

On the Strategic Use of Bargaining Pattern and Vertical Integration*

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Abstract

In a successive (bilateral) monopoly, firms have an incentive to vertically integrate to eliminate the double-marginalization problem. However, in the presence of downstream unionization, this incentive may be dissipated because the benefits are partly extracted by the union. We present a model in which a downstream monopoly engages in bargaining with an upstream supplier and a union. We characterize the conditions under which vertical integration (separation) occurs. We also evaluate the strategic use of a bargaining pattern, that is, the order of negotiation between the downstream firm and both the upstream supplier and the union.

Keywords: Vertical Integration, Double Marginalization, Wage and Input Price Bargaining, Labor Union

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1 Introduction

In a successive (bilateral) monopoly setting, a monopoly seller (e.g., a downstream firm) faces a monopsony supplier (e.g., an upstream supplier). The upstream supplier charges a price above its marginal cost to the downstream firm, while the downstream firm charges a price above the sums of its marginal cost and the supplier's price to its end consumers, thereby creating a double marginalization problem. This problem essentially arises because the downstream firm fails to take into account the positive externality that it exerts on the upstream supplier. That is, an additional unit of product sold by the downstream firm to its end consumers will benefit the upstream supplier as well.

It is well known in the literature that in such a setting the downstream firm and the upstream supplier have an incentive to vertically integrate so as to eliminate the double-marginalization problem.¹ However, when the downstream firm is unionized, it must engage in a wage negotiation with a representative union. This creates a trade-off. On the one hand, the additional benefits accrued from eliminating the double-marginalization problem will increase industry profits. On the other hand, the presence of these benefits means that the size of the pie to be bargained over with the union enlarges, implying that the negotiated wage may also rise. This renders the attractiveness of vertical integration for both firms. Zhao (2001) presented this result using a bilateral monopoly model with a unionized downstream market in an international context. In his basic model, the downstream firm only engages in a Nash bargaining game with the union, while the upstream supplier unilaterally sets the input price.²

¹For instance, see Spengler (1950) and Tirole (1988) for the basic exposition on the role of vertical integration in eliminating the double-marginalization problem. Many other papers in the literature have further examined numerous variations of the basic model of successive non-competitive industries. For instance, Greenhut and Ohta (1979), Waterson (1982), and Lin (1988) examined the case of Cournot competition with homogenous products in the downstream market, while Hart and Tirole (1990) examined the Bertrand competition with differentiated products in the downstream market.

²In the later part of his paper, Zhao (2001) briefly discussed the case in which the downstream and upstream firms also engage in a Nash bargaining game. He shows that this consideration does not change the main results of his basic model. However, it should be noted that in his model, all

In this paper we consider a setting in which not only that the wage is determined through a Nash bargaining game between the downstream firm and the union, the input price is also determined through a Nash bargaining game between the downstream firm and the upstream firm in the absence of vertical integration.

Thus, in our model, the downstream firm may engage in bargaining with the upstream supplier and the union. More specifically, we employ a generalized Nash bargaining framework, which allows us to capture differences in the relative bargaining power between the downstream firm and the upstream supplier as well as between the downstream firm and the union. We also endogenize the pattern by which the downstream firm negotiates with the upstream supplier and the union in the absence of vertical integration. We study the incentive of the downstream firm and the upstream firm to vertically integrate and the optimal choice of pattern bargaining that the downstream firm will adopt in equilibrium.

We consider three alternative bargaining patterns under vertical separation. The first is a parallel bargaining in which the downstream firm negotiates with the upstream supplier and the union simultaneously. The second is a sequential bargaining in which the downstream firm engages in an input price negotiation with the upstream supplier before engaging in a wage negotiation with the union. Finally, the third is a sequential bargaining with the reverse sequence of the second bargaining environment. That is, the downstream firm bargains over the wage with the union first before bargaining over the input price with the upstream supplier.

In this paper, the downstream firm has to decide first whether or not to vertically integrate or to remain vertically separated.³ As mentioned earlier, vertical integration is beneficial because it eliminates the double-marginalization problem.

parties share equal bargaining power, and furthermore, the model does not consider the endogenous choice of bargaining pattern to govern the bilateral negotiations between the downstream and upstream firms and between the downstream firm and the union. Also more importantly, his model focuses on the outsourcing decision of a multinational firm in an international context.

³We will show later in section 3.3 that it suffices to compare the joint profits under vertical integration and under vertical separation when evaluating the downstream firm's incentive to vertically integrate. It can be also verified that when it is individually profitable for the downstream to vertically integrate, it is also individually profitable for the upstream firm to vertically integrate. The profitability conditions for both firms are essentially identical.

Obviously, under vertical integration there will only be one bargaining game, which is the one between the downstream firm and the union. This implies that under vertical integration, there is no bargaining pattern to choose. However, in the presence of union bargaining, vertical integration could also put the downstream firm at a disadvantage since it increases the size of the surplus to be shared with the union and consequently the negotiated wage. If the union's bargaining power is too strong vis-à-vis the downstream firm, it will erode the benefits of vertical integration. In such a case, the downstream firm will prefer to remain separate from the upstream firm. To compensate for the loss in profits due to the double-marginalization problem and to avoid having to pay higher wages, the downstream firm can strategically manipulate the order of the bargaining. In particular, the downstream firm can negotiate the input price with the upstream supplier before it negotiates the wage with the union. Even though the resulting input price will be higher in this bargaining environment than in others, the subsequent negotiated wage will be lower. By deliberately committing to paying a higher input price and thus reducing the size of the pie to be shared with the union, the downstream firm can effectively lower the wage burden.⁴ Obviously, such a strategy will only be optimal if the relative bargaining power of the downstream firm vis-à-vis the upstream firm is not too weak. Otherwise, the negotiated input price will be too high, and the benefit of a lower negotiated wage will not be sufficient to outweigh the cost of having to pay a higher input price.

In our paper the number of bargaining agendas to be negotiated is endogenous. Under vertical separation we have two bargaining agendas – wage and input price, while under vertical integration we have only one - wage. Obviously, in the latter case the downstream firm can no longer use the bargaining pattern as a strategic tool. This would imply that vertical integration will only be chosen if the down-

⁴It is worth mentioning that, albeit using an entirely different modeling environment, our paper is similar in spirit to Perotti and Spier (1993), who show that debt can be used to effectively extract wage concessions from a union. By carrying more debt, a firm can reduce its employees' demands by creating fear that a higher wage will make it difficult for the firm to service the debt and thus bring it closer to bankruptcy. Both our paper and theirs thus discuss a commitment tool that can be credibly used by a firm to gain concessions from the union.

stream firm has sufficiently high bargaining power vis-à-vis the union.

