Union-Oligopoly Bargaining and Entry Deterrence: A Reassessment of Limit Pricing

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Abstract

This paper introduces wage bargaining in the framework of Milgrom and Roberts (1982, Econometrica: 50(2), p. 443-459) where the workers' reservation wage is the relevant information parameter critical for entry. We show that entry threat significantly distorts the wage, which in turn adversely affects the firm's ability to signal through price. Consequently, the separating equilibrium (in price) does not always exist. Instead, we get a semi-separating equilibrium. Pooling equilibrium may not also exist. If, however, wage agreements can be made public, signalling occurs with or without distortions in the full information wages. Pooling equilibrium in wage also exists. We also examine whether wage or price is the preferred signalling device, and whether wage agreements should be made public or not.

Keywords: Entry, Bargaining, signalling, Wage, Union-oligopoly.
JEL Classifications: L12, L13, J51, D43, L49.

I Introduction

In their seminal paper Milgrom and Roberts (1982) (MR in short) show that under asymmetric information limit pricing can arise as an equilibrium behavior, in which an

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existing firm signals its cost advantage by charging a pre-entry price significantly below the ordinary monopoly level (separating equilibrium). However, this is not the only possibility. Alternatively, the incumbent can also manipulate the entrant's beliefs in order to discourage entry, if it does not possess a cost advantage. Following Milgrom and Roberts (1982) the entry deterrence literature has been enriched by many studies, which extend limit pricing to multiple signals or multiple information parameters (e.g. Bagwell and Ramey, 1988, 1990; Albaek and Per, 1994; Martin, 1995; Church and Ware, 1996; Linnemer, 1998; Schultz, 1999; Lindsey and West, 2003 to name a few). However, these articles exclusively focus on the product market leaving out upstream considerations of input contracting. As a result the established firm's strategies are entirely based on product market characteristics.

There is another body of work that ignores the question of entry, but integrates strategic interactions in both labor and product markets. Starting with the conjectural variations approach of Dowrick (1989), a variety of issues have been studied in this so-called union-oligopoly literature: strategic choice of bargaining agenda (Bughin, 1999), national wages and global competition in product market (Cornio, 1995), strategic substitutes and complements in wage bargaining (Padilla et al., 1996), employment co-determination (Kraft, 1998), job security and wage bargaining (Majumdar and Saha, 1998), and so on so forth. But the question of entry has been somewhat neglected in the union-oligopoly literature, though empirical research has found strong correlation between unionization and less entry. Using US data Chappell et al. (1992) show that unionization has statistically significant entry deterring effect. Further evidence of correlation between pro-labor legislations and poor economic performance is found in Besley and Burgess (2004) and Botero et al. (2004). We note that there are few studies that considers, using frameworks different from that of union-oligoply models, role of trade unions on strategic product market behaviour in the context of entry. For example, Dewatripont (1987) mentions that commitment to high layoff compensation can help to deter entry, Dewatripont (1988) examines how renegotiation proof labour contracts would make entry-deterring investments (such as capital choice) credible to deter entry, Ohnishi (2001) cites life-time employment contract as an entry deterring device, etc.. However, these works primarily rely on commitment based arguments of entry deterrence in the spirit of Spence (1977) and Dixit (1980).

In this paper we introduce wage bargaining in a model of limit pricing *la* Milgrom and Roberts (1982) where wage is the principal component of the incumbent's marginal cost. Our setup is identical to that of MR except that there is a labor union in the incumbent firm which bargains every period over the wage, before the price is set (the so called "right-to-manage bargaining", Nickell and Andrews (1983)).[1]

For simplicity we consider only one-sided asymmetric information with entrant as the uninformed player. Since wage is endogenous, relevant information parameter in this model is the workers' reservation wage. A low reservation wage (low type) renders entry unprofitable, while a high reservation wage (high type) makes entry attractive. There are two periods and entry can occur only in the second period. In period 1 after setting the wage, the firm-union pair may or may not publicize the wage; price is always public information.

Thus, in our model there are two possible scenarios. If the wage is not publicized, the entrant's beliefs will be entirely based on the price (as in the MR model). This is the standard case of signalling through price. On the other hand, if the wage agreements are made public, the beliefs can be based on the wages, and price may not render additional information. We wish to investigate how price and wage behave in these two scenarios. How do the separating and pooling equilibria of this game look like? Is one of the two signalling devices better than the other from the point of view of the firm-union pair and from the point of view of the society? These are the questions, we try to answer in this paper.

When price is the signalling device, as is expected, price needs to be downwardly distorted to signal the low state. But wage bargaining adds some twists to this. Though profit is not directly type-dependent, the firm 'inherits' the union type through the bargained wage, which must be consistent with subsequent 'limit pricing' in the following sense: (i) Given the wages (unobservable to the entrant), the 'low type' incumbent must find it optimal to distort its price (downwradly) to signal its type, while the high type sticks to its monopoly price, and (ii) the entrant must be able to infer these wages correctly by applying the bargaining rule and backward induction.

We find that separating equilibrium *does not* always exist. The main reason is that when limit pricing is anticipated, bargaining with a low type union may result in a very high wage, and this wage may not permit information revelation (through limit pricing). This will occur if the union's bargaining power is very high. In such cases a semi-separating equilibrium emerges, in which limit pricing does not occur, but the high type incumbent randomizes between charging a low price and charging a high price, and the entrant also randomizes between entering and staying away, if the low price is observed. Thus, the entry outcome differs from the symmetric information scenario, or a fully separating equilibrium. For the high type union entry probability is now less than one, but for the low type union, entry probability is positive. The overall probability of entry may be greater or smaller than that in a separating equilibrium. This is a new result. In the absence of wage bargaining such a possibility will not arise, and separating equilibrium will always exists, as is the case in the MR model. [2]

The pooling equilibrium, on the other hand, *m*ay exist. In a pooling equilibrium the high type firm is expected to choose the low price to mimic the low type, and this will distort the wage for the high type union. Again, if the union's bargaining power is very high, wage will significantly rise. But pooling may or may not be possible at this high wage; this will depend on the parameters of the model. When the pooling equilibrium does not exist, another semi-separating equilibrium emerges, in which the high type incumbent randomizes, but the entrant stays away for sure if it observes the low price. Thus, the chance of entry is unambiguously improved for the entrant, compared to the pooling equilibrium.

In contrast, if wage is announced, we have a straight-forward outcome. As long as the union's bargaining power is below a critical level, full information wages are information revealing, and entry occurs only if the high wage is observed (followed by a matching high price). If the union's bargaining power exceeds the critical level, we see a wage-equivalent of limit pricing, which we may refer to as *limit wage* setting. In a separating equilibrium, limit wage is set by the low type union, while in a pooling equilibrium, both the high and low types set the low type's full information wage. Price in this case always corresponds to the monopoly level relative to the wage announced.

Thus, we see a variety of wage behavior in the face of entry. In the second scenario of signalling through wage, for both types the wage rate never goes above the full information level. This is similar to the price behavior in the MR model. But in the case of signalling through price, wage can rise above, or fall below the full information level. Here the wage rate does not play the role of information sender; nor does it affect the choice of employment for the low type in a separating equilibrium, or for the high type in a pooling equilibrium. Its main role is to distribute surplus. Therefore, we observe two extreme types of wage behavior: excessively high wage if the union is very strong, and excessively low wage if it is too weak.

These observations may be useful in understanding union behavior in the real world. In recent years trade unions reacted to globalization and liberalization in many countries throughout Asia, Africa and Latin America. See Jose (2002) for more details. In case of India trade unions in nationalized banks and airline were at the forefront of agitations during the first half of the 1990-s. Their wages were significantly raised as a measure to safeguard their interest. With entry of new players, their wages actually rose. On the other hand, in the private sector, where unions are relatively weak, wages for ordinary workers did not rise at all. See Majumdar and Saha (1998) for a discussion on the airline industry experience, and Pal and Saha (2006) for the cases where wages may be strategically set to deter or accommodate entry.

Next, we compare between the two signalling devices. Generally, the firm prefers wage to be the signalling device. Workers, on the other hand, prefers price. This asymmetry is driven by the fact that as a signalling device price inflicts disproportionately greater cost on the firm. Wage as a signalling device, on the other hand, singularly penalizes the union, and even benefits the firm. However, from the point of view of the firm and union together, price is the preferred device, unless the union's bargaining power is too high or too low. From the point of view of social welfare also price performs better everywhere except when the union is too powerful. This is because of the fact that price signals involve much greater production than wage signals. Thus, we see that whether price or wage will be chosen to transmit information depends on the institutional factors that govern the process of wage bargaining and labor relations. Finally, our analysis is extended to other setups, namely where costs are correlated across firms in an industry, or where union welcomes entry, or where bargaining covers both wages and employment ("efficient bargaining", McDonald and Solow, 1981).

The rest of the paper is organized as follows. In section II, the basic framework of the model is presented. Section III analyzes signalling through price, while Section IV concerns signalling through wage. A comparison between the two options is made in Section V. Section VI discusses some additional issues. Section VII concludes.

II The Model

There are three players: one incumbent firm, labeled firm 1, its labor union, and an entrant, labeled firm 2. The labor union is sufficiently large (having N members) to supply all the workers needed in firm 1, and it does not deal with the entrant. The incumbent firm and the union engage themselves to what is called the right-to-manage bargaining every period, in which the wage rate is first bargained over, and then employment is unilaterally chosen by the firm.

The production technologies of both firms are assumed, for simplicity, to be of CRS. In firm 1 output (x) and employment (l) are synonymous, $x = l$, which implies that the marginal cost of production is simply given by the wage rate w. The entrant's MC is exogenously given at c. The market demand curve is linear: $p = A - (x + y)$, where y refers to the entrant's output. Firm 1's profit is denoted as $\Pi = (p - w)l$ and firm 2's as $R = (p - c)y$.

