

## ***Information Sharing in Union-Firm Relationships.***

Anthony Creane and Carl Davidson<sup>1</sup>

Department of Economics, Michigan State University  
Department of Economics, Michigan State University *and* GEP, University of Nottingham

Shortened title: ***Union-Firm Information Sharing***

Abstract: Large firms often negotiate wage rates with labor unions. When they do, an ex-ante agreement to share information should make it more likely that they will reach an agreement and capture the gains from trade. However, if the firm refuses to share information, the union may shade down its wage demand to increase the probability of acceptance. This reduction in the wage can increase the joint surplus of the agents and increase social welfare. As a result, there are some circumstances in which bargaining with incomplete information can be better for the agents and society than bargaining with complete information.

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## 1. Introduction

Many firms and their input suppliers form long-term relationships in which they periodically negotiate their terms of trade. As has long been recognized, the presence of private information can cause negotiations to break down on occasion, resulting in an inefficient disruption of production. For example, the United Auto Workers, with superior knowledge of its strike fund and/or its member's outside options, may call for a strike against General Motors if the firm is unwilling to meet its wage demands. And, the firm's unwillingness to concede may be due to its superior knowledge of demand, productivity and/or its stock of inventories. Theoretically, such disruptions could be avoided if the agents would simply agree to reveal their private information before the negotiations begin.<sup>2</sup> Whether or not this will occur is unclear, however, since some agents may be unwilling to enter into such an agreement if it sufficiently weakened their bargaining position.

The literatures on non-cooperative bargaining and mechanism design have already dealt with many of the issues that arise in this environment. In the bargaining literature, it is generally assumed that the agents already possess the private information and then the implications of different bargaining processes are examined (see Ausubel, Cramton and Deneckere 2002 for a survey). In the mechanism design literature, one of the questions addressed is whether the agents can find a way to commit to ex ante information revelation in order to avoid the ex post inefficiencies that can be caused by asymmetric information. In particular, the main question is whether or not a mechanism exists which will induce the agents to reveal their information while preserving efficiency (see Chapter 7 of Fudenberg and Tirole 1991 for a survey).

In this paper, we approach this problem from a new angle. Our approach differs from that of the bargaining literature in that we focus on the long-term nature of the union/firm relationship. We emphasize that although at any point in time the agents may possess private information about key parameters, they realize that over time market conditions are likely to vary and affect these parameters in unpredictable ways. Thus, although a union may know the *present* reservation wage of its workers, it

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<sup>2</sup> The agents would, of course, also have to be able to reveal their information in a verifiable manner.

realizes that this value will change over time in ways that are likely to be beyond its control. Likewise, while the firm may have a good sense of *current* productivity, and while it may choose to enhance this value in the future by investing in process-oriented R&D, there will also be *future* productivity shocks that they cannot anticipate. As a result, the agents may wish to enter into a long-term agreement that specifies that information obtained in the future must be revealed prior to subsequent negotiations. Our goal is to determine when and if such an ex ante agreement is likely to be achieved. That is, we want to determine conditions under which the long-term relationship will be characterized by information sharing.

Our approach differs from that of the mechanism design literature in that we restrict attention to a particular type of contract. To be precise, our primary focus is on the case in which the two sides bargain over a linear wage contract after observing their private information (although we also allow for ex ante lump sum transfers). This is, by far, the most common form of contracting between firms and unions (see Farber 1986, Oswald 1993 and Gahan 2002).<sup>3,4</sup> For that reason, almost all studies of union-firm relationships assume this form of contracting (for examples see Horn and Wolinsky 1988 or Marshall and Merlo 2002). One implication of restricting the set of available contracts is that the joint surplus to be split by the agents may not be maximized with complete information, an issue that does not arise in the mechanism design literature. Thus, whereas in the mechanism design literature the presumption is always

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<sup>3</sup> In a recent study, Gahan (2002) surveyed 284 Australian union delegates. In response to the question “Is the level of employment usually determined by the employer?” 92.2% responded “yes.”