Our results from the endogenous pattern of bargaining reveal that when the bargaining power of the downstream firm in the inter-firm negotiation is not so different from its bargaining power in the wage negotiation, the parallel bargaining environment will be chosen in equilibrium. In such a case, the strategic manipulation of the bargaining sequence is not particularly useful. For it to be useful, the downstream firm must be able to exploit its relatively strong bargaining position vis-à-vis the upstream supplier to leverage its relatively weak bargaining position vis-à-vis the union. Thus, both bargaining-power positions must be sufficiently different.

It is interesting to observe that the downstream firm would never want to negotiate with the union prior to negotiating with the upstream firm to gain concession for a lower input price. This is because for the downstream firm, vertical integration is a more effective tool for achieving that goal as it eliminates the double marginalization problem completely and results in the lowest input price.

Our paper is related to the literature on pattern bargaining. However, the nature of our bargaining framework is distinct from this existing literature. The literature on pattern bargaining typically focuses on the bargaining between one party against two other parties who act independently, for instance, between one labor union against two independent firms or between one borrowing firm against two independent creditors.⁵ Our paper also has this feature. The downstream firm bargains against the upstream firm and the union independently. However, in the pattern bargaining literature, a failure to agree with one party does not automatically imply that bargaining with the other party is no longer feasible. For instance, in the example of one union negotiating with two independent firms, a failure to agree with one firm would still make it feasible for the union to negotiate with the other firm, although the outcome may be less efficient.⁶ In our paper this is

⁵See for instance Horn and Wolinsky (1988), Dobson (1994), Noe and Wang (2000), Marshall and Merlo (2004), Marx and Shaffer (2007), and Raskovich (2007).

⁶For instance, in Marx and Shaffer (2007) the efficient solution could call for the firm (i.e., the buyer) to buy from either one of two sellers, but it does not mean that when the buyer fails to negotiate with one seller, its negotiation with the other seller will no longer be feasible.

clearly not the case. When producing the final good, the downstream firm requires two inputs, namely labor that is managed by the union and an intermediate input that is supplied by the upstream firm. Should the downstream firm fail to reach an agreement with the union (or the upstream firm), the negotiation with the other party cannot continue since the downstream firm would not be able to operate with just one input.

Another significant difference between our pattern bargaining setting and that in the existing literature is that our setting allows for vertical integration (merger) between two of the players, that is, the downstream firm and the upstream supplier. By merging, the downstream firm can eliminate one of the bargaining rounds. In our case, the downstream firm no longer has to bargain for the input price with the upstream firm; instead the input price will be determined through an internal transfer pricing scheme. We evaluate whether or not vertical integration is superior to the use of pattern bargaining for the downstream firm.

By considering both the use of pattern bargaining and the vertical integration decision, our paper produces a rich interplay between the two. Our paper shows that sequential bargaining is not always optimal. In some circumstances the downstream firm will prefer to conduct parallel negotiations instead, while in others the downstream firm will prefer to vertically integrate with the upstream supplier, allowing the firm to focus solely on the union bargaining.

From a more general perspective, our paper contributes to the literature on vertical integration. More specifically, it highlights the important role of the interaction between union bargaining and inter-firm bargaining as the determinant of the optimal organizational structure. We show that in the presence of a strong union, the downstream firm and the upstream firm prefer to engage in ‘inefficient’ bargaining as it allows them to retain more rents.

This paper is organized as follows. In Section 2, we formulate the model and discuss the timing structure of the game. We also describe our bargaining environments. In Section 3, we derive the subgame perfect Nash equilibrium solution of

the model. In Section 4, we discuss the results further. Finally, Section 5 concludes our paper.

2 The Model

We consider a monopoly downstream firm d that sells a final good q to end consumers. The demand for the final good is linear and takes the form of⁷

$$p(q^d) = a - bq^d,$$

in which p denotes the price of the final good, $a > 0$, and $b > 0$. Throughout the paper, we assume that a is sufficiently large to ensure that our optimal solutions are strictly positive. To produce one unit of the final good, the downstream firm requires one unit of labor l and one unit of an intermediate input. The downstream firm's profit function can thus be written as

$$\pi^d = [p(q^d - m - w)] q^d,$$

where m denotes the price of the intermediate input and w denotes the wage.

The intermediate input is supplied by a monopoly upstream supplier u . The marginal cost of producing this input is c . The profit function of the upstream input supplier can thus be expressed as

$$\pi^u = (m - c) q^u, \tag{1}$$

in which $q^u = q^d$.

The downstream firm is unionized, and the wage w is determined through bargaining between the downstream firm and a representative union. We assume that all (potential) workers are members of the union. We follow the standard right-to-manage approach to the wage determination under which the downstream firm

⁷The use of the linear demand specification is quite common in the literature on bilateral monopoly and pattern bargaining. See, for instance, Horn and Wolinsky (1988), Dobson (1994), and Marshall and Merlo (2004).

bargains over the wage with the labor union given the firm's expected employment decisions.⁸

The union's utility function takes the form of

$$U(w, q^d) = wq^d + (\bar{L} - q^d)w_0, \quad (2)$$

in which \bar{L} denotes the number of union members and w_0 represents the level of unemployment benefits. There are $(\bar{L} - q^d)$ unemployed workers who receive unemployment benefits. Essentially, the union's utility function (2) comprises the total income earned by its members. In the presence of a disagreement between the firm and the union, members will be unemployed and consequently the union's utility will be equal to $w_0\bar{L}$. As such, the union's net utility from participating in the employment can be written as

$$U(w, q^d) - w_0\bar{L} = (w - w_0q^d).$$

This utility function is a Stone-Geary type in which the disagreement point is normalized to zero and the union is neutral with respect to the wage and employment. This type of utility function is commonly used in the literature.⁹

We assume complete information throughout the paper. Our model's timing structure is as follows. At $t=1$, the downstream firm chooses whether to vertically integrate with the upstream firm or to remain separate from it. When the downstream firm decides to integrate with the upstream firm, the two firms bargain over the share of the profit of the integrated firm. Once the deal is done, the integrated firm internalizes the externality. Vertical integration will effectively eliminate the inter-firm bargaining over the input price between the downstream firm and the upstream firm, leaving the integrated firm with only the wage negotiation to take care of. Accordingly, the choice of bargaining pattern becomes irrelevant.

⁸Our results would not qualitatively change if we considered the downstream firm and the union to negotiate over both the wage and employment.

⁹See Pemberton (1988) for a more detailed discussion. A Stone-Geary utility function takes the form of $U(w, q) = (w - w_0)^\theta q^{1-\theta}$, where $0 \leq \theta \leq 1$. The labor union is said to be wage (employment)-oriented if $\theta > (<) 0.5$, and neutral if $\theta = 0.5$.

The integrated firm is organized in the form of a joint venture or an alliance.¹⁰ The two firms divide the surplus from the cooperation according to a sharing rule that depends on their respective bargaining power.

