq 0$, so that expected profits are strictly decreasing and convex in w_j.

Lemma 1 *Π_j satisfies the cardinal complementarity condition in $(w_j; -w_i)$, for all $i \neq j$, $i, j = 1, 2$.*

[31] This section follows closely the surveys on supermodular games by Fudenberg and Tirole (1991) and references therein.

Proof. Π_j is obviously supermodular in w_j, since $w_j \in W_j$ is real-valued. Thus, it suffices to show that Π_j has increasing differences in $(w_j, -w_i)$, which follows immediately since $sign(\partial^2\Pi_j/\partial w_j\partial w_i) = sign(\partial^2\Pi_j(\cdot \mid \theta)/\partial w_j\partial w_i) = sign\left(-\frac{1}{a_j}\frac{dq_j(\theta)}{dw_i}\right) \leq 0$ for all θ. Q.E.D.

Under the assumptions of this section, we can write the survival probability, s_j, as follows,

$$s_j = (1 - \Gamma(\theta_j^*)) + \int_{\underline{\theta}}^{\theta_j^*} \frac{N_j(\theta)}{M_j} d\Gamma(\theta) \tag{14}$$

Substituting (14) into (2) above, we can immediately show that U_j, the firm j's union objective function is strictly concave in w_j (H can be increasing or decreasing in w_j depending on the relevant range). Moreover,

Lemma 2 *U_j satisfies the cardinal complementarity conditions in (w_j, w_i) for all $i \neq j$, $i, j = 1, 2$.*

Proof. U_j is supermodular since $w_j \in W_j$ is real-valued. To show that U_j satisfies the increasing differences condition in (w_j, w_i), $i \neq j$, it is enough to note that

$$\partial^2 U_j/\partial w_j \partial w_i = \partial s_j/\partial w_i + (\partial^2 s_j/\partial w_j \partial w_i)(w_j - w^a) \geq 0$$

since

$$(i)\ \partial s_j/\partial w_i = \int_{\underline{\theta}}^{\theta_j^*} \frac{1}{M_j a_j}\left(\frac{\partial q_j(\theta)}{\partial w_i}\right) d\Gamma(\theta) \geq 0 \ as\ \frac{\partial q_j(\theta)}{\partial w_i} \geq 0\ for\ all\ \theta$$

and

$$(ii)\ \partial s_j/\partial w_j \partial w_i = \int_{\underline{\theta}}^{\theta_j^*} \frac{1}{M_j a_j}\left(\frac{\partial^2 q_j(\theta)}{\partial w_j \partial w_i}\right) d\Gamma(\theta) + \frac{1}{M_j a_j}\gamma(\theta_j^*)\frac{\partial q_j(\theta_j^*)}{\partial w_i}\frac{\partial \theta_j^*}{\partial w_i} \geq 0$$

since $\partial^2 q_j(\theta)/\partial w_j \partial w_i \geq 0$ and $\partial q_j(\theta_j^*)/\partial w_i$, $\partial \theta_j^*/\partial w_i$ both ≤ 0. Q.E.D.

Firm s equilibrium wages (w_1^*, w_2^*) solve equation (9), as long as $\beta_j \geq \overline{\beta}_j(w_1^*, w_2^*) = -(\partial^2\Pi_j/\partial w_j^2)/(\partial^2 U_j/\partial w_j^2) \geq 0$ for all j (where the second-order derivatives of Π_j and U_j are evaluated at (w_1^*, w_2^*)).[32] Moreover, let β_j^* (w_1^*, w_2^*) are equal to $-(\partial^2\Pi_j/\partial w_j \partial w_i)/$ $(\partial^2 U_j/\partial w_j \partial w_i)$, (where the cross-derivatives of Π_j and U_j are evaluated at (w_1^*, w_2^*)).

Proposition 3 *If the PBE (w_1^*, w_2^*) is such that $\beta_j \geq \beta_j^*(w_1^*, w_2^*)$ then firm j's equilibrium wage (employment) is monotonically increasing (decreasing) in w^a, β_j, and β_i, and monotonically decreasing in M_j and M_i, $i \neq j$, $i, j = 1, 2$.*

[32] In equilibrium, $\frac{\partial U}{\partial w} > 0$ so that $\frac{\partial^2 \Omega}{\partial w\, \partial \beta} \geq 0$, for all j.

Proof. Let $\sigma = (w^a, \beta_1, \beta_2, -M_1, -M_2)$. The bargaining game $G \triangleq \{(W_j, \Omega_j)_j; \sigma\}$ is a smooth supermodular game around (w_1^*, w_2^*), given Lemmas 1 and 2 above and the fact that $\partial^2\Omega_j/\partial w_j \partial\sigma_k \geq 0$ for all σ_k, the k-th element of σ. Then, Proposition 3 follows directly from Theorem 2 above. Q.E.D.