<sup>4</sup> Linear contracts are also commonly used in agreements between firms and other input suppliers. For example, retail outlets pay manufacturers a price for their goods, whereas the manufacturers pay the retailers upfront “slotting allowances.” Mills (2004) provides other examples in which retailers pay a linear price to the manufacturer with the manufacturer making a reciprocal payment to the retailer. This is somewhat surprising, since optimal two-part pricing would have the manufacturer charging the retailer *both* a linear price and a fixed amount. In other words, arrangements that are commonly observed have the fixed payment going in the wrong direction. As we show below, our model provides an explanation for this phenomenon. Other examples of linear pricing in firm-firm relationships can be found in Chippy and Snyder’s (1999) discussion of pricing practices in the cable TV market; Gabrielson and Sorgard (1999), who note the prevalence of linear wholesale pricing in the grocery sector; and Delgado and Waterson (2003) in their empirical model of the market for tires in the UK. In section 6, we discuss this issue further and argue that linear pricing is the most sensible assumption to make about contracting between agents in a vertical relationship.

that the agents would prefer to share information if they could just find an efficient mechanism; it is not at all clear that information sharing will be the best outcome in our setting, either for the agents or society.<sup>5</sup>

One of our main results is that the surplus to be split by the union and the firm as well as social welfare (which includes consumer surplus) may be larger if the union and the firm do not share information. That is, more information may be harmful both for the agents and society as a whole. It follows that although incomplete information may lead to a disruption in production in some states, expected social welfare may still be higher than it would have been had the agents agreed to reveal their private information. A second result that we obtain is that it is possible for information sharing to simultaneously *increase* the joint surplus and *lower* social welfare. Thus, there are situations in which the agents themselves gain when production disruptions are eliminated, but society as a whole is still harmed! Of course, there will also be cases in which the agents prefer to share information and welfare increases when they do. In particular, if the agents are willing to share information without side payments, then revealing information increases welfare. It is interesting to note that even an agent with no bargaining power may be willing to unilaterally reveal its information. It follows that, depending on the parameters of the model (which include the union's reservation wage, labor productivity and their distributions), many fundamentally different outcomes are possible. We also find that expected profits and expected social welfare are both, surprisingly, non-monotonic in a key parameter of the model: the probability that labor productivity is relatively high.

The forces leading to these results are easy to explain. Since we are examining a setting with a bilateral monopoly and incomplete contracts, it is not surprising that the presence of wage-setting power introduces distortions and creates deadweight loss. When the union has the ability to set the terms of trade, it will demand a wage that is inefficiently high. However, if the union does not have complete

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<sup>5</sup> An alternative way to state this is to point out that there is a presumption in the literature that information sharing in bilateral relationships is a good outcome because it prevents inefficiencies that might arise due to asymmetric information. However, this implicitly rests on the assumption that all types of contracting are available to the agents. Our point is that if one restricts attention to the types of contracts that are commonly observed, then information sharing might lower both the surplus to be shared by the agents and social welfare. Or, perhaps even more worryingly, information sharing might increase the joint surplus while lowering welfare.

information about the firm, it has an incentive to shade down its offer in order to increase the likelihood that the firm will accept it. This reduction in the wage offer reduces the distortion and lowers the deadweight loss from monopoly pricing. Thus, there is a clear tradeoff for the agents and society. While incomplete information makes it harder for the union and firm to reach an agreement, it also reduces the distortion created by monopoly power when production occurs. As we show below, if production is likely to break down with incomplete information the first effect dominates and the agents will agree to share information. However, if an agreement is likely to be reached even if the agents keep their information private, then the latter effect dominates and the union will be unable to induce the firm to agree to information revelation.

The fact that agents in a vertical relationship might wish to (and actually do) share information has been recognized elsewhere, especially in the literature on supply chain management. In a recent paper, Lee and Huang (2000) provide a variety of examples of firms and their suppliers that share information about inventories, sales, capacity and measures of performance. They also acknowledge the difficulties that these firms face in establishing such agreements. Since information sharing agreements are not binding, agents that wish to reveal information *ex ante* must find a way to commit to doing so in a verifiable manner. Otherwise, after obtaining their private information, the agents might renege on the agreement or misrepresent their true type.