When the downstream firm opts to remain separate, it will face both the wage bargaining and the input-price bargaining. Obviously, the choice of bargaining pattern will be important. The downstream firm must choose whom it will first bargain with.¹¹ It has three available options. First, it can choose to conduct a *sequential bargaining* in which the input price is negotiated prior to the wage. We denote this bargaining pattern with $I \rightarrow L$. Second, it can choose to conduct a *parallel bargaining* in which both the input price and the wage are negotiated simultaneously and independently with the respective parties. We denote this bargaining pattern with $I\&L$. Finally, it can choose to conduct a *reverse sequential bargaining* in which the wage is negotiated prior to the input price. We denote this bargaining pattern with $L \rightarrow I$.

To summarize, period $t = 1$ is the initial stage of our model. We will call this stage the *organizational- and bargaining-design stage*. This is basically the stage in which the downstream firm must decide whether or not to vertically integrate. If it chooses not to, it must then choose the optimal bargaining pattern. Naturally, the basis for making this decision is a comparison between profits under vertical integration and the combined profits under vertical separation.¹²

Subsequent to the organizational- and bargaining-design stage, the downstream

¹⁰An alternative form of integration is the downstream firm buys out the upstream firm. The magnitude of the buyout price depends on the relative bargaining power of the downstream firm vis-à-vis the upstream firm. The buyout price will reduce the downstream firm's net surplus from vertical integration. Consequently, the total surplus brought into the wage bargaining table is going to be smaller. It will simply reduce the optimal negotiated wage without changing the qualitative aspects of our results. For the sake of simplicity of the calculation, we opt for the first form of integration.

¹¹It should be noted that at this stage the actual negotiations are not yet carried out. The firm is just choosing the sequence plan.

¹²Notice that we have considered the case in which the choice of the bargaining pattern is made simultaneously with the decision of whether or not to vertically integrate. It is straightforward to see that the case in which the choice of the bargaining pattern is taken before the vertical integration decision is made and the reverse case are analytically equivalent to the case we analyze here, provided that the actual negotiations are not yet carried out.

firm must carry out the bargaining with both the upstream firm and the union. We therefore label the next stage as the *bargaining stage*. Notice that this stage may last either for one period only ($t = 2$) or for two periods ($t = 2$ and $t = 3$), depending on the vertical structure and the bargaining pattern chosen in the previous stage.

At $t = 2$, if in the previous period the downstream firm has decided to remain vertically separated from the upstream firm, it may take one of three possible actions depending on the choice of the bargaining pattern. If $I \rightarrow L$ has been previously chosen, the downstream firm will bargain over the input price with the upstream firm. Alternatively, if $I\&L$ has been chosen, the downstream firm will bargain over the input price and the wage simultaneously. If instead $L \rightarrow I$ has been chosen, the downstream firm will bargain over the wage with the union. However, if the downstream firm has pursued vertical integration with the upstream firm in the previous period, it will also bargain over the wage with the union.

At $t = 3$, under vertical integration, the downstream firm will combine the intermediate inputs and labor to produce the final good and sell it to the end-consumers. Under vertical separation and $I \rightarrow L$, the downstream firm will negotiate the wage with the union. Under vertical separation and $I\&L$, the downstream firm will produce the final good and sell it to the end consumers. Finally, under vertical separation and $L \rightarrow I$, the downstream firm will bargain over the input price with the upstream firm.

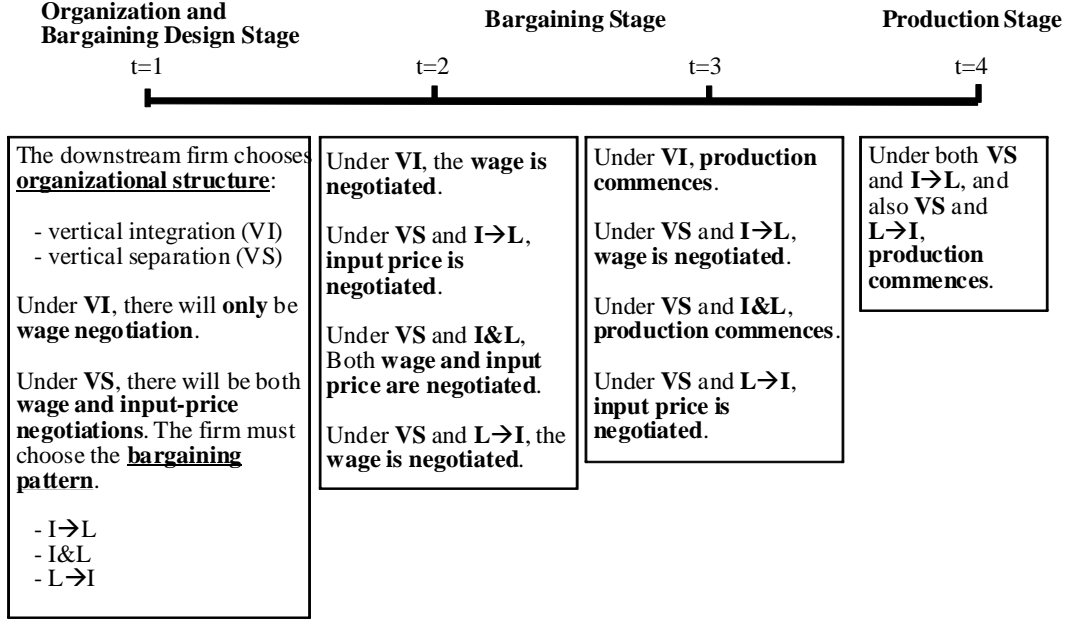


Figure 1: The Timing Structure

Once the negotiations have been completed, the *production stage* begins. This is the last stage of the game, which we will call the production stage. If the downstream firm opts for either vertical integration or vertical separation and $I&L$, then the production stage will begin in the previous period $t = 3$. Otherwise, under vertical separation and $I \rightarrow L$, and also under vertical separation and $L \rightarrow I$, the production stage will commence at period $t = 4$.

Figure 1 depicts the complete timing structure of our model. We solve for the subgame perfect Nash equilibrium using the standard backward induction procedure starting from the final stage of the game, which is the production stage.