The union's objective is to maximize its net wage bill $U = (wl + \theta(N - l)) - \theta N = (w - \theta)l$. The reservation wage rate θ is assumed to take two values: $\theta \in \{\theta_1, \theta_2\}$, $\theta_1 < \theta_2$. The entrant is uninformed about the true value of θ, but the union and the incumbent know it. However, unless additional information is available, the entrant believes that the reservation wage is high (θ_2) with probability ρ ($0 \le \rho \le 1$) and low (θ_1) with probability $(1 - \rho)$. These beliefs are common knowledge. Entry is profitable only against θ_2.

Following the Nash bargaining approach, we assume that the bargaining power of the union is given by γ, $(0 \le \gamma \le 1)$ and conversely that of the firm by $(1 - \gamma)$. The reservation payoffs of the two bargaining parties are zero. Clearly, if $\gamma = 0$, the union doesnot have any bargaining power and the incumbent firm unilaterally sets the wage rate to the threshold level ($w = \theta$). On the other hand, if $\gamma = 1$, the union has the monopoly to set wage. For intermediate values of γ, $0 < \gamma < 1$, wage bargaining between the incumbent firm and its union takes place.

The game lasts for two periods. The stages of the game are as follows.

Period 1

Stage 1:	Mother Nature chooses the reservation wage of workers (θ). (The same reservation wage prevails in both periods)
Stage 2:	Firm 1 and its union bargain over the wage rate, w, for the first period.
Stage 3:	Firm 1 chooses employment (and hence output (x) and price (p)).

Period 2

Stage 1:	Firm 2 observes only the price (p), or both the price and the wage (w), of period 1 and takes entry decision. Firm 2 enters, if it expects to earn positive profit against incurring sunk entry cost F. (In case of entry, firm 2 instantly learns the true value of θ)
Stage 2:	Firm 1 and its union bargain over the wage rate (w) for the second period.
Stage 3:	Firm 1 and 2 engage in Cournot competition, in case of entry, and firm 1 decides employment accordingly.

The symmetric information equilibrium wage, employment and payoffs can be calculated by using backward induction - starting with the employment (or output) and then solving the Nash bargaining problem with respect to the wage, for a given θ_i and monopoly or duopoly. The Nash maximand is $Z = U^{\gamma}\Pi^{(1-\gamma)}$. We assume c is such that $R(c; \theta_2) > 0 > R(c; \theta_1)$.[3] Further, the union is better off under monopoly just like the incumbent, and therefore, would like to see the entrant stay away. [4] We summarize the notation and payoff formulae in Table 1.

Table 1: Notations

Monopoly corresponding to $\theta_i, i = 1, 2$	
Wage	$w_i^M = \gamma \frac{A-\theta_i}{2} + \theta_i$
Employment in firm 1	$l_i^M = (2-\gamma)\frac{A-\theta_i}{4}$
Price	$p_i^M = \frac{A(2+\gamma)+\theta_i(2-\gamma)}{4}$
Union's utility	$U_i^M = \frac{\gamma(2-\gamma)}{8}(A-\theta_i)^2$
Incumbent's profit	$\Pi_i^M = \frac{(2-\gamma)^2}{16}(A-\theta_i)^2$
Duopoly corresponding to $\theta_i, i = 1, 2$	
Wage	$w_i^D = \frac{\gamma(A+c)+2(2-\gamma)\theta_i}{4}$
Employment in firm 1	$l_i^D = \frac{2-\gamma}{6}(A+c-2\theta_i)$
Output in firm 2	$y_i = \frac{1}{12}\{A(4+\gamma) - c(8-\gamma) + 2(2-\gamma)\theta_i\}$
Price	$p_i^D = \frac{A+c+\theta_i}{3} + \gamma\frac{A+c-2\theta_i}{12}$
Union's utility	$U_i^D = \frac{\gamma(2-\gamma)}{24}(A+c-2\theta_i)^2$
Incumbent's profit	$\Pi_i^D = \frac{(2-\gamma)^2}{36}(A+c-2\theta_i)^2$
Entrant's profit	$R_i = \frac{1}{144}\{(4+\gamma)A - (8-\gamma)c + 2(2-\gamma)\theta_i\}^2 - F$; $R_1 < 0 < R_2$
Additional notations corresponding to $\theta_i, i = 1, 2$	
Common discount factor	δ
Limit price	p_i^L
Limit wage	w_i^L
Monopoly price given an arbitrary wage w_i	$p^M(w_i)$
Firm 1's profit from the monopoly price ($p^M(w_i)$)	$\Pi_i^M(w_i)$
Firm 1's profit from price p_i and wage w_i	$\Pi_i(p_i; w_i)$
Incumbent's gains from monopoly	$\Pi_i^M - \Pi_i^D = \Delta_i$
Union's gains from monopoly	$\Omega_i = U_i^M - U_i^D$.

III Signalling through Price

Separating Equilibrium

We begin with the case where the entrant observes only the price in the first period. Neither θ_i nor w_i is observable. This was the setup considered in the MR model. As is well known, if the entrant's expected profit is positive, $\rho R(\theta_2) + (1-\rho)R(\theta_1) > 0$, the low cost incumbent would like to signal its cost through a separating equilibrium. However, in the present model, θ_i is not the true cost; instead it is just a cost determining parameter. Therefore, the entrant has to infer θ_i from the price via the wage rate, which is also unobservable. This inference is an additional requirement of the separating equilibrium in our model.

Given an arbitrary pair of wages (w_1, w_2), prices (p_1, p_2) form separating equilibrium, if by observing p_1 (alternatively p_2) the entrant concludes with certainty that the incumbent is facing a union with θ_1 (alternatively θ_2) as the true reservation wage. It is well known that if such (p_1, p_2) are to be perfect Bayesian equilibrium they must depend on the belief structure of the entrant. For the entrant to update its beliefs, it must correctly conjecture equilibrium wages [5], given which the prices must satisfy the following incentive compatibility conditions:

$$p_2 = p_2^M(w_2) \tag{1}$$

$$\Pi_1(p_1; w_1) + \delta\Pi_1^M \geq \Pi_1^M(w_1) + \delta\Pi_1^D \tag{2}$$

$$\Pi_2(p_1; w_2) + \delta\Pi_2^M \leq \Pi_2^M(w_2) + \delta\Pi_2^D \tag{3}$$

The first equation states that the high cost incumbent should set the monopoly price corresponding to w_2. The second and third inequalities are the familiar incentive compatibility conditions for the low and high cost incumbents respectively. In (2) LHS represents the total discounted profit of the low cost type when it sets p_1, typically lower than the monopoly price $p_1^M(w_1)$. By doing so it will discourage entry and its total two-period (discounted) profit will be greater than the two-period profit from charging the monopoly price and inviting entry. Conversely (3) shows that the high cost type would be better off by setting the monopoly price instead of p_1. In Figure 1, we reproduce (2) and (3) by suppressing the wage terms and rewriting them as:

$$\psi_1(p) = \Pi_1^M - \Pi_1(p) \leq \delta\Delta_1 \tag{2a}$$

$$\psi_2(p) = \Pi_2^M - \Pi_2(p) \geq \delta\Delta_2 \tag{3a}$$

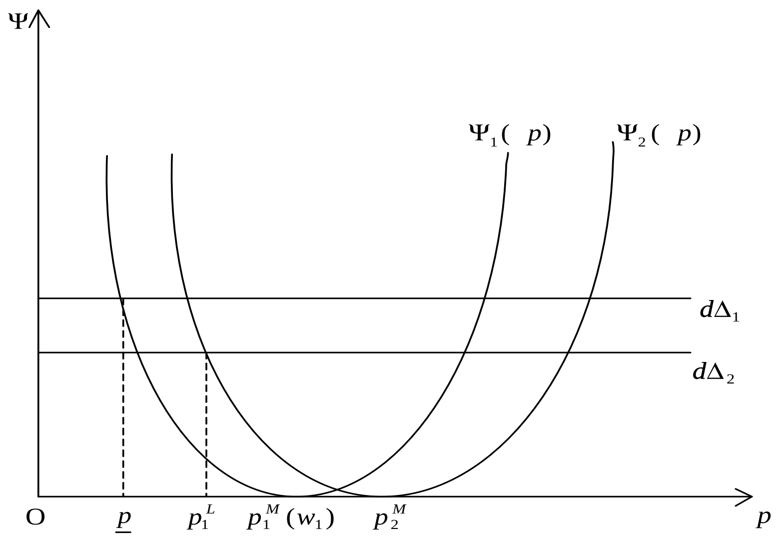

Figure 1: Separating equilibrium price

The RHS terms of (2a) and (3a) relate to second period payoffs (showing future gains from deterrence), which are independent of current prices. From Table 1, it is also clear that, under reasonable set of assumptions, $\Delta_1 > \Delta_2$. The LHS terms show current losses of deviating from the monopoly prices. For θ_1 the loss must be smaller than the gains and for θ_2 it is exactly the opposite. Simultaneously both will hold if $p_1 \in [\underline{p}, p_1^L]$, $p_2 = p_2^M$. The high cost incumbent then will have no incentive to mimic the low cost type (by setting p_1), and will therefore, just charge p_2^M. Further, the incumbent can choose p_1^L from the continuum of prices, because p_1^L brings highest profit while still being incentive compatible. This argument is well known and Figure 1 is all too familiar. In standard cases the values of the two marginal costs (equivalent to w_1 and w_2) are known to the entrant. Implicitly we have assumed $w_1 < w_2$ (equivalent to $MC_1 < MC_2$ in the MR model) to draw Figure 1. But in our case, w_1 and w_2 are not known to the entrant, who therefore must rely on conjectures. If in equilibrium these wages were to be set at their symmetric information levels, the entrant could replace w_1 (and w_2) by a monotonic function of θ_1 (and θ_2), and we would be back to the MR model. However, the wages will be different from the symmetric information level, because of the prospects of limit pricing, and the entrant must be able to conjecture it. Thus, wage bargaining forces us to step out of the MR model. We will see that even if $\theta_1 < \theta_2$, $w_1 < w_2$ is not guaranteed, and this in turn may jeopardize signalling.