Proposition 4 *If the PBE (w_1^*, w_2^*) is such that $\beta_j < \beta_j^*$ for all j, then the firm j's equilibrium wage (employment) is monotonically increasing (decreasing) in β_j and M_i, but monotonically decreasing (increasing) in M_j and β_i, $i \neq j$, $i, j = 1, 2$.*[33]

Proof. We take $\tilde{w}_1 = w_1$ and $\tilde{w}_2 = -w_2$ to be firm i's strategic variables, respectively, where $w_1 \in W_1$ and $-w_2 \in \overline{W}_2 = [-\overline{w}, -w^a]$. Let $\tilde{\sigma} = (\beta_1, -\beta_2, -M_1, M_2)$. The bargaining game $\tilde{G} = \{W_1, \overline{W}_2, (a_j)_j; \tilde{\sigma}\}$ is a smooth supermodular game around (w_1^*, w_2^*), given Lemmas 1 and 2 above and the fact that $\partial^2\Omega_j/\partial\tilde{w}_j\partial\tilde{\sigma}_k \geq 0$, for all $\tilde{\sigma}_k$, the k-th element of $\tilde{\sigma}$.[34] Then, Proposition 4 follows directly from Theorem 2 above. Q.E.D.

7 Appendix 2

This appendix explains how we compute numerically the equilibrium values of w_i and w_j. The functional forms we have chosen yield a quadratic first order condition for each firm, which represents the reaction function of the wage in one firm to the other firm's wage. The optimal w_j is given by the solution to:

$$B_j w_j^2 + (C_j + D_j w_i) w_j + (E_j w_i^2 + F_j w_i + G_j) = 0$$

where $B_j = 3/a_j^2, C_j = (6a_j M_j - 4v_j + 2v_i - 4M_j(\overline{\vartheta} - \underline{\vartheta})/(3\beta_j) - 2w^a/a_j - 2\underline{\vartheta})/a_j$, $D_j = -2/(a_j a_i), E_j = 1/(4a_i^2), F_j = (-3a_j M_j + 2v_j - v_i + 4M_j(\overline{\vartheta} - \underline{\vartheta})/(3\beta_j)$ $+2w^a/a_j + \underline{\vartheta})/(2a_i), G_j = -G_j'(3a_j M_j(\overline{\vartheta} - \underline{\vartheta})/(2\beta_j)$, and $G_j' = -\beta_j(9a_j^2 M_j -$ $12a_j M_j v_j + 6a_j M_j v_i + 4v_j^2 - 4v_j v_i + v_i^2)/(6a_j M_j(\overline{\vartheta} - \underline{\vartheta}))$ $+(4/(9a_j) + \beta_j(2w^a/a_j + \underline{\vartheta})/(3a_j M_j(\overline{\vartheta} - \underline{\vartheta})))/(3a_j M_j - 2v_j + v_i)$ $-\beta_j\underline{\vartheta}(\underline{\vartheta}/2 - 2w^a/a_j)/(3a_j M_j(\overline{\vartheta} - \underline{\vartheta})) - 4((\overline{\vartheta} - \underline{\vartheta})/2 + 3a_j M_j)/(9a_j) + \beta_j$

while the solution for w_i is found by substituting the i subindices for j subindices and vice versa.

Equilibrium wages are those roots of these quadratic equations which satisfy both equations simultaneously. Numerically we compute them by plugging an

[33]Note that in this case we cannot analytical comparative statics results for w^a, since $\partial^2\Omega_j/\partial(-w_i)w^a \leq 0$.

[34]Vives (1990) shows how two-player games with strategic substitutes can be made supermodular by transforming the strategic variables as we do in this proof.

arbitrary value for w_i in the expression for the root for w_j and vice versa, and iterating on the solutions being found until the following criterion is arbitrarily close to zero:

$$\left[(w_j(n) - w_j(n-1))^2 + (w_i(n) - w_i(n-1))^2\right]^{1/2}$$

where n denotes the number of the iteration. Once a solution is found, we check that the equilibrium wages are non-negative real numbers strictly above the alternative wage, which yield positive production levels and satisfy the second-order conditions.

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Table 1: Cross-derivatives of Π^e_j, U_j and Ω_j ($j = 1,2$) with respect to ω_j and the model's parameters

	α^1					α^2			
	ω^a	β_j	β_i	M_j	M_i	a_j	a_i	v_j	v_i
Π^e_j	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	? (?)	+ (0)	− (−)	+ (0)
U_j	+ (+)	0 (0)	0 (0)	− (−)	0 (0)	? (?)	− (0)	+ (+)	− (0)
Ω_j	+ (+)	+ (+)	0 (0)	− (−)	0 (0)	? (?)	? (0)	? (?)	? (0)

Note: Signs in parenthesis correspond to the same cross-derivatives for the monopolistic competition model.