3 The Model Solution

3.1 The Production Stage

The downstream firm's operating profit function is

$$\pi_{i,j}^d = (a - bq^d - m - w) q^d,$$

in which subscript $i \in \{VI, VS\}$ denotes the type of vertical structure, that is, either vertical integration or vertical separation, and subscript $j \in \{I \rightarrow L, I\&L, L \rightarrow I\}$ denotes the adopted bargaining pattern. Recall that under vertical integration (VI), there is no bargaining pattern to choose simply because there is only the wage negotiation. Thus, subscript j applies only to the vertical separation (VS) case. The optimal quantity of the final good can be derived as

$$q_{i,j}^d = \frac{a - m - w}{2b}. \quad (3)$$

It is obvious that the optimal quantity of the final good $q_{i,j}^d$ decreases in the negotiated wage w and the input price m . Solutions for the optimal monopoly price, the union's utility, and the downstream firm's profit can be derived respectively as

$$\begin{aligned} p_{i,j} &= \frac{a + m + w}{2}, \\ U_{i,j} &= (w - w_0) \left(\frac{a - m - w}{2b} \right) + w_0 \bar{L}, \\ \pi_{i,j}^d &= \frac{(a - m - w)^2}{4b}. \end{aligned} \quad (4)$$

Two things about the integrated firm's profit under the vertical integration case are noteworthy. First, the input price is determined through an internal transfer pricing scheme and is set equal to the upstream firm's marginal cost of producing the input. Accordingly, under vertical integration we have

$$m_{VI} = c, \quad (5)$$

in all of the above expressions.¹³ Second, the integrated firm's profit will be $\pi_{VI}^d = (a - c - w)^2 / 4b$. The share of joint profits belonging to the downstream firm is $(\pi_{VI}^d - T_{VI})$, and the one belonging to the upstream firm is T_{VI} , and T_{VI} is negotiated between the two firms.

¹³In this paper, we have not really taken into account any potential strategic benefit of transfer pricing. In practice, the optimal transfer pricing may not be set equal to the marginal cost when the integrated firm cares about eliciting effort of the upstream division and the compensation given to the upstream division is based on the performance of the upstream division. See for instance Holmstrom and Tirole (1991) and Choe and Hyde (2005) for papers on the strategic-incentive motive of transfer pricing. Our results would not be qualitatively affected by such a consideration as long as the optimal strategic transfer price for input is still lower than the input price set under vertical separation.

3.2 The Bargaining Stage

3.2.1 Vertical Integration

Under vertical integration there will be only a wage negotiation between the integrated firm and the union. We model the wage negotiation as a generalized Nash bargaining problem. If the negotiation breaks down, the disagreement payoff for the firm is normalized to zero, whereas that for the labor union is equal to $w_0\bar{L}$. Intuitively, since labor cannot be substituted by other inputs, a breakdown in bargaining implies that the demand for labor and the intermediate input as well as the firm's payoffs are equal to zero. Each of the union members will just receive the unemployment benefit w_0 . The generalized Nash bargaining solution to the wage bargaining problem is given by

$$w_{VI} = \arg \max_w [\pi_{VI}^d(w)]^\alpha [U_{VI}(w) - w_0\bar{L}]^{1-\alpha}, \quad (6)$$

where $\alpha \in [0, 1]$ is the downstream firm's relative bargaining power vis-à-vis the union.¹⁴ The union's utility and the downstream firm's profit are given by respectively (2) and (4), with $q^d = q_{VI}^d$ and $m_{VI} = c$ as specified in (3) and (5).

The optimal negotiated wage can be derived as

$$w_{VI} = A(a - c - w_0 + w_0), \quad (7)$$

with $A = (1 - \alpha)/2$.

The optimal negotiated wage w_{VI} decreases in the downstream firm's relative bargaining power vis-à-vis the union α . The intuition for this is straightforward. A higher bargaining power of the downstream firm will enable the firm to extract a larger portion of the total surplus at the expense of the union's wage. Using (7) we can derive the optimal quantity and price of the final good, the union's utility, and

¹⁴Muthoo (1999) shows that a bargaining solution is the Nash bargaining solution if and only if it satisfies the following axioms: invariance to equivalent utility representations, Pareto efficiency, symmetry, and independence of irrelevant alternatives. Since it can be shown that the solution to (13) satisfies those axioms, it is a Nash bargaining solution.

the downstream firm's profits as

$$\begin{aligned}
q_{VI}^d &= (1 - A) \frac{(a - c - w_0)}{2b}, \\
p_{VI} &= \frac{(1 + A)a + (1 - A)(c + w_0)}{2}, \\
U_{VI} &= A(1 - A) \frac{(a - c - w_0)^2}{2b} + w_0 \bar{L}, \\
\pi_{VI}^d &= (1 - A)^2 \frac{(a - c - w_0)^2}{4b}.
\end{aligned}$$

3.2.2 Vertical Separation

Under vertical separation, the downstream firm must bargain with both the upstream firm and the union. It can choose to bargain over the input price prior to the wage ($I \rightarrow L$), to bargain over both the wage and the input price simultaneously ($I\&L$), or to bargain over the wage prior to the input price ($L \rightarrow I$). We derive the optimal solutions under these three bargaining patterns.

VS and $I \rightarrow L$

Under this bargaining pattern the input price is negotiated prior to the wage. The generalized Nash bargaining solution to the wage bargaining problem is given by

$$w_{VS, I \rightarrow L} = \arg \max_w [\pi_{VS, I \rightarrow L}^d(w, m)]^\alpha [U_{VS, I \rightarrow L}(w, m) - w_0 \bar{L}]^{1-\alpha}. \quad (8)$$

The union's utility and the downstream firm's profit are given respectively by (2) and (4), with $q^d = q_{VS, I \rightarrow L}^d$ as specified in (3).

The solution to (8) is

$$w_{VS, I \rightarrow L} = A(a - m - w_0) + w_0, \quad (9)$$

in which $A = (1 - \alpha)/2$.

It can easily be verified that the optimal negotiated wage $w_{VS, I \rightarrow L}$ decreases in both the downstream firm's relative bargaining power vis-à-vis the union α and the input price m . The intuition for the negative relationship between $w_{VS, I \rightarrow L}$ and α is the same as in the vertical integration case. With respect to the input price,

the size of the surplus to be shared with the union at the bargaining table becomes smaller when the input price increases. As a result, the optimal negotiated wage decreases.

Substituting the resulting optimal wage (9) into the equilibrium quantity of the final good (3) and the downstream firm's profit (4) yields

$$\begin{aligned} q_{VS,I \rightarrow L}^d &= \frac{(1-A)}{2b} (a - m - w_0), \\ \pi_{VS,I \rightarrow L}^d &= \frac{(1-A)^2}{4b} (a - m - w_0)^2. \end{aligned} \quad (10)$$

Subsequently, the input price is also determined through a generalized Nash bargaining between the downstream firm and the upstream firm. The solution to the input price bargaining problem is given by

$$m_{VS,I \rightarrow L} = \arg \max_m [\pi_{VS,I \rightarrow L}^d(m)]^\beta [\pi_{VS,I \rightarrow L}^u(m)]^{1-\beta}, \quad (11)$$

where $\beta \in [0, 1]$ is the downstream firm's relative bargaining power vis-à-vis the upstream firm. The downstream firm's profit is given by expression (10), while the upstream firm's profit is given by expression (1) with $q^u = q_{VS,I \rightarrow L}^d$. If the bargaining breaks down, there will be no production of the final good, and consequently there will be no laborers employed and no intermediate inputs purchased. The disagreement payoffs for both the downstream firm and the upstream firm are normalized to zero. Solving for the optimal negotiated input price yields

$$m_{VS,I \rightarrow L} = B(a - c - w_0 + c), \quad (12)$$

in which $B = (1 - \beta) / 2$.