Institutional arrangements that allow firms and unions to commit to information revelation in a verifiable manner are common in OECD countries.<sup>6</sup> For example, there is evidence that Social Partnership Agreements in Britain and Joint Consultation Committees in Japan have increased

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<sup>6</sup> Lee and Huang point out that there are also a variety of ways to make such commitments in firm-firm relationships. For example, some firms (including Proctor & Gamble and Wal-Mart) use what is known as a “Continuous Replenishment Program” to share information about inventories. This program works by having the buyer provide the inventory data to the supplier and then allowing the supplier to manage the inventory within agreed upon guidelines. Alternatively, inventory data can be shared by outsourcing its management to a third party (this practice has been adopted by some of Apple Computer’s plants in the western U.S. and some of their Asian suppliers, with Fritz Companies serving as the third party). Lee and Huang also discuss a proposal put forth by Japanese semiconductor makers who wish to share information about inventories with chip makers from Japan, Korea, the United States and Europe. However, they note that the suppliers have not yet been willing to commit to this agreement. They argue that this reluctance may be due to concerns about whether the firms can be trusted to truthfully reveal their private information. Our results offer an alternative explanation: the suppliers may be unwilling to share information because their expected profits might be higher when information remains private.

information sharing between unions and firm (see Dietz 2004 and Kelly 2004 for the UK and Morishima 1991 for Japan); while Work Councils provide similar services in many Western European countries (see Freeman and Lazear 1995). Other ways to increase the information flow between unions and firms would include allowing a union representative to serve on the firm's Board of Directors, allowing a third party to audit the firm's books (this practice is used in the National Football League and has been proposed for the National Hockey League); and/or an agreement to publicly reveal data on inventories and measures of productivity. The auto industry provides an example of this latter practice. Any individual can purchase a copy of *The Harbour Report* (available at [www.harbourinc.com](http://www.harbourinc.com)) which includes, among other information, labor hours per vehicle assembly plant, which is obtained from each manufacturer.<sup>7</sup>

In terms of the existing literature, the two papers that are most closely related to ours are Riordon (1984) and Li (2002).<sup>8</sup> Riordon's paper has a similar set-up as ours, but he takes the standard mechanism design approach. In particular, he analyzes a bilateral monopoly with uncertainty and private information and asks whether an efficient mechanism for information revelation exists. In contrast to our approach, Riordon assumes that if revelation occurs an efficient contract is always secured.<sup>9</sup> Li (2002, extended in Zhang 2002) examines a situation in which one upstream firm offers a linear price contract to multiple downstream retailers that are engaged in Cournot competition in the product market. Each retailer has private information either about the common demand curve or about its own cost of production which it

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<sup>7</sup> There is evidence that union members often have conflicted views about information sharing agreements with their firms. For example, in June 2004 American Airlines' Allied Pilots Union held an election to determine its new President. Ralph Hunter, the winner, was in favor of a controversial new negotiating strategy that included sharing information and increased cooperation with the airlines, while Mark Hunnibell, his rival, backed "a more traditional approach." The election was bitterly contested and Hunter emerged with a narrow victory (Torbenson 2004).

<sup>8</sup> Our work is also related to the literature on information sharing under oligopoly (see, for example, Vives 1990 or Raith 1996). However, most of this literature focuses on information sharing in horizontal relationships (the exceptions are the Li and Zhang paper cited above and Creane 2005 and 2006).

