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A strategic approach to wage rates as barrier to entry

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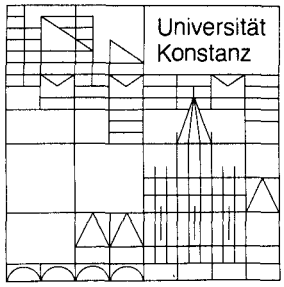

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A Strategic Approach to "Wage Rates as Barrier to Entry"

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A STRATEGIC APPROACH TO "WAGE RATES AS BARRIER TO ENTRY"

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ABSTRACT

In a seminal paper O. Williamson (1968) pointed out the relevance of wage rates as a barrier to entry. The crucial point in Williamson's argument is the technological difference between incumbents and entrants – as a potential entrant is supposed to produce with a more labor intensive technology than an incumbent it seems to be plausible to conclude that an increase in wage rates would be more disadvantageous to the potential entrant than to the incumbent.

It is the main purpose to put the problem in a game theoretical framework that seems to be more appropriate to elaborate the strategic aspects. Then as our main result we can demonstrate that there exist deterrence equilibria even if the firms are technologically identical.

I. Introduction

In a seminal paper O. Williamson (1968) pointed out to the relevance of wage rates as barrier to entry. Williamson's starting point was the famous "Pennington case", where the Supreme Court indicated that a trade union has been found in violation of antitrust laws. The United Mine Workers union has been accused of conspiration with one group of employers to impose wage rates that disadvantage another group of firms.
It was the aim of Williamson's paper to give a theoretical explanation within a consistent decision theoretical model. The crucial point in Williamson's argument is the technological difference between the incumbent and the potential entrant. As the potential entrant firm is supposed to produce with a more labor intensive technology than the incumbent it seems to be plausible to conclude that an increase in wage rates would be more disadvantageous to the potential entrant firm than to the incumbent. Consequently the incumbent might be interested in higher wage rates if it could succeed in preventing the competitor from entering the market. In his paper Williamson analyzes the problem as a standard maximization problem of the incumbent firm under a "limit pricing constraint". That is, the market price should be kept below the entrant's average costs. Conditions are given such that the optimal solution requires a positive wage premium (above the market wage).
Even though Williamson's paper is an important milestone in the theory of market entry he does not treat the strategic aspect of the problem adequately. Particularly the role of trade unions in wage determination is neglected. The wage premium in Williamson's model is a decision variable for the incumbent. It is the main purpose of the present paper to put the problem in a game theoretical framework that seems to be more appropriate to elaborate the strategic aspect. For this sake we consider a three person game where the players are a trade union, the incumbent firm and the potential entrant. This game is supposed to be composed of two subgames. Firstly there is a non-cooperative part played by the two firms and which results in a dyopolistic market outcome provided the competitor enters the market. Secondly there is a cooperative part played by the trade union and the incumbent which results in a wage rate prevailing in the labor market.
As our main result we can demonstrate that for a non-empty range of fixed costs for the two firms there exist deterrence equilibria even if both firms are technologically identical. This result supports our view that Williamson's argument need not be based on technological differences of firms if the strategic aspect of the problem is elaborated appropriately. In our framework we utilize results of the cooperative wage-bargaining theory that has been developed during the past ten years (e. g. McDonald/Solow (1981), Oswald (1985)) and standard concepts that have been introduced recently in the market entrance literature. (e. g. Dixit (1980), Milgrom/Roberts (1982)).

In some sense our argument is based on a strategy called "raising rivals costs" that has been discussed in a rather unspecific framework by Salop/Scherfman (1983).

According to the line of this arguments the incumbent firm might be interested in raising the wage rate even if his own costs increase. If the wage increase prevents the entrant from entering the market the firm specific demand function for the incumbent could be more profitable than in case of entry. Now it is plausible to expect that there might exist technologies and market demand functions such that the product market effect of wage increase overcompensates the negative technological effect. In our framework we have in addition to guarantee that the trade union agrees with a wage increase even though a potential increase in employment induced by market entry would not be realized. We will demonstrate below that the decision problem of a trade union can be formulated in the appropriate way.
Our paper has also been inspired by the work of M. Dewatripont ((1987), (1988)) who pointed out to the lacking of a precise game theoretical framework for the Williamson idea in a footnote (1987, p. 154). Dewatripont analyzes the impact of trade unions in entry deterrence in a recent paper (1988) in which there is utilized an idea of Eaton and Lipsey (1980) in entry deterrence.
We see our paper in the tradition of integrating trade union in the analysis of industrial organization. According to Dewatripont's classification (1987) it contributes to the topic "using trade unions to deter entry". In the following chapter II we will give a detailed description of the strategic situation underlying our paper. In chapter III we will attack the problem of determining subgame perfect equilibria inducing entry deterrence. In the final section of chapter III we will illustrate our results by a numerical example. Finally we mention some open problems for further research in chapter IV at the end of the paper.

II. Description of the strategic problem

We are considering here the following situation. In a market there is an incumbent firm that wants to deter a potential entrant from entering the market. Several versions of this problem have been considered in the literature up to now. We will focus here on the particular issue how the entrant firm can utilize the bargaining result with the trade union to prevent entry. This is essentially the case of entry deterrence by "raising rival's costs" as it has been mentioned by Salop/Scherfman (1983). It is the purpose of our paper to give a precise formulation of this phenomenon within a game theoretical framework.

More precisely we consider a three person three stage game. There is the trade union, the incumbent firm and the potential entrant firm. The trade union fixes the wage rate in cooperation with the incumbent firm, while the the incumbent firm fixes the employment. Then the competitor will decide whether to enter the market or to stay out. Both firms are supposed to produce a homogenous product and to

be technologically identical. If the competitor does not enter the market the incumbent firm will be a monopolistic supplier of the product and it will utilize local labour force. If the competitor decides to enter the market both firms will act as suppliers in a homogenous Cournot/Nash dyopoly and both firms will utilize local labor force. To keep the analysis as simple as possible we assume that the maximum labor demand of both firms (acting as dyopolists) can be satisfied by the labor supply and that all workers entering the local labor market are members of the trade union.