It can be seen that the optimal negotiated input price $m_{VS,I \rightarrow L}$ decreases in the downstream firm's relative bargaining power vis-à-vis the upstream firm β . A stronger bargaining power enables the downstream firm to extract a greater portion of the surplus at the expense of the upstream firm in the form of a lower input price. It is also obvious from (5) and (12) that , implying that the upstream firm imposes a markup over the marginal cost of producing the input.

Using (12), the optimal negotiated wage, the quantity of the final good, the union's utility, and the joint profits can be written as

$$\begin{aligned}
w_{VS,I \rightarrow L} &= A(1-B)(a-c-w_0) + w_0, \\
q_{VS,I \rightarrow L}^d &= (1-A)(1-B) \frac{(a-c-w_0)}{2b}, \\
U_{VS,I \rightarrow L} &= A(1-A)(1-B)^2 \frac{(a-c-w_0)^2}{2b} + w_0 \bar{L}, \\
\pi_{VS,I \rightarrow L}^d + \pi_{VS,I \rightarrow L}^u &= \left[(1-B) + \frac{B(1-B)(1+A)}{(1-A)} \right] \\
&\quad \left[\frac{(1-A)^2 (a-c-w_0)^2}{2} \frac{1}{2b} \right],
\end{aligned}$$

with $A = (1 - \alpha) / 2$ and $B = (1 - \beta) / 2$.

It is easy to see that the optimal negotiated wage $w_{VS,I \rightarrow L}$ decreases in the downstream firm's relative bargaining power vis-à-vis the union α and increases in its relative bargaining power vis-à-vis the upstream firm β . The intuitions are quite straightforward. A higher α enables the downstream firm to decrease the optimal negotiated wage $w_{VS,I \rightarrow L}$, while a higher β enables it to lower the optimal negotiated input price. This results in a larger surplus to be shared with the union in the subsequent bargaining process, resulting in a higher optimal negotiated wage $w_{VS,I \rightarrow L}$.

VS and I&L

Under this bargaining pattern, the downstream firm independently bargains over the input price with the upstream firm and over the wage with the union at the same time. Both the downstream and upstream firms obtain zero profit whenever either or both of these bargaining negotiations collapse because labor and the intermediate input are necessary inputs in the final good production. In such an event, the union obtains the unemployment benefit.

Solutions to the bargaining problems are given by

$$w_{VS, I\&L} = \arg \max_w [\pi_{VS, I\&L}^d(m, w)]^\alpha [U_{VS, I\&L}(m, w) - w_0 \bar{L}]^{1-\alpha}, \quad (13)$$

$$m_{VS, I\&L} = \arg \max_m [\pi_{VS, I\&L}^d(m, w)]^\beta [\pi_{VS, I\&L}^u(m, w)]^{1-\beta} \quad (14)$$

The upstream firm's profit is given by expression (1), the union's utility is given by expression (2), and the downstream firm's profit is given by expression (4). In (1), (2), and (4) we have $q^u = q_{VS,I\&L}^d$ as specified in (3).¹⁵

The optimal negotiated wage and input price can be

$$w_{VS, I\&L} = \frac{AB(1-B)}{(1-AB)}(a-c-w_0) + w_0, \quad (15)$$

$$m_{VS, I\&L} = \frac{B(1-A)}{(1-AB)}(a-c-w_0) + c. \quad (16)$$

with $A = (1-\alpha)/2$ and $B = (1-\beta)/2$.

It is straightforward to see from (15) that the optimal negotiated wage decreases in the downstream firm's relative bargaining power vis-à-vis the union α and increases in its relative bargaining power vis-à-vis the upstream firm β , whereas from (16) the optimal negotiated input price decreases with the downstream firm's relative bargaining power vis-à-vis the upstream firm β and increases with the downstream firm's relative bargaining power vis-à-vis the union α .¹⁶

The intuitions behind the negative relationship between $w_{VS,I\&L}$ and α , and between $m_{VS,I\&L}$ and β , are similar to those stated in our previous analysis. Essentially, a higher relative bargaining power enables the downstream firm to obtain a larger portion of the total surplus at the expense of the other bargaining party. Interestingly, an increase in α will decrease the negotiated input price $m_{VS,I\&L}$, while an increase in β will decrease the negotiated wage $w_{VS,I\&L}$. These can be explained as follows. We know that an increase in α (β) lowers the negotiated wage (the negotiated input price). This has the effect of enlarging the amount of surplus to be shared with the upstream firm (the union), leading to a higher negotiated input price (wage).

Using (15) and (16), the optimal quantity of the final good, the union's utility,

¹⁵It can be shown straightforwardly that the maximization problems (13) and (14) satisfy the second-order conditions in that both are concave in w and m .

¹⁶Formally, it can be easily shown by differentiating (15) and (16) with respect to α and β . We have $\partial w_{VS, I\&L}/\partial\alpha < 0$, $\partial m_{VS, I\&L}/\partial\alpha > 0$, $\partial m_{VS, I\&L}/\partial\beta < 0$, and $\partial w_{VS, I\&L}/\partial\beta > 0$.

and the joint profits can be written as

$$\begin{aligned}
q_{VS, I\&L}^d &= \frac{(1-A)(1-B)(a-c-w_0)}{(1-AB)2b}, \\
U_{VS, I\&L} &= \frac{A(1-A)(1-B)^2(a-c-w_0)^2}{(1-AB)^2 2b} + w_0\bar{L}, \\
\pi_{VS, I\&L}^d + \pi_{VS, I\&L}^u &= \left[\frac{(1-A)^2(1-B)^2}{(1-AB)^2} \right] \left[\frac{(a-c-w_0)^2}{4b} \right].
\end{aligned}$$

VS and $L \rightarrow I$

Under this bargaining pattern, the downstream firm negotiates with the union prior to negotiating with the upstream firm. The solutions to this case are derived in the same fashion as those derived previously under the case of VS and $I \rightarrow L$ and can be written as

$$w_{VS, L \rightarrow I} = A(a-c-w_0) + w_0, \quad (17)$$

$$m_{VS, L \rightarrow I} = B(1-A)(a-c-w_0) + c, \quad (18)$$

$$q_{VS, L \rightarrow I}^d = (1-A)(1-B) \frac{(a-c-w_0)}{2b},$$

$$U_{VS, L \rightarrow I} = A(1-A)(1-B) \frac{(a-c-w_0)^2}{2b} + w_0\bar{L}$$

$$\pi_{VS, L \rightarrow I}^d + \pi_{VS, L \rightarrow I}^u = (1-A)^2(1-B)^2 \frac{(a-c-w_0)^2}{4b}.$$

From (17) and (18) we observe that the optimal negotiated wage (input price) decreases in α (β). The intuition for this result is the same as the one derived in our previous analysis.