Now we turn to wage bargaining. When the union and the incumbent meet at stage 1 of the first period, they take into account how the wage rate will affect the second stage employment (and consequently the price). In a separating equilibrium, the high cost incumbent will choose the monopoly price $p^M(w_2)$, which gives rise to $l_2^M(w_2) = A - p_2^M(w_2) = \frac{A-w_2}{2}$. This in turn in the first stage Nash bargaining implies maximizing $Z = U_2^\gamma \Pi_2^{(1-\gamma)}$, subject to $l_2 = \frac{A-w_2}{2}$. The resultant wage is w_2^M, the symmetric information wage for type θ_2 as shown in Table 1.

The entrant can easily infer this. Then given this conjecture about w_2, it can also figure out p_1^L, the limit price set by the low cost incumbent, by solving (3) for p_1 after setting it as a relation of equality. An important point to note is that p_1^L does not depend on w_1; instead it solely depends on w_2 and thereby on θ_2, and also on A and γ. At the wage setting stage, once again the union (of type θ_1) and the incumbent bargain over w_1 knowing that subsequently the price will be set at p_1^L, which will not depend on w_1.

The Nash bargaining problem is now to maximize $Z = U_1^\gamma \Pi_1^{(1-\gamma)}$, subject to $l_1^L = A - p_1^L(w_2^M)$. It can be shown that, $l_1^L = l_2^M + \sqrt{\delta\Delta_2}$ and the resultant wage is:

$$w_1^L = \gamma(A - l_1^L - \theta_1) + \theta_1 \tag{4}$$

The equilibrium wages (w_1^L, w_2^M) are followed by the choices of (p_1^L, p_2^M), and the entrant will correctly infer the wages after seeing the prices. In this way, wages and prices will be mutually consistent, and will allow the entrant to update its beliefs. In addition we can specify the out of equilibrium beliefs of the entrant to narrow down to the (standard) perfect Bayesian equilibrium.

The consistency between wages and prices, however, cannot be maintained at all possible values of γ. Though implicitly we have assumed in Figure 1, $w_1 < w_2$, it turns out that w_1 may not always be less than w_2, even though $\theta_1 < \theta_2$. The bargained wage in the limit pricing state can be so high that it can even exceed w_2. That is, the firm 1 dealing in with a union with a lower reservation wage might be forced to pay higher equilibrium wage than the other type, if the union is strong. That, however, does not necessarily rule out separating equilibrium. If we take a closer look at Figure 1, for separating equilibrium $p_1^M(w_1) < p_2^M(w_2)$ is only a sufficient condition, but not necessary. What is crucially important is that $\underline{p}$ must be less than p_1^L. Note that the functions, $\psi_1(p)$ and $\psi_2(p)$, differ only with respect to the wage rates (in period 1), and the two curves diverge only when the two wage rates are different. So if the two wages are equal or even w_1 is marginally greater than w_2, still we can have $\underline{p} < p_1^L$. If, however, w_1 is so greater that $\underline{p}$ exceeds p_1^L, then there is no price that can satisfy both incentive compatibility constraints (2a) and (3a), and signalling is not possible. This is indeed the case at all values of γ above a critical level.

In Figure 2 we graph the relationship between γ and w_1^L. As can be seen, though it is steadily increasing, w_1^L can be lower than the symmetric information wage rate w_1^M at low values of γ; but after a point, it exceeds not only w_1^M, but also w_2^M. [6] The line $\underline{w}_1$ represents the wage rate at which (2) holds with equality. As long as w_1^L is less than $\underline{w}_1$, $\underline{p}$ will be less than p_1^L, because w_1^L is derived from p_1^L (or (3a)). But, when $w_1^L = \underline{w}_1$, $\underline{p}$ and p_1^L coincide. A further increase in w_1^L will shift $\underline{p}$ to the right of p_1^L, and no longer will the firm facing θ_1 union be able to signal its type. Thus, γ^S is the highest value of γ up to which signalling is possible. At $\gamma > \gamma^S$ not only is $p_1^M(w_1^L) > p_2^M$, but also $\underline{p} > p_1^L$. No separating equilibrium exists at $\gamma \in (\gamma^S, 1]$.[7] Formally, $\underline{w}_1 = A - 2l_1^L + 2\sqrt{\delta\Delta_1}$, which is increasing in γ.[8]

In order to understand the above result more clearly, let us see what happens in the two extreme situations: $\gamma = 0$ and $\gamma = 1$. If the union does not have any bargaining power ($\gamma = 0$), wage rate will always be set at the reservation wage rate: $w_1^M = \theta_1 = w_1^L$ and $w_2^M = \theta_2$. The high cost incumbent sets the monopoly price, $p_2^M = \frac{A+\theta_2}{2}$, and the low cost incumbent sets $p_1^L = p_2^M - \sqrt{\delta\Delta_2}\ |_{\gamma=0}$ that signals the true state credibly to the entrant. That is, if $\gamma = 0$, separating equilibrium exists and equilibrium outcomes are same as that of MR model. On the other hand, if $\gamma = 1$, the monopoly union will set

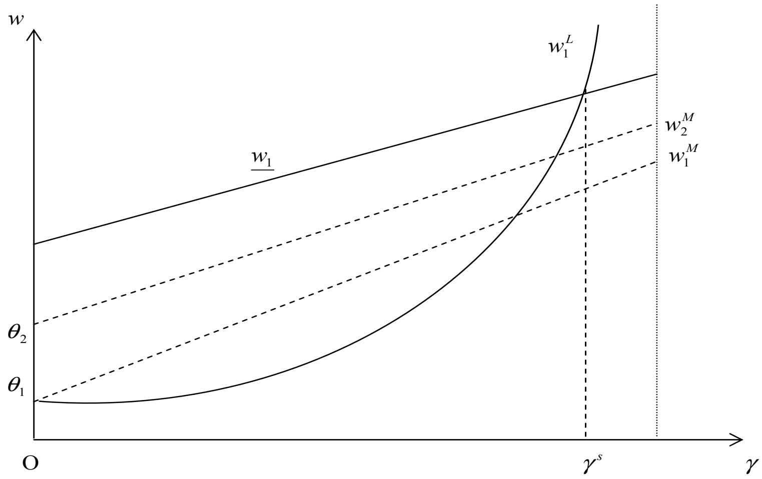

Figure 2: Separating equilibrium wage

the highest wage, $w_2^M = \frac{A+\theta_2}{2}$, $w_1^M = \frac{A+\theta_1}{2}$, $w_1^L = \frac{A+\theta_2}{2} + [l_2^M - \sqrt{\delta\Delta_2}]_{\gamma=1}$ $(> w_2^M)$, and $p_1^L = \frac{3A+\theta_2}{4} - \sqrt{\delta\Delta_2}\ |_{\gamma=1} > \underline{p} = A - \sqrt{\delta\Delta_1}\ |_{\gamma=1}$. So, in case of monopoly union, it is not possible to signal the true state by the incumbent firm.

Basically, when engaged in limit pricing the incumbent firm loses out in the wage bargaining after a point. Here both sides know that the negotiated wage will only distribute rent, but will not affect employment. A very strong union can raise the wage so high that the low cost firm will not be able to profitably distance itself form its high cost counterpart, and the separating equilibrium will cease to exist.[9]

Clearly, the above findings encompasses MR's result as a special case. Moreover, we find that the incumbent firm dealing in with a union with a lower reservation wage, actually pays higher wage, in equilibrium, than the other type, if the union is sufficiently strong. These are interesting findings of this paper.

Proposition 1: a. *The following prices, wages and entrant's beliefs form a separating equilibrium:*

$$[p_1 = p_1^L,\ p_2 = p_2^M],\ [w_1 = w_1^L, w_2 = w_2^M].$$

Observing p_1^L (p_2^M) the entrant believes that the union's reservation wage is θ_1 (θ_2). That is, $\beta(\theta_1|p_1^L) = 1$, $\beta(\theta_2|p_1^L) = 0$ and $\beta(\theta_2|p_2^M) = 1$. Finally, the out-of-equilibrium beliefs are $\beta(\theta_2|p \neq p_1^L) = 1$.

b. *The separating equilibrium exists if $\gamma \leq \gamma^S$.*

Semi-separating Equilibrium

There is a hybrid equilibrium at $\gamma > \gamma^S$. Note that when the low cost type cannot separate itself, the best it can do is set the symmetric information monopoly price p_1^M. If the entrant cannot update its belief, it will enter because $ER = \rho R_2 + (1-\rho)R_1 > 0$. For the high cost incumbent, however, the choice is not clear cut. If the entrant is going to enter regardless of the current price, the high cost firm should sell at p_2^M, the symmetric information monopoly price. But once it does so, the entrant cannot stick to its entry rule. As soon as it recognizes that the high cost firm's pure strategy is to set p_2^M, its best response against p_1^M would be 'stay away'. By realizing that the high cost firm then would like to mimic the low cost firm, and in turn the entrant would revert to the entry rule based on $ER > 0$. Thus, there is no pure strategy equilibrium, when $ER > 0$ and $\gamma > \gamma^S$.

Instead, we can consider a mixed strategy equilibrium, in which the high cost firm will randomize between p_1^M and p_2^M, and the entrant after observing p_1^M, will randomize between entering and staying away. Against p_2^M it will surely enter. Since the low cost incumbent sets p_1^M for sure, its corresponding wage will be w_1^M the symmetric information wage. The high cost firm will have to randomize between two employment levels corresponding to p_1^M and p_2^M, and therefore, its wage bargaining will be constrained, similar to the determination of w_1 in a separating equilibrium. But this time both employment levels are to be taken as constraints. Bargaining will then determine the wage rate in state θ_2. Clearly the wage rate w_2 will be different from the symmetric information wage rate w_2^M as shown in Table 1. We assume that the high cost entrant will not subsequently deviate to some other price such as $p^M(w_2)$, instead of p_2^M, due to some implicit commitment to the union. However, any such deviation will not alter the entry outcome.