In the following let us denote by L_i the labor force employed by firm i (firm 1 = incumbent, firm 2 = potential entrant), by w the wage rate prevailing on the labor market and by u(w) the utility the trade union extracts from the wage rate w paid to the union members. Then the pay-off function of the trade union is supposed to be given by[1)]

$$U(L_1, L_2, w) = Lu(w)$$

where $L=L_1+L_2$ denotes total labor demand. To write down the firms' pay off function we denote by f(.) the production function of the firms, by $R_i^{M(D)}$ the revenue function of firm i if it acts as a monopolist resp. dyopolist. And we denote for short the monopoly profit function by $\Pi_M(.)$, the dyopoly profit function by $\Pi_D(.)$. Finally let us denote by $F(>0)$ the fixed costs of each firm. Then the pay-off functions of the firms can be written as follows.

$$\Pi_1(w_1,L_1,\text{out}) = \Pi_M(w,L_1) = \left(R_1^M(f(L_1)) - wL_1 - F\right) \quad \text{if 2 does not enter}$$

$$\Pi_1(w,L_1,L_2) = \Pi_D(w,L_1L_2) = \left(R_1^D(f(L_1) + f(L_2)) - wL_1 - F\right) \quad \text{if 2 enters}$$

$$\Pi_2(w,L_1,L_2) = \Pi_D(w,L_1L_2) = \left(R_2^D(f(L_1) + f(L_2)) - wL_2 - F\right) \quad \text{if 2 enters}$$

$$\Pi_2(w,L_1,\text{out}) = 0 \quad \text{if 2 does not enter}$$

The complete game is a "mixture" of a cooperative game between the incumbent and the trade union and a non-cooperative game between the incumbent and the potential entrant. According to our introductory remarks the wage rate prevailing in the local labor market is determined cooperatively in the first stage. We will be more precise on the utilized cooperative solution concept below. The incumbent firm responds by setting its labor force demand in the second stage[2)] and finally

1) For a justification of the explicit shape of the pay-off function we refer to McDonald/Solow (1981) resp. to Oswald (1985), here we set $\bar{u} = 0$.

2) This paticular sequence of moves has been justified elsewhere (see Manning (1987)).

the potential entrant decides either to stay out or enter the market and setting its labor force demand in the third stage of the game. Furthermore the players are supposed to have complete information and the two firms have to make their decisions simultaneously.
Then the extensive form of this game can be described by the following "tree" where the simultaneity of the firms' decisions has been formalized by imperfect information of the entrant.

Fig 1.

To keep the representation simple we have inserted in the drawing above only two paths ((w, L_1, L_2), (w, L_1, out)) completely. From this scheme the remaining paths can easily be constructed. One should be aware of the fact that the strategic variables of the players can take uncountably many values. This is marked in the figure by the dashed lines.

Concerning the cooperative phase of the model there are many solution concepts that could be used. To simplify the analysis we will suppose that trade union and incumbent firm agree on a pareto-efficient outcome. This approach is flexible enough to incorporate different bargaining power of the players such that our solution could also be viewed as an asymetric cooperative Nash-bargaining solution. Concerning the non-cooperative phase of the game we can regard this part as a standard Cournot/Nash game given a particular wage rate w. Therefore we can analyze the non-cooperative game between the two firms separately for each path that starts with a given w.

In the remaining part of our paper we will analyze the subgame perfect equilibria of the entrance game as it has been described above. Particularly we are interested in establishing conditions that quarantee the existence of "deterrence equilibria", that is, equilibrium solutions such that the potential entrant can be effectively prevented from entering the market. In this case we would support Williamson's result of "wage rates as barrier to entry" in a strategic framework even for identical firms.

III. Computing Deterrence Equilibria

1) Introductory Considerations

Obviously it would be hopeless to attack the problem of computing equilibria for the entrance game directly. But as we are interested exclusively in subgame perfect equilibria we can simplify the problem considerably by solving it step by step backwards.

Let us consider primarily the problem of the potential entrant. Given the wage rate w prevailing on the labor market the firm will, provided it enters the market, determine its labor demand by solving the problem[1,2)]

$$(1) \qquad \left(R(f(L_1) + f(\overline{L_2})) - wL_2 - F\right) \rightarrow \max_{L_2}$$

$$s.t.: \quad L_2 \geq 0 \ ,$$

where $\overline{L_1}$ is the given labor demand of the incumbent firm. Without loss of generality we will suppose that the incumbent firm already has anticipated its rivals' decision and sets its Cournot/Nash labor demand denoted by $L_{1D}(w)$. Then we can concentrate on solutions of problem (1), denoted by $L_{2D}(w)$ and on the profit-function $\Pi_2(.)$ that is defined as the maximal profit given a particular wage rate $w \geq 0$

$$(2) \qquad \Pi_2(w) = R\left(f(L_{1D}(w)) + f(L_{2D}(w))\right) - wL_{2D}(w) - F$$

of firm 2 as supplier in a symmetric homogenous dyopoly. As we have identical firms it will be more comfortable in the sequel to omit the index at $L_{iD}(.)$. Then we will write instead of (2) above

$$(2') \qquad \Pi_D(w) = R\left(2f(L_D(w))\right) - wL_D(w) - F$$

for firm 2's maximal profit if it enters the market. As the future arguments only depend on firm 1's decision to supply as a dyopolist or monopolist no confusion in notation seems to be possible.
Obviously firm 2 will not enter the market if $\Pi_D(w)<0$. It will be indifferent for a wage rate $\tilde{w}$ where $\Pi_D(\tilde{w}) = 0$ and will enter the market otherwise.
To assure that $\tilde{w}$ is uniquely determined we will need the following (standard) assumptions about the concepts introduced so far.