3.3 Organizational- and Bargaining-Design Stage

The following table summarizes the optimal solutions derived so far.

[INSERT TABLE 1 HERE]

Before solving for the downstream firm's optimal choice of organizational form and bargaining pattern, let us take a closer look at the optimal final good quantities, negotiated wages, and negotiated input prices under different organizational structures and bargaining patterns. Comparing these optimal outcomes gives us the following result:

Proposition 1 *Given that $\alpha, \beta \in [0, 1]$, we have*

$$(i) \quad q_{VI}^d > q_{VS, I\&L}^d > q_{VS, I \rightarrow L}^d = q_{VS, L \rightarrow I}^d$$

$$(ii) \quad w_{VI} = w_{VS, L \rightarrow I} > w_{VS, I\&L} > w_{VS, I \rightarrow L}$$

$$(iii) \quad m_{VS, I \rightarrow L} > m_{VS, I\&L} > m_{VS, L \rightarrow I} > m_{VI}$$

Proof. Given that $\alpha, \beta \in [0, 1]$, it can easily be verified that $1/(1 - AB) \geq 1$ and $(1 - B)/(1 - AB) \leq 1$. With this information, it is straightforward to see that the above proposition holds. ■

It can be observed that vertical integration leads to the highest employment level and negotiated wage. Under vertical integration the downstream firm has to deal only with the wage negotiation. The double marginalization problem is also fully eliminated, resulting in a higher total surplus to be shared with the union in the wage negotiation. This explains the higher negotiated wage obtained by the union. The removal of the double-marginalization problem also boosts the final good production and thus increases the employment level.

The negotiated input price is highest under both VS and $I \rightarrow L$ and lowest under VI . In the latter, the upstream firm sets the input price at the marginal cost. It is interesting that although the negotiated input price is highest under VS and $I \rightarrow L$, the negotiated wage is actually lowest. Essentially, by committing to negotiating first with the upstream firm and thus paying a higher input price, the downstream firm is able to gain some wage concessions from the union. The reverse bargaining pattern, that is VS and $L \rightarrow I$, can also be used by the downstream firm

as a credible commitment device to extract some concessions, in the form of a lower input price, from the upstream supplier. However, we have $m_{VS,L \rightarrow L} \geq m_{VI} = c$, thus clearly vertical integration is a more effective tool to lower down the input price than VS and $L \rightarrow I$. In the latter, the double marginalization problem remains.

Next, we compare joint profits of the downstream and upstream firms under all organizational forms and bargaining patterns. We show that it is individually incentive compatible for each of the firms to pursue vertically integration when the joint profits under vertical integration are larger than the joint profits under vertical separation.

The vertical integration decision is modeled as a generalized Nash bargaining game between the downstream and upstream firms. Here, β also represents the downstream firm's relative bargaining power when negotiating for surplus sharing from vertical integration. Solution to the bargaining problem is given by

$$T_{VI}^* = \arg \max_{T_{VI}} (\Pi_{VI} - T_{VI} - \pi_{VS,j}^d)^\beta (T_{VI} - \pi_{VS,j}^u)^{1-\beta}, \quad (19)$$

in which T_{VI} denotes the lump-sum share of the integrated profits belonging to the upstream firm. For the purpose of comparison, we define the integrated profits as Π_{VI} . The disagreement payoff for each firm is their respective profit obtained under vertical separation $\pi_{VS,j}^d$ and $\pi_{VS,j}^u$. Subscript $j \in \{I \rightarrow L, I\&L, L \rightarrow I\}$ denotes the adopted bargaining pattern. The optimal lump-sum share can be derived from the first order condition of (19) as

$$T_{VI}^* = \beta \pi_{VS,j}^u + (1 - \beta) (\Pi_{VI} - \pi_{VS,j}^d).$$

It is straightforward to show that the following proposition holds.

Proposition 2 *It is mutually profitable for the downstream and upstream firms to vertically integrate if $\Pi_{VI} > \pi_{VS,j}^d + \pi_{VS,j}^u$*

Proof. The Nash bargaining solution to (19) exists if $\Pi_{VI} - T_{VI} > \pi_{VS,j}^d$ and $T_{VI}^* > \pi_{VS,j}^u$. Substituting T_{VI}^* into these two constraints yields the condition stated in the proposition. ■

Under the condition of $\Pi_{VI} > \pi_{VS,j}^d + \pi_{VS,j}^u$, we can immediately observe that when β decreases (increases), T_{VI}^* increases (decreases). That is, the share of profits becomes larger as the downstream firm has a weaker bargaining power. In the next Proposition, however, we will see that this relationship may not hold for all range of β , because the change in β may affect the relative size of profits of $\pi_{VS,j}^d + \pi_{VS,j}^u$ to that of Π_{VI} . To simplify our notation, we denote joint profits under vertical separation as $\Pi_{i,j} = \pi_{VS,j}^d + \pi_{VS,j}^u$.

Proposition 3 *Given that $\alpha, \beta \in [0, 1]$, we have*

- (i) $\Pi_{VS, I \rightarrow L} > \Pi_{VS, I \& L} > \Pi_{VI} > \Pi_{VS, L \rightarrow I}$ for $\bar{\beta} < \beta < 1$
- (ii) $\Pi_{VS, I \& L} > \Pi_{VS, I \rightarrow L} > \Pi_{VI} > \Pi_{VS, L \rightarrow I}$ for $\tilde{\beta} < \beta < \bar{\beta}$
- (iii) $\Pi_{VS, I \& L} > \Pi_{VI} > \Pi_{VS, I \rightarrow L} > \Pi_{VS, L \rightarrow I}$ for $\underline{\beta} < \beta < \tilde{\beta}$
- (iv) $\Pi_{VI} > \Pi_{VS, I \& L} > \Pi_{VS, I \rightarrow L} > \Pi_{VS, L \rightarrow I}$ for $0 < \beta < \underline{\beta}$

Where $\underline{\beta} = \frac{(\alpha^2 + 6\alpha - 3)}{(\alpha^2 - 2\alpha + 5)}$, $\tilde{\beta} = \frac{(3\alpha - 1)}{(3 - \alpha)}$, $\bar{\beta} = \frac{(\alpha^2 + 12\alpha + 3)}{16}$, and $0 \leq \underline{\beta} \leq \tilde{\beta} \leq \bar{\beta} \leq 1$.

Proof. The proof is relegated to the appendix. ■

Using Proposition 2 we can derive the subgame perfect Nash equilibrium organizational structure and bargaining pattern.