Suppose the incumbent facing the θ_2 type union chooses p_1^M with probability α and p_2^M with probability $(1-\alpha)$. On the other hand, the incumbent facing θ_1 type union always sets p_1^M. Then the entrant updates its belief via the Bayes rule as follows:

$$\begin{aligned}\beta(\theta_2|p_1^M) &= \frac{\rho\alpha}{\rho\alpha + (1-\rho)} \\ \beta(\theta_1|p_1^M) &= \frac{(1-\rho)}{\rho\alpha + (1-\rho)} \\ \beta(\theta_2|p_2^M) &= 1\end{aligned}$$

Note that randomization by θ_2 type is optimal if the entrant is also going to randomize, i.e. if it is indifferent between entering and not entering, when it observes p_1^M. Thus, α should be such that

$$\beta(\theta_2|p_1^M)R_2 + \beta(\theta_1|p_1^M)R_1 = 0$$

Substituting the value of $\beta(.)$ we get:

$$\alpha = \frac{(1-\rho)}{\rho}\frac{(-R_1)}{R_2}. \tag{5}$$

It can be easily checked that $\alpha < 1$, if $\rho R_2 + (1-\rho)R_1 > 0$.

Next, we can determine the entrant's mixed strategy, by setting the high cost incumbent's expected payoff from setting p_1^M equal to the payoff from setting p_2^M. Let μ be the probability by which the entrant will enter after seeing p_1^M. Then μ must solve the following:

$$\Pi_2(p_1^M; w_2^H) + \mu\delta\Pi_2^D + (1-\mu)\delta\Pi_2^M = \Pi_2(p_2^M; w_2^H) + \delta\Pi_2^D,$$

where w_2^H is the (hybrid) equilibrium wage set through bargaining in the first stage of period 1. Clearly,

$$\mu = 1 - \frac{[\Pi_2(p_2^M; w_2^H) - \Pi_2(p_1^M; w_2^H)]}{\delta\Delta_2} \tag{6}$$

Finally, we apply Nash bargaining on the expected payoffs of the union and the incumbent as $EU_2 = (w_2 - \theta_2)(\alpha l_1^M + (1-\alpha)l_2^M)$ and $E\Pi_2 = \alpha(p_1^M - w_2)l_1^M + (1-\alpha)(p_2^M - w_2)l_2^M$. It is noteworthy that p_2^M and l_2^M do not depend on w_2; instead they are set at the symmetric information levels, as are p_1^M and l_1^M; α is also independent of w_2. Two reasons can be given to justify this. First, the entrant's wage inference in this case does not affect its updating of beliefs $\beta(.)$-s. Incentive compatibility conditions are also less important here. Therefore, p_2 need not depend on w_2. Second, the wage inference is necessary only to the extent that the entrant is required to play 'enter' with correct probability μ, anticipation of which allows the incumbent to randomize in the first place. Therefore, a simple wage rule is in order. The firm can be assumed to make implicit commitment to the (θ_2 type) union to play p_2^M with probability $(1-\alpha)$, as it does to play p_1^M. Given this argument, the role of the wage rate is reduced to just distributing the surplus. This is similar to the wage under limit pricing.

$$w_2^H = (1-\gamma)\theta_2 + \gamma\frac{[\alpha p_1^M l_1^M + (1-\alpha)p_2^M l_2^M]}{\alpha l_1^M + (1-\alpha)l_2^M} \tag{7}$$

The equilibrium wage w_2^H is a weighted sum of 'average expected revenue' and the reservation wage. With an extremely powerful union, the wage will rise close to the average expected revenue. The low state wage is $w_1^M = \theta_1 + \gamma\frac{(A-\theta_1)}{2}$.

Proposition 2: *When $\gamma > \gamma^S$ there is a semi-separating equilibrium in which the low cost incumbent sets p_1^M, but the high cost incumbent randomizes between p_1^M (with probability α as given in (5)) and p_2^M (with probability $(1-\alpha)$. The entrant enters surely if it observes p_2^M or any other price than p_1^M. When it observes p_1^M, it enters with probability μ as given in (6), and stays away with probability $(1-\mu)$.*

Pooling Equilibrium

Pooling equilibrium is relevant when $\rho R_2 + (1-\rho)R_1 < 0$. In this case, the low cost incumbent has no incentive to deviate from p_1^M. But the high cost incumbent would like to mimic the low cost type, and play for sure p_1^M, so that the entrant cannot update its belief and does not enter. In other words, if $p_1 = p_2 = p_1^M$ the incentive compatibility constraint (2) is satisfied, but (3) will be violated. The condition (3) is now reversed as:

$$\Pi_2(p_1^M; w_2) + \delta\Pi_2^M \geq \Pi_2^M(w_2) + \delta\Pi_2^D \tag{3b}$$

Suppose as in Figure 1, we have $\underline{p} < p_1^L < p_1^M < p_2^M$ (which occurs if $w_1 < w_2$). The high cost incumbent will now sell at p_1^M and discourages entry. However, this will induce the θ_2 union to distort its wage w_2. Through Nash bargaining we get w_2 as:

$$w_2^P = \theta_2 + Max[\gamma(p_1^M - \theta_2), 0]. \tag{8}$$

The low state wage will be equal to the symmetric information wage w_1^M. We need to assume that w_2^P cannot fall below w_1^M. It can be checked that w_2^P can initially remain much below the monopoly wage, thus giving the firm some advantage. But after a point, as γ rises, w_2^P will exceed the symmetric information wage w_2^M, and will make price distortion costlier for the high cost incumbent. It is fairly plausible that w_2^P can rise so much that p_1^L will exceed p_1^M. At least such parameter configurations cannot be ruled out. Let γ^P be the critical value of γ above which pooling fails.

Then we can say that at all $\gamma \leq \gamma^P$, the standard pooling equilibrium occurs, in which both types play p_1^M for sure; the entrant stays away if it observes p_1^M and enters otherwise.

Beyond γ^P we get a hybrid equilibrium, similar to the earlier case, but this time only the high cost incumbent randomizes, and not the entrant. By whatever probability it chooses to play p_1^M or p_2^M, the expected profit of the entrant will always be negative: $\beta(\theta_2|p_1^M)R_2 + \beta(\theta_1|p_1^M)R_1 < 0$ for all $\alpha \in [0,1]$, if $\rho R_2 + (1-\rho)R_1 < 0$. Therefore, the entrant will surely stay away, whenever it observes p_1^M.

But for the high cost incumbent to be indifferent, its payoffs from choosing p_1^M and p_2^M must be same. That is:

$$\Pi_2(p_1^M; w_2) + \delta\Pi_2^M = \Pi(p_2^M; w_2) + \delta\Pi_2^D \tag{9}$$

Now let w_2^h solve this equation. From the Nash bargaining problem, we know as before the union and the firm can set $w_2^H(\alpha)$ as before (see equation(7). Setting $w_2^H(\alpha)$ equal to w_2^h we get a unique α, say α^P. This is the equilibrium mixed strategy by which the high cost incumbent is going to play.

Proposition 3: *In a pooling equilibrium, the incumbent always set the price at* p_1^M *and the entrant stays away. But the pooling equilibrium may not always exist above a critical value of* γ*, in which case the high cost incumbent will randomize between* p_1^M *and* p_2^M*, and the probability of entry will also increase from zero to* $(1-\alpha^P)$.

Effects on Wages

As can be seen, the effects of firm behavior on wages are considerable. Both in the cases of limit pricing and pooling the firm over-employ against one type of the union. Anticipation of this over-employment constrains the bargaining process. The resulting effects on wages are similar in both cases. Under limit pricing (or separating equilibrium) w_1, though always increasing, remains below the symmetric information level over a significant range of γ. This suggests that if the union is relatively weak in bargaining, the firm is going to get an advantage at the wage setting stage due to its strategic behavior at the output setting stage. This is more pronounced in the case of pooling. Here the wage rate for the θ_2 union is pinned down to the lowest level over an interval of γ. Outwardly this may appear as an act of co-operation or sacrifice on the part of the union.

This story is, however, reversed if the union is very powerful. The wage rate will then be significantly higher than the symmetric information level. It can be so high that limit pricing or even pooling may not be possible. As we have explained already, in the states of over employment, the wage rate does not play the role of marginal cost; instead, it is just a device of sharing rents. With high bargaining power the rent share will rise, which then in the output setting game can make the firm unable to either *s*ignal its true cost advantage or to *d*isguise its cost disadvantage. The result is that, in both cases, entry probability will rise.

Proposition 4: *Entry threat reduces wage (for the union type facing over-employment) below its symmetric information level, when the union's bargaining power is low, and the* *opposite is true when the union's bargaining power is high.*

IV Signalling through Wage

From the discussion of the previous section it appears that the unobservability of wage constrains the bargaining process considerably, which then in some cases renders signalling impossible. It may, however, be more efficient in terms of information processing to publicize the wage rate and thus directly signal true θ, without distorting the subsequent price choice. In this section, we examine this possibility, assuming that wage agreements can be credibly made public.[10]

Of course at the time of wage bargaining both sides will pay attention to the incentive compatibility conditions similar to (2) and (3). Implicitly, both sides will have to agree on distorting the wage while separating or pooling. We must note here that from the point of view of the firm a lower wage is now preferred to a higher wage, because subsequently it will choose employment from the labor demand curve (unlike in the previous case of price signalling), and its profit is not type-dependent. So, even if a θ_1 union would like to signal itself through a very low wage, which a θ_2 type would find unprofitable to mimic, the firm may still like the θ_2 type to imitate θ_1 by offering a lump-sum bribe. Indeed if such lump-sum transfers were allowed, θ_1 type would never be able to signal its type.