A.1 : a) $R(.): \mathbb{R}_+ \rightarrow \mathbb{R}$ and $f(.): \mathbb{R}_+ \rightarrow \mathbb{R}_+$ are differentiable and concave functions, where $R(0) = f(0) = 0$.

1) As we consider only identical firms in the same market we omit the index of the revenue function.

2) Without explicitly mentioning it in the sequence we suppose that all optimization problems have unique solutions. A justification for this assumption will be given in section 2.) below.

b) There is at least one wage rate $w' > 0$ such that $\Pi_D(w') > 0$.

Then we can derive the following result concerning the uniqueness of the critical wage rate $\tilde{w}$

Fact 1: Given A.1 and suppose there exists a wage rate $\tilde{w} \in \mathbb{R}_+$, such that $\Pi_D(\tilde{w}) = 0$, then $\tilde{w}$ is unique.

Proof: see Appendix.

With these considerations in mind we can now turn to the cooperative decision problem. The trade union knows that for[1] $w \geq \tilde{w}$ the entrant will prefer not to enter the market but for $w < \tilde{w}$ it will enter the market. In the former situation the trade union might obtain a high wage rate but total labor demand is only equal to a monopolistist's labor demand, denoted by $L_M(w)$. In the latter situation the trade union will obtain a lower wage rate that is compensated by higher employment, equal to $2L_D(w)$. Here we can see how entry deterrence with the help of union activity might be possible. If it is more advantageous for the trade union to have a higher wage rate one can imagine that both players, incumbent and trade union, are interested in wages that are sufficiently high to deter entry.
We can now formalize the problem of wage determination as follows. The trade union anticipates that the incumbant will accomodate to each wage rate optimally according to the entrance decision of the competitor. Then the trade union is supposed to solve the following problem:

$$
\begin{aligned}
(3) \qquad & \tilde{U}(w) \rightarrow \max \\
& \text{s.t.} \quad \tilde{\Pi}(w) \geq c , \\
& \qquad w \geq 0 ,
\end{aligned}
$$

where

$$
\tilde{U}(w) := \begin{cases} L_M(w)u(w) & w \geq \tilde{w} , \\ 2L_D(w)u(w) & 0 \leq w < \tilde{w} , \end{cases}
$$

1) To simplify the strategic problem we propose that firm 2 will prefer to stay out if $\pi_D(w) = 0$.

$$\tilde{\Pi}(w) := \begin{cases} R(L_M(w)) - w L_M(w) - F & w \geq \tilde{w}, \\ R(2L_D(w)) - wL_D(w) - F & 0 \leq w < \tilde{w}. \end{cases}$$

In other words we have to solve a maximization problem under restrictions such that the objective function and the restriction function change over the domain of definition. Obviously in c there is incorporated the bargaining power of the incumbent firm. For technical reasons that will be explained later we assume that there is a lower bound $\underline{c} > 0$ for c. In case $c=\underline{c}$[1)] we have approximately the model of a monopoly trade union (e.g. Oswald (1985)) modified by a survival condition for the firm. The greater the parameter c is the more advantageous is the result for the incumbent firm. Anyway the result will be pareto-efficient.
Obviously it would be hopeless to solve problem (3) directly. To get an overview of the solution we will solve the problem separately for $w \in [0,\tilde{w})$ and $[\tilde{w},\infty)$ and then compare the outcome.
To be more precise we define the sets

$$B_M(F,c) := \{w | R(f(L_M(w))) - wL_M(w) \geq c + F\} \cap [\tilde{w},\infty),$$

$$B_D(F,c) := \{w | R(2f(L_D(w))) - wL_D(w) \geq c + F\} \cap [0,\tilde{w}).$$

which are to be interpreted as the set of admissible wage rates for the maximization problem of the trade union if firm 2 stays out (= $B_M(.)$) resp. enters the market (= $B_D(.)$). As a preliminary assumption we suppose that there exists at least one pair $(F,c) \in \mathbb{R}^2_{++}$ such that $B_M(F,c) \neq \emptyset$ and $B_D(F,c) \neq \emptyset$. We will justify this assumption within a particular framework below.
The objective function $\tilde{U}(.)$ exhibits another shape over $B_M(.)$ and over $B_D(.)$. Now let us consider the maximal utilities

$$\tilde{U}^*_D(F,c) := \max_{w \in B_D(F,c)} \tilde{U}(w),$$

$$\tilde{U}^*_M(F,c) := \max_{w \in B_M(F,c)} \tilde{U}(w).$$

Then we can formulate the problem of the existence of a (subgame perfect) deterrence equilibrium as follows:

(*) Does there exist a pair (F,c) such that $\tilde{U}^*_D(F,c) < \tilde{U}^*_D(F,c)$?

1) And $\underline{c}$ is almost equal to zero.

If the inequality in (*) could be fulfilled then it would be worthwhile for the trade union to set a wage rate large enough to deter entry. According to the reasoning above given this wage rate no firm would want to deviate from its chosen labor demand (= $L_M(w)$) resp. from its decision to stay out. Consequently we have a Nash-equilibrium.

At the current level of generality it would be rather difficult to analyze the problem further, as its solution set essentially depends on the shape of the profit functions and the objective function $\tilde{U}(.)$. Therefore we will continue our discussion by considering the special case of linear demand and production functions below.

2) Equilibrium solutions in the "Linear Case"

In this section we will consider the problem of determining deterrence equilibria by making the following assumptions about the revenue and the production function of the firms.