<sup>9</sup> Our approach is also related to work on information transmission such as in Crawford and Sobel (1982), though there are differences. One crucial difference is that we have the agents choosing whether to transmit information *before* they know their types, while in Crawford and Sobel (1982) the sender makes its choice *after* learning its type. Our different approaches arise from our different focuses: we are concerned with the informational implications of long-term relationship between the two parties while Crawford and Sobel study a one-shot game. In that sense, Crawford and Sobel (1982) is closer to the signaling literature. Interestingly, Crawford and Sobel (1982) note that in the example they consider (p. 1444) an ex ante commitment to reveal the information is always beneficial but that they were "unable to verify whether this is true under more general conditions." Our results shows that it is not so. Another difference is that we examine bilateral transmission while in Crawford and Sobel (1982) there is only one sender and only one receiver.

may reveal to the upstream firm. The decision to disclose the private information is made *ex ante*, and the upstream firm is given the choice of whether or not it wants to acquire the information. After all information revelation takes place, the upstream firm then sets a common price for the input. Although there are similarities in our approaches, there are also important differences. For example, the incomplete information in Li's framework is one-sided while in our model it is two-sided. In addition, in Li's model, by sharing information with the upstream firm, the downstream firm implicitly reveals information to its own horizontal rivals. Finally, in Li's model the upstream firm sets the price (which is natural given his setting) while we examine the case of bilateral monopoly.

The remainder of the paper divides into 6 sections. In the next section, we describe our model in which a firm and its unionized workforce know that they will both possess private information that they can agree to reveal before wage negotiations begin. This decision is made *ex-ante*; that is, before the information is obtained. In order to focus on the economic incentives to share information, we assume throughout that the agents can always find a way to commit to information revelation in a verifiable manner. In section 3, we examine the case in which the firm has all the bargaining power. This means that the firm offers a wage that the union may accept or reject. We show that in this case, information revelation always leads to an efficient outcome in that it maximizes the union-firm joint surplus as well as social welfare. It follows that the firm, which prefers to be informed, can always afford to bribe the union to share information if lump sum transfers are allowed.<sup>10</sup> As a result, when the firm has all the bargaining power, simple wage setting with lump sum transfers is an efficient mechanism.

In Section 4, we turn to the case in which the union has all the bargaining power. We show that, even though the union always gains from information sharing, there are cases in which it cannot afford to compensate the firm enough to get them to accept such an agreement. Moreover, we show that the joint

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<sup>10</sup> The type of side payments that we have in mind would be any payment made by the firms to the union (or vice versa) that would not affect the firms' marginal costs of production. So, for example, any agreement to alter the contribution made by the firms in the auto industry to the UAW's "job fund" would qualify; as would a signing bonus paid to all union members who vote "yes" on a new proposed contract. Another example would be an agreement to change the pension formula that results in a more (or less) favorable retirement package for workers. We thank Paula Voos for suggesting some of these examples. See also footnote 17 below.

surplus and social welfare are both strongly non-monotonic in the probability that labor productivity is high. One of the main reasons for the dramatic difference in results is that there is an important asymmetry between the set-ups in Sections 3 and 4. In Section 3, the firm controls both the wage and employment and thus has two instruments at its disposal; whereas in Section 4, in which the union controls the wage, the firm still has the power to set employment. Since the two set-ups yield such different outcomes, in Sections 5 and 6 we consider several important extensions of the model in order to check the robustness of our results. In particular, we allow the bargaining power to vary continuously between the two sides and discuss how our results would change if we allowed for more complex contracts. We also examine the implications of Employee Stock Ownership Plans for information sharing. Finally, we close the paper in Section 7 with a brief summary of our main results.

## 2. The Model

Our model consists of a monopolistic firm that employs labor that is represented by a union; however, it should be clear that our results hold for other vertical relationships. We assume that the agents' contracting problem is complicated by the presence of incomplete information in that the productivity of labor and the reservation wage of the union's members (that is, their opportunity cost for working) are initially unknown. We use  $\lambda$  to denote the productivity parameter, whereas the reservation value is denoted by  $v$ . Specifically, the productivity parameter represents the number of units of labor required to produce one unit of output. If we use  $L$  to denote total employment and  $q$  to denote total output, then it follows that  $L = q\lambda$ . Note that in this setting, high values for  $\lambda$  indicate *low* productivity. We assume throughout that the firm has private information about  $\lambda$  while the union has private information about  $v$ . We also assume that the demand for the downstream product is linear in that  $P = 1 - q$  with  $P$  denoting the price of the final product.