Fig. 1 Equilibrium with strategic substitutability

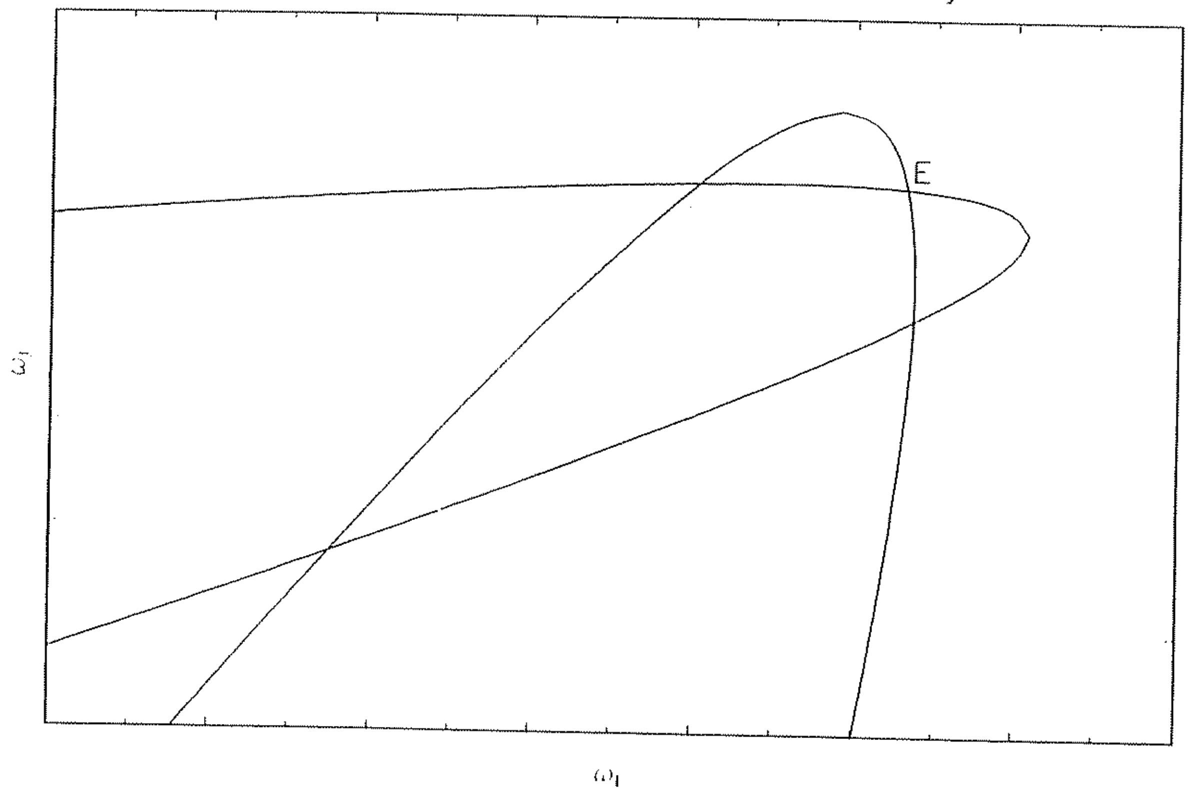

Fig. 2. Multiple equilibria with strategic complementarity