A.2 Let us denote by x the produced quantity of the commodity, then we set

$$R(x) = (b-ax)^+ x \; ; \qquad (b, a > 0) \; ,$$

$$f(L) = L \; .$$

Now we can express the concepts introduced in the previous section more explicitly over the domain of definition [0,b]

$$L_M(w) = [\frac{b - w}{2a}] \; ,$$

$$L_D(w) = 2 \, [\frac{(b - w)}{3a}] \; ,$$

$$\Pi_M(w) = \frac{(b - w)^2}{4a} - F,$$

$$\Pi_D(w) = \frac{(b - w)^2}{9a} - F \; ,$$

$$\tilde{w} = b - 3\sqrt{aF} \; ,$$

$$B_M(F,c) = \left\{ w \in \mathbb{R}_+ \mid \tilde{w} \leq w \leq b - 2\sqrt{a(F+c)} \right\},$$

$$B_D(F,c) = \left\{ w \in \mathbb{R}_+ \mid 0 \leq w \leq b - 3\sqrt{a(F+c)} \right\},$$

$$\tilde{U}(w) = \begin{cases} \left(\frac{b-w}{2a}\right)u(w) & w \geq \tilde{w}, \\ \frac{2(b-w)}{3a}\,u(w) & w < \tilde{w}. \end{cases}$$

To assure that $B_M(.) \neq \emptyset$, $B_D(.) \neq \emptyset$, $B_M(.) \cap B_D(.) = \emptyset$ and $\tilde{w} \geq 0$ we have to impose some restrictions on F and c. By simple calculation we can see that the set of admissable (F, c) pairs A can be illustrated by the following drawing. Obviously this set is not empty.

Fig. 2.

Remark 1. We suppose that there exists a lower boundary $\underline{c} > 0$ for the bargaining power to assure that $B_M(.)$ and $B_D(.)$ are disjoint. For $c = 0$ we would have $B_M(F,0) \cap B_D(F,0) = \{\tilde{w}\}$ and $\underline{w} = \tilde{w}$. Consequently the objective function of the trade union would not be defined uniquely in $\tilde{w}$. And furthermore for $\underline{w} = \tilde{w}$ there would be an inconsistency with our convention that the entrant already would stay out at wage rate $\tilde{w}$. Consequently $\tilde{w}$ should not belong to $B_D(.)$.
Remark 2. The definition of the set A is mainly motivated by economic reasoning. One could for example consider to modify this set such that it contains fixed costs F so large that firm 2 never considers to enter the market (as its profit is negative for all wage rates). Naturally in this case the problem of market entry becomes a trivial one. Therefore we require a pair (F,c) to be admissible if $B_M(.)$ and $B_D(.)$ are non-empty sets.

Before we proceed further we will make some standard assumptions concerning the trade union's wage-utility function u(.) .

A.3: The function $u(.) : \mathbb{R}_+ \to \mathbb{R}_+$ is twice differentiable, strictly increasing and concave with the normalization $u(0) = 0$.

Now let us consider the decision problem (*) of the trade-union in our particular framework where assumption A.3 is valid.

We can illustrate the problem by the following drawing.

Fig. 3.

Here we denote by $\tilde{U}_D(.)$ (resp. $\tilde{U}_M(.)$) the trade union's objective function in case firm 2 enters the market (resp. does not enter the market).

That is, $\tilde{U}_D(w) = \frac{2(b - w)}{3a} u(w)$ and $\tilde{U}_M(w) = \frac{(b - w)}{2a} u(w)$. Obviously for $w \in B_D(.)$ we have $\tilde{U}(.) = \tilde{U}_D(.)$, for $w \in B_M(.)$ we have $\tilde{U}(.) = \tilde{U}_M(.)$. The sets $B_D(F,c)$, $B_M(F,c)$ are non empty intervals for $(F,c) \in A$ where $B_D(F,c) = [0,\underline{w}]$ and $B_M(F,c) = [\tilde{w},\bar{w}]$. For $c \geq \underline{c}$ we have $B_M(F,c) \cap B_D(F,c) = \emptyset$ and $\underline{w} = \sup B_D(F,c) < \tilde{w} = \inf B_M(F,c)$. That is, the domain $B_M(.)$ is always strictly separated from $B_D(.)$ and is situated "to the right" of $B_D(.)$.

Now it is easy to prove the following facts that can also be read off already from the drawing in Fig. 3.

Fact 2: a) $\tilde{U}_D(.)$ resp. $\tilde{U}_M(.)$ are strictly concave, where $\tilde{U}_D(0) = \tilde{U}_M(0) = \tilde{U}_D(b) = \tilde{U}_M(b) = 0$.

b) $\tilde{U}_D(.)$ and $\tilde{U}_M(.)$ have the same maximand w^*.

From these observations together with Fig. 3 we can easily derive the following statements that will help us in determining the solution of problem (*).

- If $\underline{w} \geq w^*$ then the trade union will not prefer to deter entry (as $w^* \in B_D(.)$ and $\tilde{U}_D(.) \geq \tilde{U}_M(.)$).
- If $\underline{w} < w^*$ then there might be a chance that $\tilde{U}^*_D(F,c) < \tilde{U}^*_M(F,c)$, consequently that an entry deterring wage rate will be chosen by the trade union.

As we are interested in the existence of a solution involving entry deterrence we will investigate further the conjecture above for $\underline{w} < w^*$. First of all let us assume that (F+c) are large enough such that $\bar{w} < w^*$ and

$$\tilde{U}_M(\tilde{w}) < \tilde{U}_M(\bar{w}).$$

According to the definition of $B_D(.)$, $B_M(.)$ and the concavity of u(.) there exists such a pair (F,c).
Then a deterrence equilibrium would be established if we could show that there exists at least one admissable pair (F,c) such that

$$D(F,c) := \tilde{U}_D(\tilde{w}) - \tilde{U}_M(\bar{w}) < 0.$$

It is easy to see that there is at least one such pair $(\bar{F},\bar{c})$ such that $\tilde{w} = 0 < \bar{w}$. In this case we have

$$D(\bar{F},\bar{c}) = - \tilde{U}_M(\bar{w}) < 0.$$

Because of the continuity of D(.) there exists a neighbourhood U of $(\bar{F},\bar{c})$ such that

$$D(F,c) < 0 \qquad \text{for all } (F,c) \in U \cap A.$$

Consequently we can assure that there exists a continuum of deterrence equilibria for the case of linear demand and production functions.