As described in the introduction, our goal is try to capture the idea that the union and the firm are engaged in a long-term relationship with two key features. First, at any point in time, the parties may possess private information that affects their ability to reach an agreement over the wage. Second, over



time, each side faces unanticipated changes in market conditions that alter the value of this information. As a result, the agents may wish to enter into a long-term agreement that specifies that any private information must be revealed to both parties prior to negotiations.

Although the model that we have in mind is dynamic, we believe that we can capture the essential features of the long-term relationship by considering the following five-stage one-shot (static) game. In the initial stage, before the firm learns the productivity parameter and the union learns its workers' reservation wage, the agents decide whether to share any private information that they may possess at any stage in the game. If one side is willing to share information *without* side payments, then we say that they are "unilaterally willing to share." An agreement by *both* sides to reveal their information is referred to as an "information sharing agreement." In order to focus on the incentives to share information, we assume that if they do agree to reveal their private information, that they can do so in a verifiable way. In the second stage of the game,  $\lambda$  and  $v$  are determined by independent random draws by nature, the firm learns  $\lambda$ , and the union learns  $v$ . The agents then reveal these values in stage three, provided that they have agreed to do so. In stage four, one agent makes a wage offer that the other side may accept or reject. If the offer is rejected, the game ends and production does not take place.<sup>11</sup> If the offer is accepted, then in the final stage the firm chooses employment and production occurs. We assume that the firm's goal is to maximize expected profits; whereas the union's goal is to maximize the expected wage bill (i.e., the product of employment and the wage in excess of the reservation wage). We characterize the solution to this game for two different cases, depending upon whether the agents can use lump sum transfers in the initial period to entice their rivals to enter into an information sharing agreement.

As for the unknown parameters, we assume that  $\lambda$  may take on one of two values,  $\lambda_1$  and  $\lambda_2$  with  $\lambda_1 < \lambda_2$ . Likewise,  $v$  can take on one of two values, 0 or  $r$ . We use  $\gamma$  to denote the probability

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<sup>11</sup> We focus our attention on linear wage contracts for two reasons. To begin with, simple wage bargaining that leaves the employment decision to the firm is far and away the most common form of union/firm negotiations (see, for example, Farber 1986, Oswald 1993 and Gahan 2002), as well as being common in firm-firm relationships (see footnote 2). Second, as we noted in the introduction, the question of whether or not to share information *ex ante* in this environment has hardly been examined and it seems natural to start with the simplest and most common mechanism. In section 6, we compare the results here to those when more sophisticated contracting is allowed.

that  $\lambda = \lambda_1$  and  $\rho$  to denote the probability that  $v = 0$ . Note that when  $v = r$ , the union is in a stronger bargaining position than it would be if  $v = 0$  (although the joint surplus at the efficient outcome is lower when  $v = r$ ). In addition, when  $\lambda = \lambda_1$ , the firm is relatively productive. This implies that the firm is willing to pay a relatively high wage and that the joint surplus at the efficient outcome is relatively high (as compared to the case in which  $\lambda = \lambda_2$ ). As we show below, one combination of  $\lambda$  and  $v$ ,  $\lambda = \lambda_2$  and  $v = r$ , plays a particularly important role in our analysis. Since these parameter values imply that the union is strong and the firm weak, we refer to this as the *dominant union* case.

We assume throughout that the parameters of the model are such that under complete information production would always occur.<sup>12</sup> This assumption also implies that it is common knowledge that there are gains from trade even when we have a dominant union. With this assumption in place, unguided intuition might lead one to conclude that the agents will always be able to settle on a sharing agreement. After all, under incomplete information there will be cases in which transactions that increase the joint surplus of the union and the firm might not take place. Sharing information removes such inefficiencies and should allow the agents to use lump sum payments to make sure that they both end up better off after revealing their information. Below we show that this intuitive argument does not always hold.