But we rule out such transfers, and therefore, it is natural to require that a deviation from the normal monopoly (bargained) wage must be based on consensus with neither parties being worse off. Thus, effectively the firm's incentive compatibility constraint becomes less relevant than the union's incentive compatibility constraints. In the spirit of the analysis of the previous section, we can suggest $w_1 = w_1^L (\leq w_1^M)$ and $w_2 = w_2^M$ as a separating equilibrium, where w_2^M is the symmetric information wage in the high state ($\theta = \theta_2$), and w_1 solves the following problem:

$$\text{Max } Z = U_1^{\gamma} \Pi_1^{(1-\gamma)}, \text{ subject to}$$

$$\begin{aligned} l_1 = & \quad \tfrac{A-w_1}{2} \\ U_1(w_1;\theta_1) + \delta U_1^M \geq & \quad U_1^M + \delta U_1^D \qquad (10) \\ U_2(w_1;\theta_2) + \delta U_2^M \leq & \quad U_2^M + \delta U_2^D. \qquad (11) \end{aligned}$$

The first constraint says that employment in state θ_1 will be chosen from the labor demand curve. The second and third inequalities are the incentive compatibility conditions for θ_1 and θ_2 type unions respectively.[11] Their interpretations are identical to (2) and (3).

It can be shown that up to a critical value of γ, say $\hat{\gamma}$, neither constraints, (10) or (11), bind. Hence the full information wage w_1^M is optimal (and information revealing). Above $\hat{\gamma}$, we have the standard separating equilibrium through a downward distortion in w_1, where constraint (11) binds, but (10) does not.

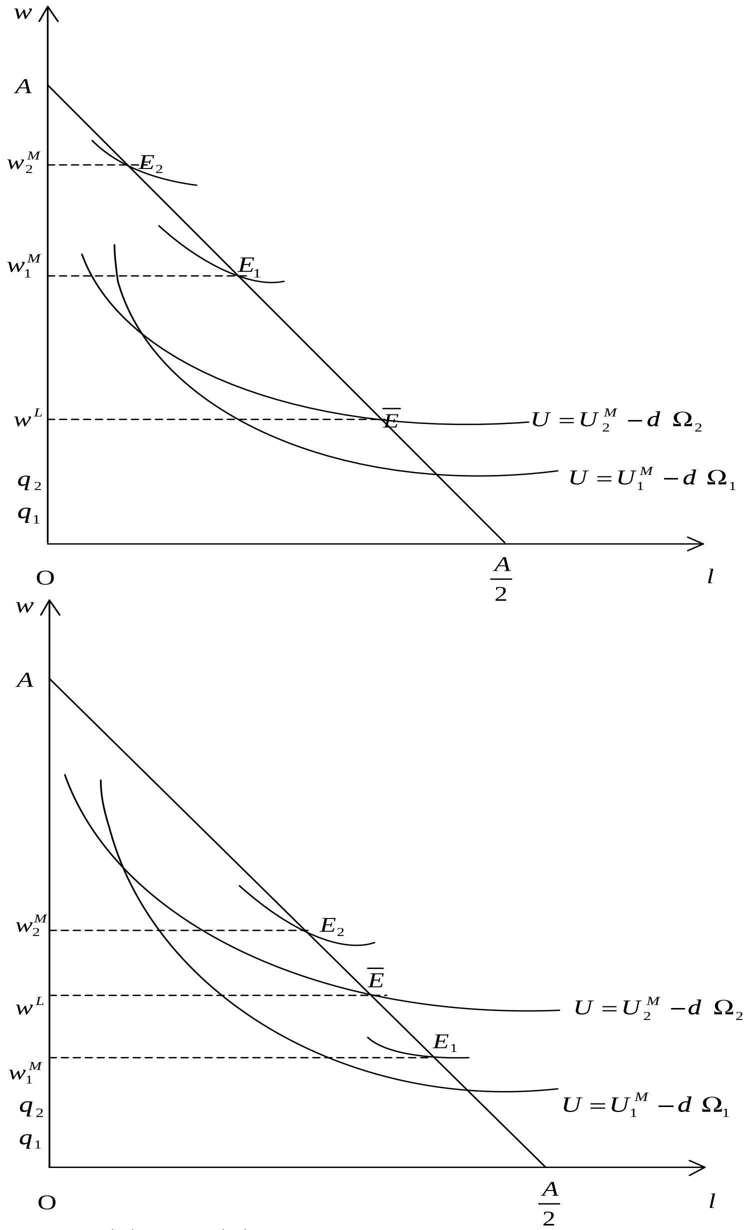

Figure 3 (a) and (b): Two possible equilibrium scenarios

This intuition can be better understood with the help of a graph. Denoting $\Omega_i = (U_i^M - U_i^D)$, $i = 1, 2$, we can rewrite (10) and (11) as:

$$U_1(w; \theta_1) \geq U_1^M - \delta\Omega_1 \tag{10a}$$

$$U_2(w;\theta_2) \leq U_2^M - \delta\Omega_2 \tag{11a}$$

In Figures 3(a) and (b), we plot the union's indifference curves with levels as $(U_1^M - \delta\Omega_1)$ and $(U_2^M - \delta\Omega_2)$. Two full information equilibrium wage-employment pairs are E_1 and E_2, corresponding to θ_1 and θ_2 respectively . Under full information the firm would like to go south-east towards the lowest wage θ_i, while the union would like to go north-west towards the tangency point between its indifference curve and the labor demand curve $l(w)$. Typically, E_1 will lie south-east of E_2. The point $\bar{E}$ where $U_2^M - \delta\Omega_2$ cuts $l(w)$ gives rise to the wage rate w_1^L. Now the nature of separating equilibrium will depend on whether the point E_1 lies to the north-west of $\bar{E}$ as shown in 3(a), or south-east of $\bar{E}$, as shown in 3(b).

If the situation is the one shown in Figure (3a), then we have the standard separating equilibrium at $\bar{E}$ with the limit wage specified at w_1^L. Actually any wage on the labor demand curve lying between the two indifference curves, $(U_2^M - \delta\Omega_2)$ and $(U_1^M - \delta\Omega_1)$, will correctly reveal type θ_1. By the standard argument the union's interest is best served if w_1^L is chosen, and this is also closest to the symmetric information wage w_1^M. On the other hand, if the parameters are such that E_1 lies south-east of $\bar{E}$ as shown in Figure (3b), the symmetric information monopoly wage w_1^M itself be incentive compatible and fully revealing. The high state wage in both cases would be w_2^M or at point E_2.

It turns out that there is a critical γ below which the situation of Figure (3b) occurs and above which we have the case of Figure (3a). If we set $l(w) = U_2(w;\theta_2) - [U_2^M - \delta\Omega_2]$ and solve for w, we get

$$w_1^L = \frac{A+\theta_2}{2} - \frac{1}{2}\sqrt{(A-\theta_2)^2 - 8\gamma(2-\gamma)[(1-\delta)\frac{(A-\theta_2)^2}{8} + \delta\frac{(A+c-2\theta_2)^2}{24}])}. \tag{12}$$

Now it is straight-forward to check that w_1^L starts from θ_2 when $\gamma = 0$ and steadily rises. But w_1^M starts from θ_1 and increases at a higher rate. So w_1^M remains below w_1^L up to a critical γ, say $\hat{\gamma}$. At all these values of γ the full information wages are incentive compatible and truth revealing. Above $\hat{\gamma}$ we have the usual configuration where w_1^L becomes the information revealing wage. By setting $w_1^M = w_1^L$, we get

$$\hat{\gamma} = \frac{2(\theta_2-\theta_1)(A-\theta_2)}{(A-\theta_1)^2 - 8[(1-\delta)\frac{(A-\theta_2)^2}{8} + \delta\frac{(A+c-2\theta_2)^2}{24}]} \tag{13}$$

It is also clear that the pooling equilibrium will be relevant only if $\gamma > \hat{\gamma}$ and if the entrant's expected profit is negative, i.e. $\rho R_2 + (1-\rho)R_1 < 0$. In that case, both types will set w_1^M, and the entrant will stay away.

Proposition 5: *If $\gamma \leq \hat{\gamma}$ full information (monopoly) wages are information revealing. If $\gamma > \hat{\gamma}$, then we have the following perfect Bayesian equilibria: (i) When $ER > 0$, $w_1 = w_1^L$, $w_2 = w_2^M$ and $\beta(\theta_1|w_1^L) = 1$ and $\beta(\theta_2|w \neq w_1^L) = 1$. (ii) When $ER < 0$, $w_1 = w_2 = w_1^M$, and $\beta(\theta_1|w_1^M) = \rho$, $\beta(\theta_2|w \neq w_1^M) = 1$.*

Intuitively, it follows that, if $\gamma = 0$, wage rates will be set to reservation wages ($w_1 = \theta_1$ and $w_2 = \theta_2$), and that will reveal the true information credibly, since the high type union will never opt to go for wage rate less than θ_2. Clearly, in this case, information will be revealed through wage signalling without any distortions in wage and price, and pooling equilibrium is not possible - this is in sharp contrast with the case of price signalling. On the other hand, if $\gamma = 1$, the monopoly union needs to accept a lower wage in order to signal the low state credibly, or to supress the information that it is high type. As a result, in case of monopoly union, low (high) state wage rate will be lower and employment will be higher under separating (pooling) equilibrium than the symmetric information case, which is different from the price signalling case. In case of price signalling, the low state's wage even exceeds the high state's symmetric information wage, under separating equilibrium, if the union is strong.

In sum, when the wage is the signalling device, 'limit wage' instead of limit pricing occurs in the low state. That is, wage is distorted downward to signal the low state. However such distortions are necessary only if the union's bargaining power is above a critical level. This is consistent with the MR model. In the MR model, where the union would be having zero bargaining power, signalling through wage means, revealing the marginal cost, or the full information scenario. We show that giving some amount of bargaining power to the union does not change anything, if the wage agreements are to be made public. Still wages would be set at their full information level, and information will be revealed. It is only after achieving a critical level of bargaining strength, the union may be able to exploit its private information (through a pooling equilibrium) or will have to send a costly signal (as in a separating equilibrium).

V Comparison between Price and Wage Signalling

Price as a signal, as we have seen, imposes a fair amount of cost to the firm because of lower price and loss in wage bargains. On the other hand, in case of signalling through wage, the firm gains due to lower wage, but the union looses if symmetric information wage can not transmit the information credibly. As a result, the firm will always prefer signalling through wage, but the union will prefer signalling through price. This is quite intuitive and the proof is fairly simple. So, we are not providing details over here.[12]

In this section, we examine the question whether from the firm-union pair's point of view any particular device - wage or price - is preferred for the purpose of signalling. Can we also suggest a socially optimal device of signalling?