Proposition: Suppose assumption A. 3 is fulfilled then there exists at least on (F,c)-pair in A such that an equilibrium solution with entry deterrence will result. The resulting wage rate is given by

$$w = b - 2\sqrt{a(F+c)} \ .$$

Remark 1. It should be remarked here that our result does not depend on the explicit shape of the utility function u(.). We only utilize the fact that the functions $\tilde{U}_D(.)$ and $\tilde{U}_M(.)$ are strictly increasing over a non-degenerate interval near zero and that $B_M(.)$ is situated to the right of $B_D(.)$. This supports our view that the result is true for much more general models. But it seems to be rather difficult to formulate general conditions assuring that the crucial properties of the concepts described above are fulfilled.

Remark 2. In contrast to Williamson's model our result does not depend on any technological differences of the firms in question. We do not make this symmetry assumption because of its relevance in real world entrance games but mainly for the sake of revealing the essential strategic aspect of wage rates as barrier to entry. Naturally the set of entry deterring (F,c) pairs will be enlarged if the potential entrant firm is characterized by a more labor intensive technology.

From an economic point of view our argument implying the proposition can be interpreted as follows. Suppose there is a region of wages such that the trade

unions objective function is increasing[1)] (in our model an appropriate neighbourhood of zero). And let there be (F,c) pairs (in our model large fixed costs F) such that $B_D(.)$ and $B_M(.)$ are contained in this region. As the trade union is more interested in wages than in employment it pays to increase wages even if it has to dispense with aggregate larger labor demand induced in a dyopoly. Naturally in this case the trade union will increase the wage as far as possible. As the incumbent's monopoly profits are larger than its dyopoly profits one can hope to find a wage rate large enough that would make the expected profits of the entrant negative but would still allow a satisfactory level of profits for the incumbent firm.

3) A numerical example

Obviously from an economic point of view it would be interesting to characterize entry deterrence equilibria and its market outcomes completely. More precisely it would be interesting to determine the range of fixes costs that are able to induce deterrence equilibria and to determine the corresponding wage rates resp. labor force demand. We will analyze the problem for given values of bargaining power, represented by the real number c.
To give a complete characterization of deterrence equilibria we need to specify our model, developed in the previous section, by numerical values as follows.

Let there be a linear demand schedule

$$p(x) = [b - ax]^+$$

where $b = 10$, $a = 1$, and a linear production function $f(L) = L$. Furthermore the trade union's wage utility function is given by

$$u(w) = w .$$

The minimal admissible vaue of c is equal to $\underline{c} = 0{,}1$.

With this specification in mind we can construe the set of admissible (F,c)-pairs below.

Fig. 4

For all (F,c) pairs below the graph of $g_2(.)$ (where $g_2(F) = 5/4\ F$) we have $B_M(F,c) \neq \emptyset$ and for all pairs below the graph of $g_1(.)$ (where $g_1(F) = 100/9 - F$) we have $B_D(F,c) \neq \emptyset$.

1) This implies that a decrease in labor demand is overcompensated by a utility increase generated by an increase in the wage rate.

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Now let us consider a given value c', then we will analyze the deterrence equilibria corresponding to c' by varying the fixed costs F between $\underline{F}$' and $\overline{F}$ (see Fig. 4).[1] For $F<\underline{F}$' we have $B_M(F,c')=\emptyset$ and for $F>\overline{F}$' we have $B_D(F,c')=\emptyset$.
Our strategy in characterizing the set of deterrence equilibria can be illustrated with the help of the drawing below.

Fig. 5.

For given $(F,c') \in A$ we have

$$B_D(F,c') = [0, \underline{w}] = [0{,}10 - 3\sqrt{F + c'}\,] ,$$

$$B_M(F,c') = [\tilde{w}, \overline{w}] = [10 - 3\sqrt{F}, 10 - 2\sqrt{F+c}\,] .$$

Now let us consider values of F such that $B_D(.) \subset [0,5]$ and $B_M(.) \subset [0,5]$, i.e. such that the sets are contained in the subset of the domain of definition of $\tilde{U}_D(.)$ and $\tilde{U}_M(.)$ where both functions are strictly increasing. Then we can define the indirect utility function by

$$\tilde{U}^*_D(F,c') = \left(10 - 3\sqrt{F + c'}\right) 2\sqrt{F + c'}$$

and

$$\tilde{U}^*_M(F,c') = \left(10 - 2\sqrt{F + c'}\right) \sqrt{F + c'}$$

Furthermore let us define the difference function

$$D_{c'}(F) := \tilde{U}^*_D(F,c') - \tilde{U}^*_M(F,c') = \tilde{U}_D(\underline{w}) - \tilde{U}_M(\overline{w}) =$$

$$= 10\sqrt{F + c'} - 4(F + c')$$

which reflects the fact that only the right hand boundaries of B_D an B_M are relevant as candidates for equilibria if we consider the domain [0,5].
As we will show immediately the set of admissible F that induce deterrence equilibria, denoted by $DE_{c'}$ is given by [2]

$$DE_{c'} := \{F \mid (F,c') \in A \text{ and } D_{c'}(F) \le 0\} =$$

$$\left[\left(\frac{10}{4}\right)^2 - c', \left(\frac{10}{3}\right)^2 - c'\right] ,$$

1) In technical terms we consider the " section of A at c' ".

2) Implicitly we are using the convention that the trade union will choose the entry deterring wage $\tilde{w}$ in case $\tilde{U}_D(\underline{w}) = \tilde{U}_M(\tilde{w})$.

where $\left[\left(\frac{10}{3}\right)^2 - c'\right]$ is equal to $\overline{F}$' in Fig.4 and $D_{c'}\left[\left(\frac{10}{4}\right)^2 - c'\right] = 0$.