Before closing this section, we briefly discuss the importance of our assumption that union's objective is to maximize the wage bill. As we have noted, the most common form of labor-market bargaining is characterized by what is known as the "right-to-manage" in which firms are allowed to set employment after wages have been set. In an attempt to provide a theoretical justification for this outcome, Oswald (1993) offered a model of labor negotiations in which union members vote on proposed contracts. Assuming that layoffs are determined by seniority, he shows that contract negotiations result in the wage that maximizes the median union worker's wage and that the union allows the firm to set employment. This result implies that the union's objective is to maximize the wage of its median member with little or no regard to the level of employment. Though this provides a rationalization for our

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<sup>12</sup> This implies that the union is never labor constrained.

assumption that firms chose employment it also clashes with our assumption about the union's goal. Thus, based on Oswald's model, one could question whether our framework accurately captures the union-firm relationship.

We justify our assumption in three ways. First, as we pointed out at the beginning of this section, we would like our model to be flexible enough so that it can be viewed as a representation of many different types of vertical relationships.<sup>13</sup> Thus, if one is uncomfortable with the union-firm interpretation, one can view our two agents as profit-maximizing upstream and downstream firms. In such a setting, having an input supplier that maximizes profit is equivalent to a union that maximizes the wage bill (the reservation wage is then equivalent to the input supplier's marginal cost of production).

Our second justification is to point out that although Oswald's paper has certainly been influential due to its documentation of the importance of the "right-to-manage" model (in which the firm sets employment); it does not seem to have altered the manner in which most economists model the union-firm relationship. Assuming that the union cares about both wages and employment, is by a wide margin, the most common assumption made about union preferences – assuming that they maximize the wage bill is just a convenient and tractable way to capture this notion. This brings us to our third and most important justification. Although there are some difficulties in directly applying the Oswald model to our framework, if one does so, the results are qualitatively the same. That is, it can be shown that our results generalize to the Oswald setting in which the union's goal is to maximize the wage of an individual worker. Interested readers can find the details of the argument along with a description of the problems that arise when attempting to apply the Oswald model to our framework in a supplemental appendix which is available at [www.msu.edu/~davidso4/currentnew.html](http://www.msu.edu/~davidso4/currentnew.html).

### **3. The Firm Sets the Wage**

In this section we assume that the firm makes the wage offer. We solve the model backwards, beginning in the last stage. At this point, the wage ( $w$ ) is already set. So, the firm must choose output ( $q$ )

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<sup>13</sup> Of course we are abstracting from a number of other issues that would arise in such as setting (such as rivalry in both the final goods market and the input market).

to maximize profits. As we noted above, we are assuming that it takes  $\lambda q$  workers to produce  $q$  units of output. Given our specification for demand, our assumption that production always occurs with complete information requires that  $\lambda_2 r < 1$ . With our demand curve, the firm's profits are  $\pi = (1 - q - w\lambda)q$ . Note that profits are certain, since the firm knows the productivity parameter; they are maximized when

$$(1) \quad q(\lambda, w) = \frac{1 - w\lambda}{2}$$

This leads to a profit of

$$(2) \quad \pi(\lambda, w) = \frac{(1 - w\lambda)^2}{4}$$

The wage bill, which we denote by  $\theta$ , is given by  $\theta = \lambda q(w - v)$ . Substitution from (1) yields

$$(3) \quad \theta(\lambda, w) = \frac{\lambda}{2}(1 - w\lambda)(w - v).$$

We now turn the wage setting stage. If the firm knows  $v$ , it will set the wage at  $v$ . Thus, profits and the wage bill become

$$(5) \quad \pi_C^F(\lambda) = \frac{(1 - v\lambda)^2}{4} \quad \theta_C^F(\lambda) = 0.$$

In (5), the super-script F denotes that the firm is setting the wage. The sub-script C denotes that these values apply to the case in which the firm has complete information. Let  $S$  denote the joint surplus to be split between the firm and the union. In this case the (ex ante) expected joint surplus is

$$(6) \quad ES_C^F = \frac{1}{4}\{\rho + (1 - \rho)[\gamma(1 - r\lambda_1)^2 + (1 - \gamma)(1 - r\lambda_2)^2]\}.$$