Proposition 4

- (i) *For $1 > \beta > \bar{\beta}$, the downstream firm prefers to remain vertically separated, and the downstream firm bargains with the upstream firm prior to bargaining with the union.*
- (ii) *For $\bar{\beta} > \beta > \underline{\beta}$, the downstream firm prefers to remain vertically separated, and the downstream firm bargains with both the upstream firm and the union simultaneously.*

(iii) For $\underline{\beta} > \beta > 0$, the downstream firm prefers to be vertically integrated. Under vertical integration, the downstream firm engages only in a wage bargaining with the union.

Figure 2 below presents a graphical depiction of the above proposition.

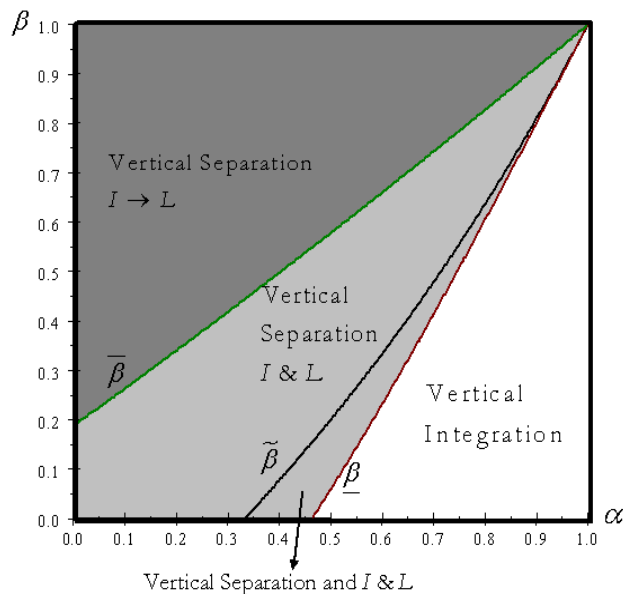


Figure 2: The Equilibrium Outcomes

4 Discussion

Essentially, the optimal choice of organizational structure and bargaining pattern depends on a trade-off between the elimination of double marginalization and the surplus extraction by the union at the bargaining table.¹⁷ This trade-off can be elaborated as follows. The lower the relative bargaining power of the downstream firm vis-à-vis the upstream firm, the worse the double-marginalization problem

¹⁷In our paper, the extent of the double-marginalization problem depends on the downstream firm's relative bargaining power vis-à-vis the upstream firm. When the downstream firm has all the bargaining power ($\beta = 1$), the input price will be set equal to the marginal cost of producing the input. This result is similar to the one obtained under either perfect downstream competition or vertical integration. In contrast, when the downstream firm has no bargaining power at all ($\beta = 0$), the input price will be set equal to the monopoly input price. Thus, the negotiated input price lies between the competitive price and the monopoly price.

is. Vertical integration removes this problem and enlarges the total surplus to be shared with the union at the bargaining table. However, when the downstream firm's relative bargaining power vis-à-vis the union is weak, a larger portion of the surplus will be captured by the union in the form of a higher negotiated wage. This makes vertical integration unattractive. The optimal vertical structure and bargaining pattern will be determined by this trade-off.

When β is relatively higher than α , that is, when the downstream firm is relatively stronger vis-à-vis the upstream firm than vis-à-vis the union (see the dark grey area of Figure 2), vertical separation will dominate vertical integration because the benefits of vertical integration will be mostly captured by the union. To compensate for the loss in profits due to the double-marginalization problem that exists when firms remain vertically separated, the downstream firm can strategically manipulate the sequence with which it bargains with the upstream firm and the union. In this particular case, the downstream firm should first bargain over the input price with the upstream firm prior to bargaining over the wage with the union. In effect, by committing to negotiating the input price first, the downstream firm is willing to pay a higher input price than would prevail under the simultaneous bargaining framework in order to strategically reduce the amount of surplus to be shared with the union in the subsequent wage negotiation. The resulting negotiated wage will hence be lower.¹⁸ Naturally, this strategy is only feasible if the downstream firm's relative bargaining power vis-à-vis the upstream firm is not too weak; otherwise the resulting input price will be too high, and the benefit of a lower negotiated wage cannot outweigh the cost of having to pay a higher input price.

When β is relatively equal to α , that is, when the downstream firm is equally strong compared with the upstream firm and the union (see the light grey area of Figure 2), vertical separation will still dominate vertical integration; however, the downstream firm will now prefer to bargain with the upstream firm and the union simultaneously. Here, the benefit of the strategic commitment of negotiating the

¹⁸It can be seen from Proposition 1 that the negotiated input price under VS and $I \rightarrow L$ is the highest, but the negotiated wage in this case is the lowest.

input price prior to the wage is small. For this strategic commitment to be feasible, the downstream firm must be able to exploit its relatively strong bargaining position vis-à-vis the upstream firm to leverage its relatively weak bargaining position vis-à-vis the union. Accordingly, we require that both relative bargaining positions should in general be sufficiently different.

When β is relatively lower than α , that is, when the downstream firm is relatively stronger vis-à-vis the union than vis-à-vis the upstream firm (see the white area of Figure 2), vertical integration dominates vertical separation. Under vertical integration, the downstream firm only has to negotiate over the wage with the union. With a low β , the benefits of vertical integration are substantial. Consequently, the surplus to be bargained over with the union will also be substantial. If α is not sufficiently high, most of the surplus will be captured by the union, making vertical integration unattractive. Vertical integration is only attractive for the downstream firm if it has a sufficiently large α .

The downstream firm has no incentive to bargain over the wage with the union prior to bargaining over the input price with the upstream firm. Presumably such a strategy will only be pursued if the benefit of committing to a higher negotiated wage outweighs the cost. The benefit is in the form of a lower input price while the cost is in the form of a higher negotiated wage. In our model, the cost always dominates the benefit. This is essentially because for the downstream firm, vertical integration is a more effective tool for gaining a lower input price than is the sequential bargaining with the wage negotiation prior to the input price negotiation.

Finally, in contrast to the existing papers on pattern bargaining such as Dobson (1994) and Marshall and Merlo (2004), we show that sequential bargaining does not always dominate parallel (simultaneous) bargaining. In the event that sequential bargaining is optimal, our paper further shows that the feature of the sequence is important. More specifically, we show that the downstream firm must bargain over the input price prior to bargaining over the wage with the union. The reverse bargaining sequence is never optimal. Essentially, the downstream firm must bargain

with the weaker bargaining party first, that is, the upstream firm.

5 Conclusion

This paper examines the incentive of a downstream firm to vertically integrate with an upstream firm in a bilateral monopoly setting with a unionized downstream market. The downstream firm requires an intermediate input and labor input to produce a final good. The former is provided by the upstream firm, and the price is determined through bargaining between the downstream and upstream firms. Labors are represented by a union and the wage is determined through bargaining between the downstream firm and the union.