As we have $D_{c'}(\overline{F}) < 0$ and $D_{c'}(.)$ is strictly decreasing on $DE_{c'}$ the set $DE_{c'}$ really consists exclusively of fixed costs inducing entry deterrence.
We mentioned before that it makes only sense to determine deterrence equilibria by the difference function $D_{c'}(.)$ if the domain sets $B_D(.)$ and $B_M(.)$ are contained in the interval [0,5] in which the objective functions $\tilde{U}_D(.)$ and $\tilde{U}_M(.)$ are strictly increasing. It will be demonstrated below that this is true for our numerical example. Furthermore we will show that the set really contains all $DE_{c'}$ equilibria. Consequently the set of deterrence equilibria is characterized completely in our example.

Fact 3: a) For $F \in DE_{c'}$ we have $B_D(F,c') \subset [0,5]$ and $B_M(F,c') \subset [0,5]$,

b) There does not exist another $(F,c') \in A$ outside of $DE_{c'}$ inducing a deterrence equilibrium.

Proof: See Appendix

Concerning the market outcome we will consider the set of wage rates that are associated to the deterrrence inducing fixed costs $F \in DE_{c'}$. According to the result in Fact 3 we can associate to each F the wage rate $\overline{w}(F) = 10 - 2\sqrt{F+c'}$.

Fig. 6.

Now it is easy to determine the labor demand for $F \in DE_{c'}$. As the incumbent firm is the only demander for labor force for fixed costs $F \in DE_{c'}$, the labor demand curve is given by $L_M(\overline{w}(F))$. The labor demand curve is concave and increasing in F, the wage rate curve is decreasing and convex as it is shown in Fig. 6 above. Finally let us summarize the main points of the numerical analysis:

α) The range of fixed costs inducing entry deterrence does not depend on the value of c'. But the upper and lower limits of $DE_{c'}$ decrease as c' increases. Now let us consider a situation where the technology of both firms is given by fixed costs F^0 that induce entry of both firms. If the bargaining power of the incumbent firm increases such that F^0 is contained in $DE_{c'}$ for an appropriate c' then an entry deterrent wage would be chosen by the trade union. Therefore

large bargaining power of the incumbent firm increases the chance for deterrence.

But one should be careful with this argument as c is limited from above (by the graph of $g_1(.)$ in Fig. 4). If c is too large the problem might not have a non-trivial solution at all.

β) The interval of entry deterring wage rates (=[3.33, 5]) is independent of the bargaining power c' and the maximal entry deterrence wage is equal to the maximand of the trade union's objective function $\tilde{U}_M(.)$ resp. $\tilde{U}_D(.)$.

γ) In contrast to traditional microeconomic monopoly theory labor demand is not independent of fixed costs. Surprisingly we have rising labor demand associated to rising fixed costs.
This reflects the effects of wage bargaining. Given particular bargaining power of the incumbent firm, larger fixed costs are only compatible with lower wage rates. But lower wage rates are associated with larger labor demand according to the "law of demand".

We think that the above conclusions α)-γ) do not only reflect particular figures of our numerical assumptions but show more general properties of our model.

IV. Concluding Remarks

In the previous sections we tried to formalize Williamson's idea of entry deterrence with the help of wage bargaining with a trade union. As Williamson's reasoning is not very precise other formalizations seem to be possible. But we think that our formal model is rather close to Williamson's informal considerations.
With regard to future research on this topic we believe it to be most promising to alter the essentially static character of our model. It would be desirable to adjoin a further round in the game such that the potential entrant is allowed to bargain with the trade union too. This could change our results considerably as the entrant firm not only has to accept a given wage rate but can actively try to influence it. Naturally there seem to be different ways in modelling this. One could take the account of a cooperative bargaining solution between three parties or consider a separate sequential bargaining process between trade union and entrant. These generalizations would soon complicate the model considerably.
Another way of extending our results would be to incorporate the insider-outsider problem in our framework (see for instance Oswald (1985)).
We have assumed implicitly that the trade union is interested in employment of the total available labour force. In other words we have assumed that all workers are members of the trade union. It seems to be more natural to assume that not all workers are union members. In this case one should expect that the trade union

is primarily interested in the employment of its members and afterwards in high wages exclusively. Oswald/Caruth (1986) propose a trade union's objective function that takes account of the insider-outsider problem. We would expect that our results would have to be modified as follows. As the trade union is interested in higher employment (induced by entry of firm 2) only over a restricted domain the set of deterrence equilibria will grow resp. will not shrink. Further investigations are necessary to give a precise formulation of this result.

APPENDIX

Proof of Fact 1: We have to show that $\pi_D(.)$ is non-increasing in w and strictly-decreasing in a neighbourhood of w. By differentiating $\pi_D(.)$ we obtain

$$\pi_D'(w) = 2R'\big(2f(L(w))\big)f'(L(w))\ L'(w) - L(w) - wL'(w) =$$
$$= \Big[2R'\big(2f(L(w))\big)\ f'(L(w))\ L'(w) - w\Big] - L(w) < 0 \quad \text{for } L(w) > 0$$

as the bracketed term vanishes at L(w). This follows from the first order condition for problem (1). The result follows from the continuity of L(.) and as we cannot have $L(\tilde{w}) = 0$.

Proof of Fact 3: a) Obviously, given F, the wage rate $\bar{w}(F) = 10 - 2\sqrt{F+c'}$ will be chosen provided $D_{c'}(F) \leq 0$. Starting from largest fixed costs

$$\overline{F'} = ((10/3)^2 - c')$$

we have $B_D(\overline{F'}, c') = \{0\}$ and $(\sup B_M(\overline{F'}, c') = \{\overline{w}\} = 3{,}33 < 5$. As we have $D_{c'}(\overline{F'}) < 0$, $D_{c'}(.)$ is strictly decreasing over $DE_{c'}$ and $\overline{w}(.)$ is strictly decreasing in F the result follows from the inequality

$$\tilde{w}((10/4)^2 - c') = 10 - 5 = 5 \leq 5.$$

b) It follows from the proof above that

$U_D\big(\underline{w}((10/4)^2 - c')\big) = U_M\big(\overline{w}((5/3)^2 - c')\big)$ (see also the sketch below).