If we use  $W$  to denote social welfare, which equals the sum of consumer surplus, profits and wage bill (since the reservation wage is a worker's opportunity cost), then  $W = q - (q^2/2) - \lambda qv$ .<sup>14</sup> Applying this formula yields expected welfare which is

$$(7) \quad EW_C^F = \frac{3}{8}\{\rho + (1 - \rho)[\gamma(1 - r\lambda_1)^2 + (1 - \gamma)(1 - r\lambda_2)^2]\}$$

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<sup>14</sup> This follows directly from the fact that with this demand curve Consumer Surplus =  $.5(1 - P)q = .5q^2$  and, as shown above,  $\pi = (1 - q - w\lambda)q$  and  $\theta = \lambda q(w - v)$ .

Now, suppose that the firm does not know  $v$ . Then it will choose  $w$  to maximize expected profits, which are given by

$$(8) \quad E\pi(\lambda, w) = \begin{cases} \frac{(1-w\lambda)^2}{4} & \text{if } w \geq r \\ \frac{\rho(1-w\lambda)^2}{4} & \text{otherwise} \end{cases}$$

Recall that since  $(1-r\lambda_2)^2 > 0$ , the firm can always guarantee itself a positive profit by offering a wage of  $r$ . Clearly, expected profits are maximized at either  $w = 0$  or  $w = r$ . From (8) we obtain

$$(9) \quad w_I^F(\lambda) = \begin{cases} 0 & \text{if } \rho \geq (1-r\lambda)^2 \\ r & \text{otherwise} \end{cases}$$

In (9), the sub-script  $I$  denotes that the firm has incomplete information.

From (9) it is clear that if  $\rho \geq (1-r\lambda_1)^2$  or  $\rho < (1-r\lambda_2)^2$ , the firm's wage offer will not depend on its type. In the former case, the firm always offers a wage of zero; whereas in the latter case, the wage offer is always  $r$ . However, if  $(1-r\lambda_2)^2 \leq \rho < (1-r\lambda_1)^2$ , then the wage offer varies with the firm's type. Specifically, a low productivity firm offers a wage of zero while a high productivity firm offers  $r$ . Thus, if  $(1-r\lambda_2)^2 \leq \rho < (1-r\lambda_1)^2$  there is an ex ante probability  $\gamma$  that the firm will offer a wage of  $r$ . Combining these results, we find that if the probability that the union has a low reservation wage ( $\rho$ ) is sufficiently low, both types of firms offer the higher reservation wage and production always occurs. As the probability that the union is the low reservation type increases, the *low productivity* firm eventually lowers its offer to 0, while the high productivity type continues to offer  $r$ .<sup>15</sup> In this case, the ex ante probability of no production is  $(1-\gamma)(1-\rho)$ : the joint probability that the firm has low productivity and

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<sup>15</sup> The force behind this result is easy to explain. Note that since we have assumed that there are always gains from trade even when we have a dominant union (since  $\lambda_1 r < 1$ ), a low productivity firm can always offer  $r$ , ensure that production will occur, and make positive profits. Thus, as  $\rho$  increases and the low productivity firm switches its offer from  $r$  to 0, it does so because it suddenly finds that the gains from capturing a low reservation wage union's entire surplus larger exceeds the cost of losing the profits it could earn by settling with a high reservation wage union. *The fact that as  $\rho$  increases the low productivity switches from  $r$  to 0 before the high productivity firm is not an artifact of our assumption that the low reservation wage is zero.* If the two reservation wages were given by  $r_1$  and  $r_2$  with  $r_1 < r_2$ , the condition for switching is  $\rho < [(1-r_1\lambda)/(1-r_2\lambda)]^2$  which is decreasing in  $\lambda$ .—the low productivity firm always switches first.

the union has a high reservation wage (i.e., we have a dominant union). Thus, we have a somewhat counter-intuitive result: as the likelihood that the union will accept a low wage increases (from a value just below  $(1 - r\lambda_2)^2$  to a value just above it), it becomes more likely that no production occurs.<sup>16</sup>