We restrict our attention mainly to separating equilibrium, and a θ_1 type union. With a θ_2 union both devices lead to same wage and price and therefore, one would be indifferent between the two devices.[13] We consider the *joint payoff* of the union and the firm (profit plus the union's utility), which takes the following expression under signalling through price:

$$\begin{aligned} Z_p &= (A - \theta_1 - l_1^L)l_1^L + \delta(U_1^M + \Pi_1^M), \text{ if } \gamma \leq \gamma^S \\ &= (A - \theta_1 - l_1^M)l_1^M + \delta[\mu(U_1^D + \Pi_1^D) + (1-\mu)(U_1^M + \Pi_1^M)], \text{ if } \gamma > \gamma^S \end{aligned}$$

where $l_1^L = \frac{2-\gamma}{2}\{\frac{A-\theta_2}{2} + \sqrt{\delta(\frac{(A-\theta_2)^2}{4} - \frac{(A+c-2\theta_2)^2}{9})}\}$ and l_1^M, U_1^M, Π_1^M, U_1^D, and Π_1^D are as shown in Table 1.

On the other hand, if wage is the signalling device, the discounted joint payoff is:

$$\begin{aligned} Z_w &= (A - \theta_1 - l_1^M)l_1^M + \delta(U_1^M + \Pi_1^M), \text{ if } \gamma \leq \hat{\gamma} \\ &= (A - \theta_1 - l_1^L)l_1^L + \delta(U_1^M + \Pi_1^M), \text{ if } \gamma > \hat{\gamma}, \end{aligned}$$

where $l_1^L = \frac{A-w_1^L}{2}$ (w_1^L is as given in equation (12)), and $\hat{\gamma}$ is given in (13).
Comparing Z_p and Z_w we find, for $\gamma \in (\underline{\gamma}, \bar{\gamma})$, $Z_p > Z_w$ and therefore price is preferred in this range. Elsewhere wage is the preferred device. In Figure 4, the curves GMFNH and BMEND represents Z_p and Z_w respectively. These two curves intersect at point M and N, which correspond to $\underline{\gamma}$ and $\bar{\gamma}$ respectively. Within this range $Z_p > Z_w$.

To understand this result, let us note that $Z = (A - \theta_1 - l_1)l_1$, which will rise (fall) if $l_1 < (>)(A - \theta_1)/2$. When price is the signalling device, $l_1 (= l_1^L)$ does not depend on w_1; instead it (inversely) depends on w_2. At a very low γ, limit pricing causes l_1^L to exceed $(A - \theta_1)/2$ by a significant margin. This reduces the joint payoffs considerably below the

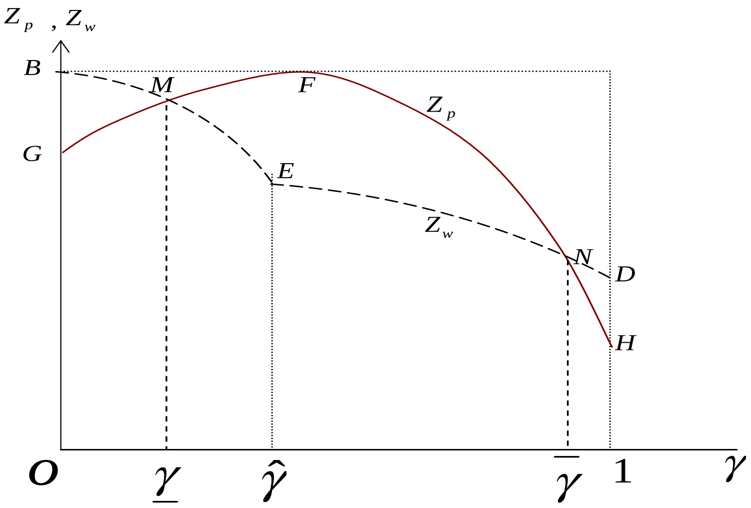

Figure 4: Jointly optimal signalling device

full information level. However, with an increase in γ, w_2^M rises and l_1^L will fall towards the critical level $(A - \theta_1)/2$. This will make Z_P rise and then eventually fall, as shown in Figure 4.

On the other hand, under wage signalling, l_1 will now (inversely) vary with w_1. With an increase in γ, w_1 is at best non-decreasing and employment non-increasing. At $\gamma = 0$, l_1 is exactly at $(A - \theta_1)/2$, and Z_W is also at the highest level. As γ begins to rise w_1 also rises, and l_1 steadily falls from $(A - \theta_1)/2$ and so will Z_w against γ. Here of course the fall in Z_w depends on whether γ is greater or smaller than $\hat{\gamma}$ (because of the possible distortion in w_1). Thus, the two curves are bound to intersect at least once. It turns out that they intersect twice rendering price signalling equally unattractive at very high values of γ.

This result suggests that if wage and price are equally efficient in transmitting information, the firm as an organization may have preference for one over the other depending on how the rents are shared within the organization. labor regulations, laws and other institutional factors that govern the rent sharing mechanisms will therefore matter for the choice of the signalling device.

Proposition 6: *Signalling through price is preferred from the joint payoff point of view, if the labor union's bargaining power is neither very low nor very high ($\underline{\gamma} \leq \gamma \leq \bar{\gamma}$); otherwise, signalling through wage is preferred.*

Proof: See Appendix 2.

We now turn to social welfare, which defined as the sum of consumers' surplus, firm's profit, and the labor union's payoff. If the first period's level of employment and the wage rate are l and w respectively, the social welfare (SW) in the first period with a θ_1 union is, $SW = \frac{1}{2}l_1^2 + (A - w_1 - l_1)l_1 + (w - \theta_1)l = (A - \theta_1 - \frac{l_1}{2})l_1$. Clearly, SW is maximum at $l_1 = (A - \theta_1)$ and it is increasing in l_1 for $l_1 < (A - \theta_1)$.

Under price signalling, social welfare is

$$SW_1^p = (A - \theta_1 - \frac{l_1^L}{2})l_1^L, \text{ if } \gamma \leq \gamma^S$$
$$= (A - \theta_1 - \frac{l_1^M}{2})l_1^M, \text{ if } \gamma > \gamma^S.$$

Alternatively, under wage signalling social welfare becomes

$$SW_1^w = (A - \theta_1 - \frac{l_1^M}{2})l_1^M, \text{ if } \gamma \leq \hat{\gamma}$$
$$= (A - \theta_1 - \frac{l_1(w_1^L)}{2})l_1(w_1^L), \text{ if } \hat{\gamma} < \gamma,$$

where $l_1(w_1^L) = \frac{A - w_1^L}{2}$.

Comparing SW_1^p and SW_1^w we find that $SW_1^p > (<) SW_1^w$, if $\gamma < (>) \bar{\gamma}$, where $\hat{\gamma} < \bar{\gamma} < 1$. We plot the two social welfare functions against the union's bargaining power in Figure 5. SW_1^p and SW_1^w are represented by the downward sloping curves MRN and BERD respectively. Point R corresponds to the union's bargaining power $\bar{\gamma}$. To the left (right) of point R, SW_1^p lies above (below) SW_1^w.

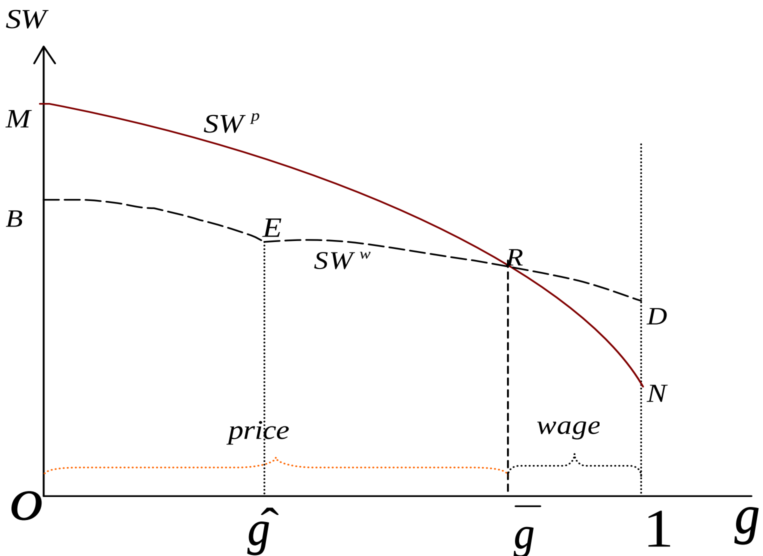

Figure 5: Social welfare comparison

The main reason that price as a socially optimal device dominates over a significant range of γ is that under price signalling production is much higher. Wage (w_1) in this case does not affect the price p_1; instead it determines the rent share of the union. This resembles to some extent, efficient wage bargaining, which is known to generate highest social welfare. Wage as a signal always suffers from the inefficiency associated with right-to-manage bargaining. At low γ this is very pronounced. As γ exceeds $\hat{\gamma}$, wage will be donwardly distorted, and employment will rise above the monopoly level eventually enlarging the social welfare to a great extent. At very high γ, wage is socially more optimal device.

Here, we should also keep in mind that for $\gamma > \gamma^S$ we get the semi-separating equilibrium, in which entry occurs with probability μ, from the observance of p_1^M. But this entry is wasteful and reduces the second period payoff. On the other hand, wage signalling will discourage entry for sure. So the overall social welfare (over two periods) will be lower under price signalling, and therefore, wage will be preferred.

Proposition 7: *Signalling through price is socially optimal, if the labor union's bargaining power is not very high.*

Proof: See Appendix 3.