For $F < ((10/4)^2 - c')$ the trade union will choose either $\underline{w}(F)$ (provided $\underline{w}(F) \leq 5$) or $w^* = 5$, where $w^* \in B_D(.)$. That induces entry of firm 2 in both case.

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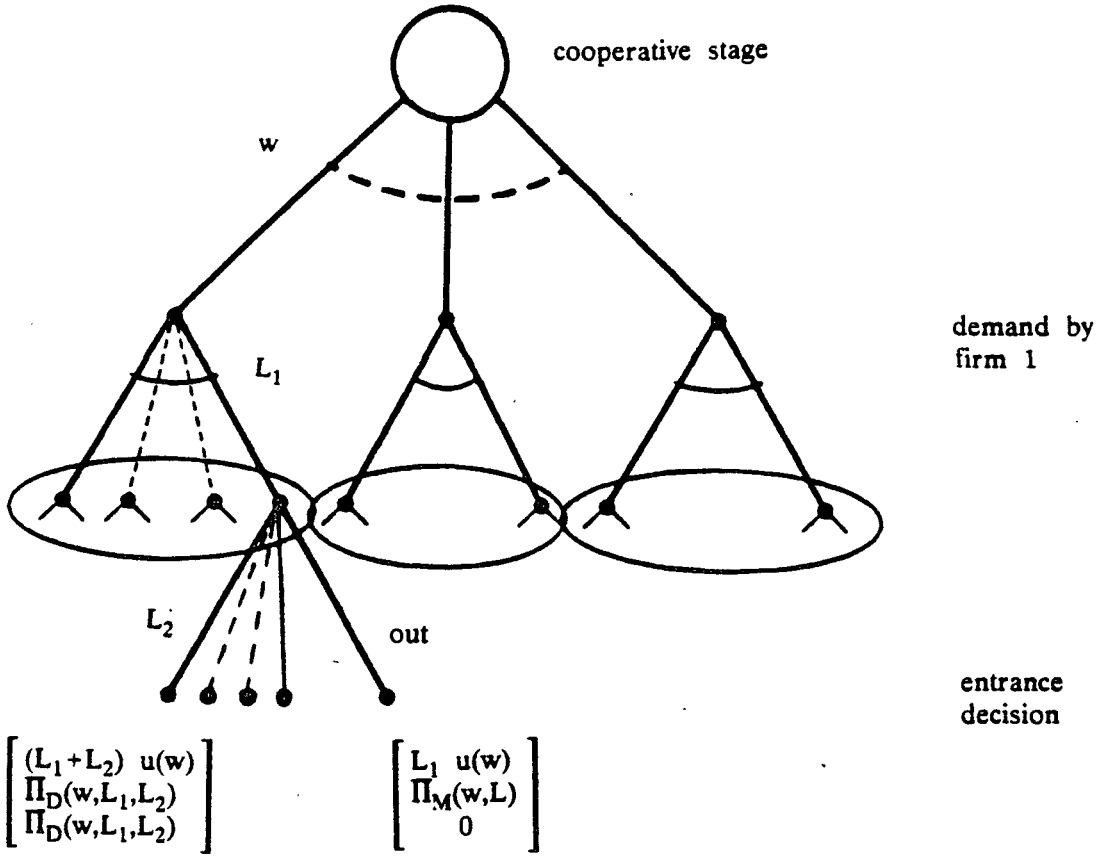