It is well established in the literature that in the absence of downstream unionization, the upstream firm and the downstream firm have an incentive to vertically integrate to eliminate the double-marginalization problem that typically plagues vertically separated entities. However, the presence of downstream unionization may dissipate the incentive for vertical integration because the benefits of vertically integrating enlarge the surplus to be shared with the union. If the bargaining power of the union is too strong, it will extract most of the surplus in the form of a higher negotiated wage, thereby dissipating the benefits of vertical integration for the downstream firm. This renders vertical integration unattractive.

In the paper, we model the bargaining between the downstream firm and the upstream firm, and between the downstream firm and the union, as the generalized Nash bargaining game. We endogenize the bargaining agenda(s) to be negotiated. That is, when the downstream firm opts for vertical integration, it faces only the wage bargaining, but when it opts for vertical separation, it faces both the wage bargaining and the input price bargaining. We also allow for the timing of these two bargaining negotiations to be endogenously designed. That is, the downstream firm can choose to conduct these negotiations either simultaneously or sequentially. If the sequential bargaining framework is chosen, the downstream firm will have to decide the pattern by which it will carry out the sequence. It can bargain with the

upstream prior to bargaining with the union or vice versa.

This paper derives conditions under which vertical integration is (or is not) optimal. These conditions crucially depend on the interplay between organizational structure, pattern bargaining, and the trade-off between elimination of the double-marginalization problem and the surplus extraction by the union in the wage bargaining.

More importantly, we also show that when sequential bargaining under vertical separation is optimal, the downstream firm will prefer to bargain over the input price with the upstream firm prior to bargaining over the wage with the union. Essentially, by choosing this bargaining pattern, the downstream firm can strategically manipulate the negotiated input price to gain wage concessions from the union. More precisely, by negotiating with the upstream firm first, the downstream firm commits to paying a higher input price to reduce the size of the surplus to be negotiated with the union at the bargaining table. This will result in a lower negotiated wage. This bargaining pattern is optimal when the downstream firm's relative bargaining power vis-à-vis the upstream firm is stronger than its relative bargaining power vis-à-vis the union. This bargaining pattern also implies that the downstream firm negotiates with the weaker bargaining party first, which in this case is the upstream firm.

Appendix

Proof of Proposition 3

Notice that all profits can be expressed in terms of π_{VI} . Thus, we can write $\Pi_{VS,I \rightarrow L} = \left[(1 - B) + \frac{B(1-B)(1+A)}{(1-A)} \right] \pi_{VI}$, $\Pi_{VS,I \& L} = \frac{(1-B^2)}{(1-AB)^2} \pi_{VI}$, and also $\Pi_{VS,L \rightarrow I} = (1 - B^2) \pi_{VI}$. Since $\alpha, \beta \in [0, 1]$, we have $(1 - B^2) \leq 1$ and $1/(1 - AB)^2 \geq 1$.

Next, we do pairwise comparisons of these profits. It is obvious that $\Pi_{VS,L \rightarrow I} = (1 - B^2) \pi_{VI} \leq \pi_{VI}$ because $(1 - B^2) \leq 1$. We can also verify that $\Pi_{VS,I \& L} = \frac{(1-B^2)}{(1-AB)^2} \pi_{VI} \geq \Pi_{VS,L \rightarrow I} = (1 - B^2) \pi_{VI}$ because $1/(1 - AB)^2 \geq 1$, and $\Pi_{VS,I \rightarrow L} = \left[(1 - B) + \frac{B(1-B)(1+A)}{(1-A)} \right] \pi_{VI} \geq \Pi_{VS,L \rightarrow I} = (1 - B^2) \pi_{VI}$. The latter can be evaluated in the following way. Suppose that this is not the case, and instead we

have $\left[(1 - B) + \frac{B(1-B)(1+A)}{(1-A)} \right] \pi_{VI} < (1 - B^2) \pi_{VI}$. Simplifying the expression yields $\frac{B(1-B)(1+A)}{(1-A)} < B(1 - B)$ and $2A < 0$. This is clearly a contradiction because $0 \leq A$. Thus, we have $\Pi_{VS,I \rightarrow L} \geq \Pi_{VS,L \rightarrow I}$. To sum up, we observe that VS and $L \rightarrow I$ is clearly dominated by other organizational forms and bargaining patterns.

Now we focus our attention on the following three cases, namely, (1) VI , (2) VS and $I \rightarrow L$, (3) VS and $L \& I$. We will have $\pi_{VI} = \Pi_{VS,I \rightarrow L}^d$ if only if $\pi_{VI} = \left[(1 - B) + \frac{B(1-B)(1+A)}{(1-A)} \right] \pi_{VI}$, which can be simplified into $\tilde{\beta} = \frac{(3\alpha-1)}{(3-\alpha)}$.

Next, we have $\pi_{VI} = \Pi_{VS,I \& L}^d$ if only if $\pi_{VI} = \frac{(1-B^2)}{(1-AB)^2} \pi_{VI}$, which can be rewritten as $\underline{\beta} = \frac{(\alpha^2+6\alpha-3)}{(\alpha^2-2\alpha+5)}$. We have $\Pi_{VS,I \rightarrow L}^d = \Pi_{VS,I \& L}^d$ if only if $\left[(1 - B) + \frac{B(1-B)(1+A)}{(1-A)} \right] \pi_{VI} = \frac{(1-B^2)}{(1-AB)^2} \pi_{VI}$, which can be simplified into $\bar{\beta} = \frac{(\alpha^2+12\alpha+3)}{16}$.

Subsequently, we compare $\bar{\beta}$, $\tilde{\beta}$, and $\underline{\beta}$. Let us first start with $\underline{\beta}$ and $\tilde{\beta}$. Suppose that we have $\underline{\beta} \geq \tilde{\beta}$, or $\frac{(\alpha^2+6\alpha-3)}{(\alpha^2-2\alpha+5)} \geq \frac{(3\alpha-1)}{(3-\alpha)}$. Simplifying this relationship yields $-4(1 - \alpha)^2(1 + \alpha) \geq 0$, which is clearly a contradiction since $0 \leq \alpha \leq 1$. Consequently, we have $\underline{\beta} \leq \tilde{\beta}$. Next, we compare $\bar{\beta}$ and $\tilde{\beta}$, and we suppose that we have $\tilde{\beta} \geq \bar{\beta}$, or $\frac{(3\alpha-1)}{(3-\alpha)} \geq \frac{(\alpha^2+12\alpha+3)}{16}$. Simplifying this relationship further gives us $(1 - \alpha)(5 + \alpha)^2 \leq 0$, which is clearly a contradiction given that $0 \leq \alpha \leq 1$. Thus, we have $\tilde{\beta} \leq \bar{\beta}$. Thus, all in all we have $0 \leq \underline{\beta} \leq \tilde{\beta} \leq \bar{\beta} \leq 1$. Using the results derived above, it is straightforward to show that the proposition holds. ■

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