VI Some Additional Issues

Cost Correlation: If the entrant's marginal cost is correlated with the bargained wage (w) in the incumbent firm, low price or low wage that signals low reservation wage has two opposite effects: (a) it implies unattractiveness of entry due to high competitiveness of incumbent firm, and (b) it signals low cost of the entrant and thereby increase attractiveness of entry. To illustrate it further, we assume that the entrant's marginal cost is $MC_e = c_e + rw$, as in Pal and Saha (2006), where c_e is exogenously determined and r measures the degree of correlation between w and MC_e.

Now, given the bargained wage w_i, outputs and profits of the incumbent and the entrant are $l_i = \frac{A+c_e-(2-r)w_i}{3}$, $y_i = \frac{A-2c_e+(1-2r)w_i}{3}$, $\Pi_i = \frac{(A+c_e-(2-r)w_i)^2}{9}$, and $R_i = \frac{(A-2c_e+(1-2r)w_i)^2}{9} - F$, $i = 1, 2$, respectively. It is evident that, if there is weak wage correlation ($r < \frac{1}{2}$), improved competitiveness of the incumbent firm, due to lower wage, dominates the effect of cost reduction of the entrant. As a result, the entrant earns less profit due to lower wage of the incumbent firm. Moreover, the bargained wage, $w_i = \frac{\gamma}{2(2-r)}(A + c_e) + \frac{2-\gamma}{2}\theta_i$, is increasing in the degree of wage correlation (r) Therefore, if $r < \frac{1}{2}$, entry is profitable only in the high state ($R_1 < 0 < R_2$) [14]. Therefore, qualitative results of our analysis will go through.

However, if there is strong cost correlation ($r > \frac{1}{2}$), the entrant earns higher profit in the low state than that in the high state; since, in this case, the effect of entrant's cost reduction dominates the improved competitiveness of the incumbent firm due to lower wage. To illustrate it further, let us consider the case of perfect wage correlation: $r = 1$ and $c_e = 0$. In this case, the entrant's profit in the low and high states are $R_1^D = \frac{(2-\gamma)^2}{36}(A-\theta_1)^2 - F$ and $R_1^D = \frac{(2-\gamma)^2}{36}(A-\theta_2)^2 - F$, respectively. Clearly, $R_1^D > R_2^D$, since $\theta_1 < \theta_2$. Since monopoly payoffs of the incumbent and its union are higher than that under duopoly, entry deterring strategies will now get reversed. The incumbent union-firm pair will now try to signal the high state of reservation wage credibly to the entrant in order to deter entry by setting a high price (or wage), which is similar to Harrington (1986).

Union Welcomes Entry: We now cosider the alternative scenario, where the union prefers entry.[15] In this case, interests of the incumbent and its union are no longer unified, instead these are conflicting with each other. The high type union (firm) will try to signal (hide) the true state in order to induce (deter) entry.

The union, however, can do very little, if the entrant cannot observe wage, to induce entry effectively, due to unavailability of credible signalling device to it; and, hence, qualitative results of our analysis go through. On the other hand, if wage agreements are public, the phenomena of 'signal-jamming' (as in Kim, 2003) will occur: the union will try to prevent the incumbent from conveying information regarding the true state of the world to the uninformed entrant via a signal, by influencing the wage rate appropriately. It is not clear, however, how the equilibrium will look like in an environment of signal jamming. This seems to be a potentially interesting avenue of research.

Efficient Bargaining: Throughout our analysis we have assumed that the incumbent and its union bargain over wage (right-to-manage bargaining), but one might argue that bargaining takes place over employment as well (efficient bargaining). Do our results change, if we include employment, along with wage, in bargaining agenda? The answer is 'no', as long as the union's bargaining power is not very high.

In case of efficient bargaining, the firm maximizes its profit, setting the wage equal to the reservation wage, and then Nash bargaining determines the share of maximized profit given to the union. It follows that, under entry threat, the incumbent and its union will negotiate $w = \theta_i$, entry would be deterred, profits will be maximized, and then this profit will be shared in proportion to bargaining powers. Therefore, when the entrant observes only the price in the first period (as in Section 3), it can easily find out the underlying equilibrium wages upon observing the pair of prices (p_1, p_2). Moreover, if a pair of prices

(p_1, p_2) satisfies incentive compatibility conditions of the incumbent to signal (or to hide) the true state, that price pair will also be incentive compatible for the union to do the same, since the bargaining power parameter plays no role here. Therefore, even if union's bargaining power is very high, the incumbent will be able to signal (or hide) the true state of reservation wage credibly. In other words, separating (pooling) equilibrium will always exist, if the entrants expected profit is positive (negative). So, the possibility of hybrid equilibrium, which occurs in case of wage bargaining if union's bargaining power is very high and if the entrant observes only the price, is ruled out in case of efficient bargaining.

On the other hand, when wage is public information, the high type incumbent and its union needs to choose the same wage rate, along with the same price, of the low type to hide the true information. As a result, any price-wage pair (p, w) that is incentive compatible for the incumbent firm in the low state, will also be incentive compatible in the high state. However, the incumbent and its union's incentive compatibility conditions will now be different. Therefore, the union's incentive compatibility conditions will determine the equilibrium. It can be easily checked that, in this case, the equilibrium outcomes will be similar to that in Proposition 5.[16]

VII Conclusion

We have developed a model of entry deterrence in the union-oligopoly framework under asymmetric information about the worker's reservation wage. In our setting, a union in the incumbent firm have two signalling devices at their disposal, which they can use alternatively via publicizing bargained wage (i.e. signalling through wage) or by not publicizing the wage (singalling through price).

We show that when price is used to signal the reservation wage, separating equilibrium does not always exist. The prospect of limit pricing strains the wage bargaining so much that the low cost type may not be able to separate itself from the high cost type. In this case, we identify a semi-separating equilibrium in which the high cost incumbent randomizes between low price and high price, and the entrant also randomizes between entering and not entering when it observes the low price. Pooling equilibrium on the other hand may exist. In all cases, the bargained wages are significantly distorted.

When wage is used as the signalling device, full information wages can be incentive compatible and fully revealing, as long as the union is not too powerful. But if the union is sufficiently powerful, wage has to be distorted downward to signal low cost. Pooling equilibrium will also exist.

But over to the two signalling devices, the firm and the union may have different preference. From the society's point of view, price signalling is better. Our analysis can be extended to other setups as well, namely where costs are correlated across firms in an industry, or where the union welcomes entry, or where bargaining covers both wage and employment.

Notes

[1] There is ample evidence of wage bargaining at the firm level (See Aronsson et al., 1993; Clark and Oswald, 1991; Jose, 2002; Vannetelbosch, 1997 to name a few)

[2] We note that Dewatripont (1987) argues that, if only the incumbent firm knows its cost and the trade union is strong, instead of limit pricing, limit output takes place.

[3] It can be readily checked that we need $\underline{c} = \frac{(4+\gamma)A+2(2-\gamma)\theta_1-12\sqrt{F}}{8-\gamma} < c < \bar{c} = \frac{(4+\gamma)A+2(2-\gamma)\theta_2-12\sqrt{F}}{8-\gamma}$.

[4] We have considered that the union is locked in, in the sense that it is not allowed to deal with the entrant. Such an assumption is realistic in many cases: international competition, large difference in skill requirements of the incumbent and the entrant firm, localized trade unions by law or by institutional set up, etc.. We have discussed the opposite case, where the union prefers entry, in Section 6

[5] Note that, it is an additional requirement as compared to MR model.

[6] It is not necessary to reverse the sequence of events (as in Lingens (2007)) to get higher wage and employment.

[7] See Appendix 1.

[8] Explicitly, $\underline{w}_1 = A - (2-\gamma)[\frac{A-\theta_2}{2} - \sqrt{\delta\{\frac{(A-\theta_2)^2}{4} - \frac{(A+c-2\theta_2)^2}{9}\}} + \sqrt{\delta\{\frac{(A-\theta_1)^2}{4} - \frac{(A+c-2\theta_1)^2}{9}\}}]$.
There is another value of $\underline{w}_1$, $\underline{w}_1 = A - 2l_1^L - 2\sqrt{\delta\Delta_1}$, that also satisfies equations (2a). However, w_1^L will always be greater than that, and at this latter value the $\Psi_1(.)$ cuts $\delta\Delta_1$ line at the right most point, which is irrelevant.

[9] It is, however, possible as are seen in the real world that the union may 'co-operate' by agreeing to a lower wage; but it is not clear how the entrant will infer such 'cooperative' wages.

[10] Note that, if wage rate is observed by the entrant, price does not carry any extra information. Because, once wage rate is determined, the best option of the incumbent firm is to choose employment according to the labour demand function (the labour demand function is a common knowledge), and the employment level uniquely determines the price.

[11] It may appear that in Section 3 the Nash bargaining before entry take account the current payoff of the union, but here the union takes into account both current and future payoffs. In case of price signalling, union's total discounted payoff is greater than that under symmetric information. Moreover, where price is the signalling device, the incumbent firm does not need to pay any attention whether union also gains along with the firm or not.

[12] Details of the proof is available upon request.

[13] This is not entirely true, because of the semi-separating equilibrium at $\gamma > \gamma^S$. Here price will be the preferred signalling device. In this case, the joint payoffs under alternative signalling devices, price and wage, are $Z_p = \alpha(A-r-l_1^M)l_1^M + (1-\alpha)(A-r-l_2^M)l_2^M + \delta[(\alpha(1-\mu)(U_2^M+\Pi_2^M)+(\alpha\mu)+(1-\alpha))(U_2^D+\Pi_2^D)]$, and $Z_w = U_2^M + \Pi_2^M + \delta(U_2^D + \Pi_2^D)$, respectively. Clearly $Z_p > Z_w$, since $l_1^M > l_2^M$.

[14] We need to have, $\frac{1}{8-\gamma-2r(2-\gamma)}[A(4+\gamma-2r(1+\gamma))+(2-\gamma)(1-2r)(2-r)\theta_1-6(2-r)\sqrt{F}] < c_e < \frac{1}{8-\gamma-2r(2-\gamma)}[A(4+\gamma-2r(1+\gamma))+(2-\gamma)(1-2r)(2-r)\theta_1-6(2-r)\sqrt{F}]$.