Fig. 1: "Tree" of the entrance game

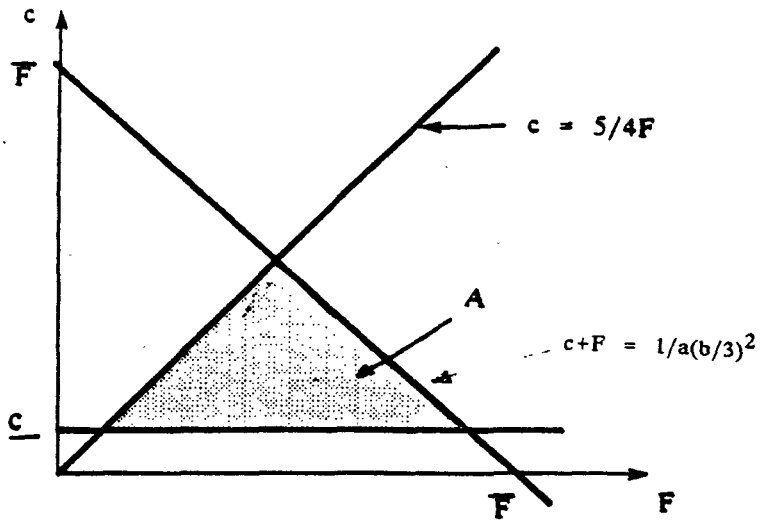

Fig. 2: Set of admissible (F,c)-pairs A, where $\overline{F} = 1/a(b/3)^2$

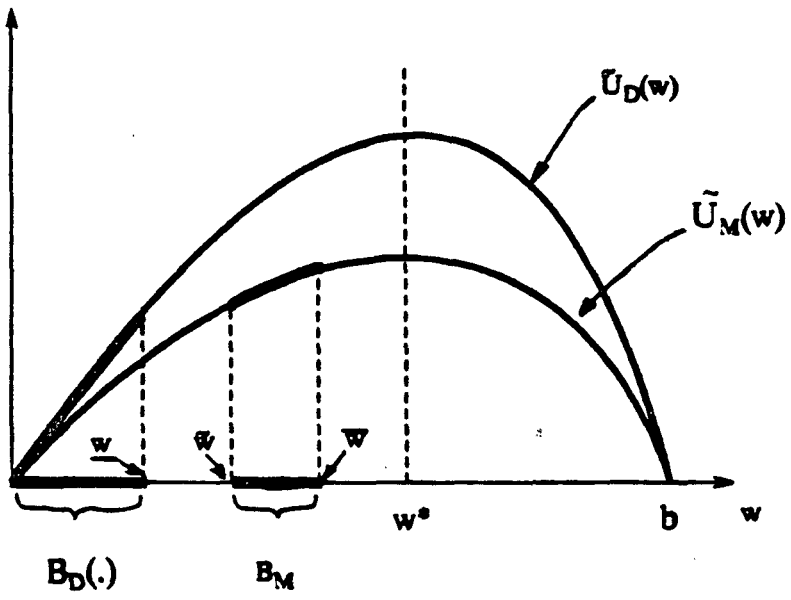

Fig. 3: Illustration of problem (*), where $\underline{w} = b-3\sqrt{a(F+c)}$, $\overline{w} = b-2\sqrt{a(F+c)}$

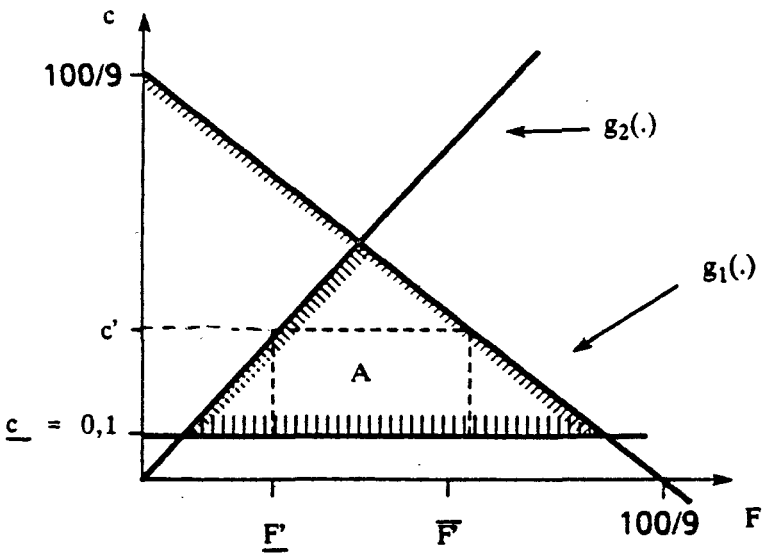

Fig. 4: Set of admissible (F,c)-pairs

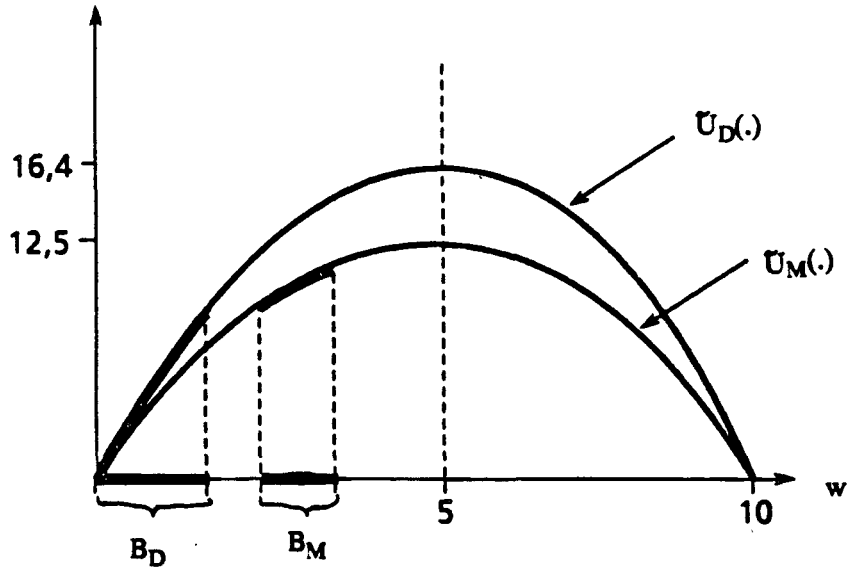

Fig. 5: Illustration of a deterrence equilibrium

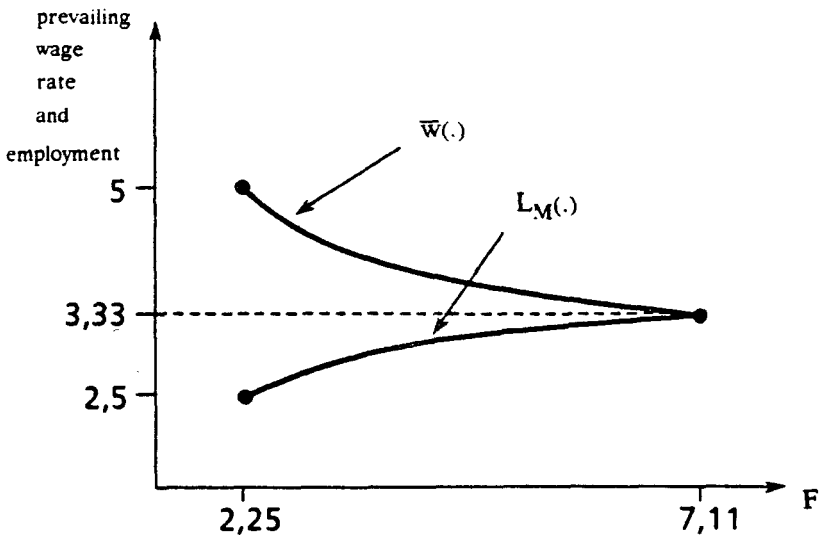

Fig. 6: wage and employment curve for c' = 4