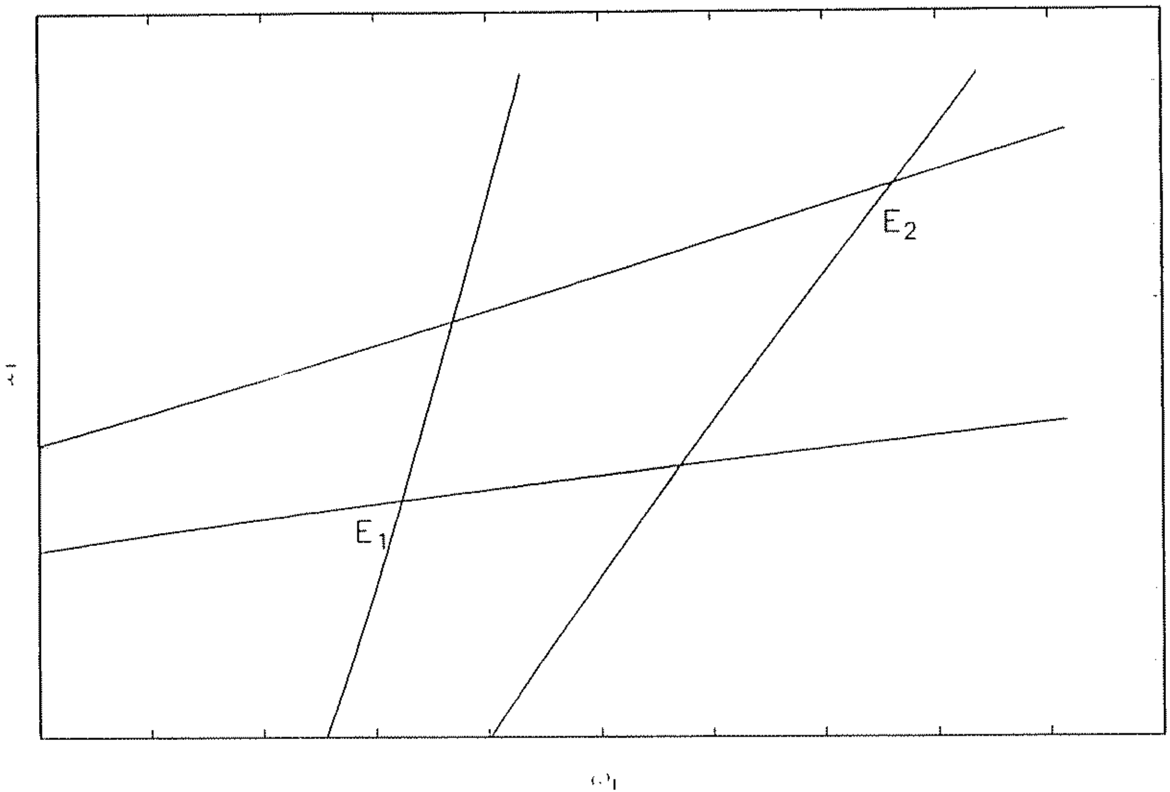

Fig. 3. Effects of higher alternative wage

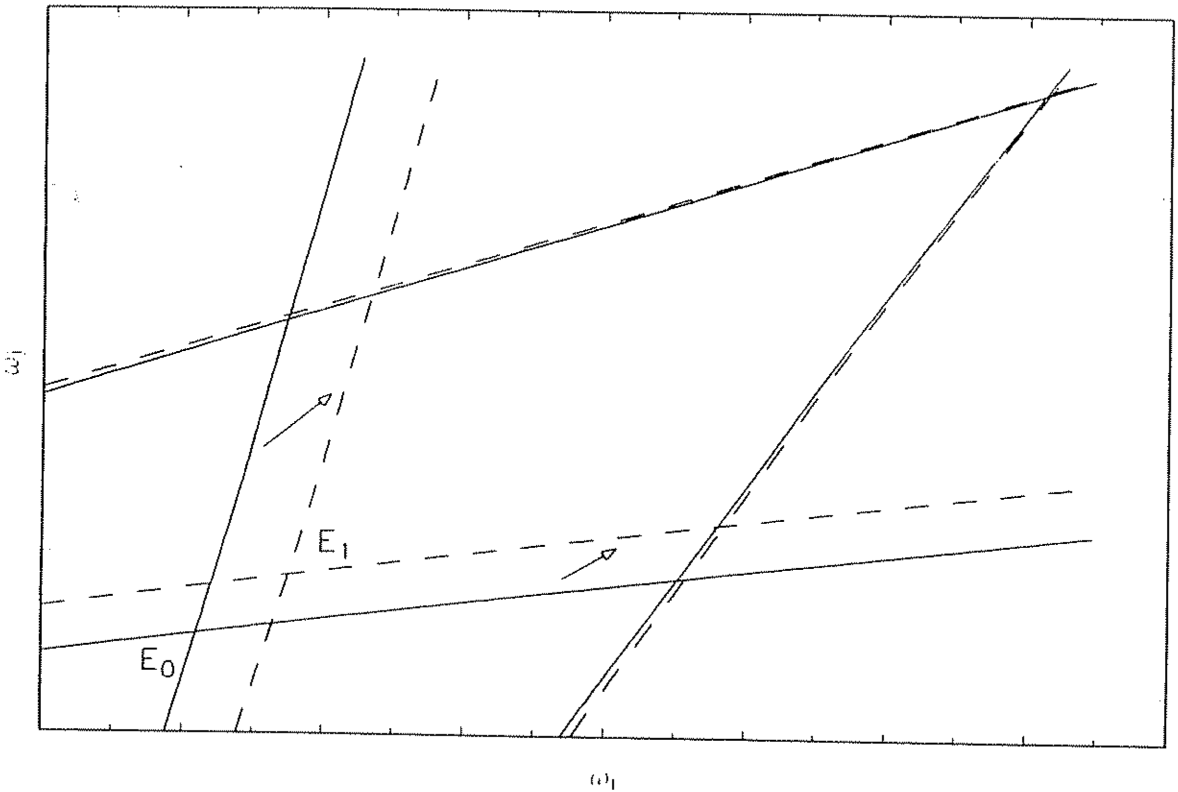

Fig. 4 Numerator of $\partial \omega_i^* / \partial a_i$