[15] It is possible, if the union supplies workers to the entrant as well, or the entrant plans to hire workers from a union that maintains solidarity with the union of the incumbent firm. Centralised union might also lead to the similar scenario.

[16] See Appendix 4

Appendix

Appendix 1: Non-existence of Separating Equilibrium

We need to prove that $\underline{p} > p_1^L$, if $1 \geq \gamma > \gamma^S$. We know, $\underline{p}$ solves $\psi_1(p) = \delta\Delta_1$, this implies $\underline{p} = \frac{A+\theta_1(1-\gamma)}{2-\gamma} - (2-\gamma)\sqrt{\delta\{\frac{(A-\theta_1)^2}{16} - \frac{(A+c-2\theta_1)^2}{36}\}}$. Also, p_1^L solves $\psi_2(p) = \delta\Delta_2$, this implies $p_1^L = A - \frac{2-\gamma}{2}\{\frac{A-\theta_2}{2} + \sqrt{\delta(\frac{(A-\theta_2)^2}{4} - \frac{(A+c-2\theta_2)^2}{9})}\}$.

If $\gamma = 0$, $\underline{p} = \frac{A+\theta_1}{2} - 2\sqrt{\delta\{\frac{(A-\theta_1)^2}{16} - \frac{(A+c-2\theta_1)^2}{36}\}}$ and $p_1^L = A - \{\frac{A-\theta_2}{2} + \sqrt{\delta(\frac{(A-\theta_2)^2}{4} - \frac{(A+c-2\theta_2)^2}{9})}\}$; clearly, $\underline{p} < p_1^L$. On the other hand, if $\gamma = 1$, $\underline{p} > p_1^L \Rightarrow \frac{A-\theta_2}{4} > (\sqrt{\delta})[\sqrt{\frac{(A-\theta_1)^2}{16} - \frac{(A+c-2\theta_1)^2}{36}} - \sqrt{(\frac{(A-\theta_2)^2}{4} - \frac{(A+c-2\theta_2)^2}{9})}]$, which is true.

Now, $\frac{\partial \underline{p}}{\partial \gamma}$, $\frac{\partial p_1^L}{\partial \gamma} > 0$. Moreover, $\frac{\partial^2 \underline{p}}{\partial \gamma^2} > 0$ and $\frac{\partial^2 p_1^L}{\partial \gamma^2} = 0$. Hence, there exists a γ, say γ^S, such that $\underline{p} > p_1^L$, if $1 \geq \gamma > \gamma^S$.

Appendix 2: Proof of Proposition 6:

We know, $(A-r-l)l$ is maximum at $l = \frac{A-\theta_1}{2}$. Now, $l_1^L = \frac{2-\gamma}{2}\{\frac{A-\theta_2}{2} + \sqrt{\delta(\frac{(A-\theta_2)^2}{4} - \frac{(A+c-2\theta_2)^2}{9})}\} < (>) \frac{A-\theta_1}{2}$, if $\gamma > (<) \tilde{\gamma}$; where $\tilde{\gamma} = 2 - \frac{A-\theta_1}{\frac{A-\theta_2}{2} + \sqrt{\delta(\frac{(A-\theta_2)^2}{4} - \frac{(A+c-2\theta_2)^2}{9})}}$ $(0 < \tilde{\gamma} < 1)$.

Now, if $\gamma = 0$, $l_1^M = \frac{A-\theta_1}{2}$; and $(A-\theta_1-l_1^M)l_1^M$ is decreasing in γ. Therefore, $\exists\ \underline{\gamma}$ such that, if $\gamma = \underline{\gamma}$, $l_1^L = l_1^M$. Hence, if $\gamma < \underline{\gamma}$, $Z_p < Z_w$.

We have, $l_1^L(w)$ is decreasing in γ, and it is less than $\frac{A-\theta_1}{2}$ $\forall\ \gamma$. ($l_1^L(w) = A - p_1^L(w)$, $p_1^L(w)$ is the limit price in the low state when wage is the signalling device). Now, if $\gamma = \tilde{\gamma}$, $l_1^L > l_1^L(w)$; and if $\gamma = 1$, $l_1^L < l_1^L(w)$. Hence, $\exists$ a $\bar{\gamma}$ $(\tilde{\gamma} < \bar{\gamma} < 1)$ such that, if $\gamma = \bar{\gamma}$, $l_1^L = l_1^L(w)$. Also we have, $\{(A-\theta_1-l_1^M)l_1^M + \delta[\mu(U_1^D+\Pi_1^D) + (1-\mu)(U_1^M+\Pi_1^M)]\} < \{(A-\theta_1-l_1^M)l_1^M + \delta(U_1^M+\Pi_1^M)\} < \{(A-\theta_1-l_1^L)l_1^L + \delta(U_1^M+\Pi_1^M)\}$

Hence, $Z_p > Z_w$, if $\underline{\gamma} < \gamma < \bar{\gamma}$; otherwise, $Z_p < Z_w$.

Appendix 3: Proof of Proposition 7:

We consider the case, $\gamma \leq \gamma^S$. Note that, we have, (a) $l_1^L, l_1^M, l_1^L(w) < A - \theta_1$, (b) $l_1^M < l_1^L\ \forall\gamma$, and (c) $l_1^L > l_1^L(w)$, if $\gamma < \bar{\gamma}$, and $l_1^L < l_1^L(w)$, if $\gamma > \bar{\gamma}$. Hence, $SW_1^p > SW_1^w$, if $\gamma < \bar{\gamma}$, and $SW_1^p < SW_1^w$, if $\bar{\gamma} < \gamma \leq 1$. In the high state social welfare is same under both strategies of signalling.

Appendix 4: Efficient Bargaining:

The bargaining problem, in case of monopoly, can be written as: $\max_{w,l} Z = [(w-\theta_i)l]^\gamma[(A-w-l)l]^{1-\gamma}$, $i = 1, 2$. It implies, $w = \gamma(A - l - \theta_i) + \theta_i$ and $l = \frac{A-w}{2-\gamma}$. The resultant wage, employment, incumbent's profit, and union's payoff are, $w_i^M = \gamma\frac{A-\theta_i}{2} + \theta_i$, $l_i^M = \frac{A-\theta_i}{2}$, $\Pi_i^M = (1-\gamma)\frac{(A-\theta_i)^2}{4}$ and $U_i^M = \gamma\frac{(A-\theta_i)^2}{4}$. The duopoly wage, employment, incumbent's profit, union's payoff, and the entrant's profit are, $w_i^D = \frac{A-2\theta_i+c}{3} + \theta_i$, $l_i^D = \frac{A-2\theta_i+c}{3}$, $\Pi_i^D = (1-\gamma)\frac{(A-2\theta_i+c)^2}{9}$, $U_i^D = \gamma\frac{(A-2\theta_i+c)^2}{9}$, and $R_i = \frac{(A-2c+\theta_i)^2}{9} - F$, $i = 1, 2$, respectively. We assume that $R_1 < 0 < R_2 \Rightarrow \frac{A+\theta_1-3\sqrt{F}}{2} < c < \frac{A+\theta_2-3\sqrt{F}}{2}$.

Now, if the etrant observs only price, a pair of prices (p_1, p_2) will constitute the separating equilibrium, if it satisfies incentive compatibility conditions (IC) of the low and high cost incumbent (and hence of the union), $(p_1-\theta_1)(A-p_1) \geq \frac{(A-\theta_1)^2}{4} - \delta[\frac{(A-\theta_1)^2}{4} - \frac{(A-2\theta_1+c)^2}{9}]$, and $(p_1-\theta_2)(A-p_1) \leq \frac{(A-\theta_2)^2}{4} - \delta[\frac{(A-\theta_2)^2}{4} - \frac{(A-2\theta_2+c)^2}{9}]$, respectively. These conditions can be represented in terms of similar graphs as in Figure 1. Upon inspection, we find that, in equilibrium, the low type incumbent will set the price $p_1^L = \frac{A-\theta_2}{2} - \sqrt{\delta\{\frac{(A+\theta_2)^2}{4} - \frac{(A-2\theta_2+c)^2}{9}\}}$, which will credibly signal the low state, and the high type incumbent will set the monopoly price p_2^M. Pooling equilibrium, $p_1^* = p_2^* = p_1^M$, will also exist.

If wage is made public, IC of the incumbent firm in the low state: $(p_1-w_1)(A-p_1) \geq (1-\gamma)\{\frac{(A-\theta_1)^2}{4} - \delta[\frac{(A-\theta_1)^2}{4} - \frac{(A-2\theta_1+c)^2}{9}]\}$; and the IC in the high state for *not* to mimic low: $(p_1 - w_1)(A-p_1) \leq (1-\gamma)\{\frac{(A-\theta_2)^2}{4} - \delta[\frac{(A-\theta_2)^2}{4} - \frac{(A-2\theta_2+c)^2}{9}]\}$. Clearly, $\nexists$ any (p, w) that satisfy the both. On the other hand, the union in the low state will choose the (p_1, w_1) pair to signal the true state, if the following two conditions are satisfied in the low and high state, respectively (which are similar to (10) and (11)): $(w_1-\theta_1)(A-p_1) \geq \gamma\{\frac{(A-\theta_1)^2}{4} - \delta[\frac{(A-\theta_1)^2}{4} - \frac{(A-2\theta_1+c)^2}{9}]\}$, and $(w_1-\theta_2)(A-p_1) \leq \gamma\{\frac{(A-\theta_2)^2}{4} - \delta[\frac{(A-\theta_2)^2}{4} - \frac{(A-2\theta_2+c)^2}{9}]\}$. It implies that the symmetric information price-wage pair will constitute the separating equilibrium, if the union's bargaining power is low ($\gamma < \frac{(\theta_2-\theta_1)\frac{A-\theta_1}{2}}{(A-\frac{\theta_1+\theta_2}{2})+\delta\{\frac{(A-\theta_2)^2}{4} - \frac{(A-2\theta_2+c)^2}{9}\}} = \gamma_1$, say).

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