If we use (9) to substitute into (8), we obtain expected profits under incomplete information:

$$(10) \quad E\pi_1^F(\lambda) = \begin{cases} \frac{\rho}{4} & \text{if } \rho \geq (1 - r\lambda)^2 \\ \frac{(1 - r\lambda)^2}{4} & \text{otherwise} \end{cases}$$

For the union, the wage expected wage bill depends on  $\lambda$ , which it does not know. So, if the union's reservation wage is zero, we have an expected wage bill of

$$(11) \quad E\theta_1^F(0) = \begin{cases} .5r[\gamma\lambda_1(1 - r\lambda_1) + (1 - \gamma)\lambda_2(1 - r\lambda_2)] & \text{if } \rho \leq (1 - r\lambda_2)^2 \\ .5r\gamma\lambda_1(1 - r\lambda_1) & \text{if } \rho \in [(1 - r\lambda_2)^2, (1 - r\lambda_1)^2] \\ 0 & \text{otherwise} \end{cases}$$

If the union's reservation wage is  $r$ , we have an expected wage bill of (since  $w$  is never above  $r$ ):

$$(12) \quad E\theta_1^F(r) = 0$$

Now, since the union's wage bill is driven to zero with complete information, it always prefers incomplete information (this is a strict preference since there is a possibility of getting a wage of  $r$  under incomplete information and since the firm does not know its own type at the time that it must decide on information sharing). For the firm, there is no way to do better than when they are informed, so they always prefer complete information. Moreover, the firm gains enough with sharing that they can always afford to offer the union an upfront bribe (i.e., before anyone observes their information) that is sufficient to get them to commit to revealing their reservation wage.

To see this, we can use (10)-(12) to calculate the expected joint surplus with incomplete information. If  $\rho \leq (1 - r\lambda_2)^2$  then we obtain:

$$(13) \quad ES_1^F = \frac{1}{4}[\gamma(1 - r\lambda_1)^2 + (1 - \gamma)(1 - r\lambda_2)^2] + \frac{\rho r}{2}[\gamma\lambda_1(1 - r\lambda_1) + (1 - \gamma)\lambda_2(1 - r\lambda_2)].$$

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<sup>16</sup> However, note that as  $\rho$  rises further, the probability of no production starts to fall, as one would expect.

If  $\rho \in [(1-r\lambda_2)^2, (1-r\lambda_1)^2]$  then we have

$$(14) \quad ES_I^F = \frac{\gamma}{4}(1-r\lambda_1)^2 + \frac{\rho r \gamma \lambda_1}{2}(1-r\lambda_1) + \frac{\rho(1-\gamma)}{4}.$$

Finally, if  $\rho > (1-r\lambda_1)^2$  we have

$$(15) \quad ES_I^F = \frac{\rho}{4}.$$

Straightforward comparison of (6) with (13)-(15) reveals that in all three cases  $ES_C^F > ES_I^F$ . So, as expected, the joint surplus is always larger if the agents agree to share information.

Social welfare calculations have the same form. If  $\rho \leq (1-r\lambda_2)^2$ , then the firm always offers  $r$  and production always occurs. It follows that expected welfare is given by:

$$(16) \quad EW_I^F = \frac{3}{8}(1-\rho)[\gamma(1-r\lambda_1)^2 + (1-\gamma)(1-r\lambda_2)^2] + \frac{\rho}{8}[\gamma(r\lambda_1+3)(1-r\lambda_1) + (1-\gamma)(r\lambda_2+3)(1-r\lambda_2)]$$

If  $\rho \in [(1-r\lambda_2)^2, (1-r\lambda_1)^2]$ , then a high productivity firm offers  $r$  and a low productivity firm offers 0 so there is no production when there is a dominant union. Thus, expected welfare is given by

$$(17) \quad EW_I^F = \frac{\rho\gamma}{8}(1-r\lambda_1)(3+r\lambda_1) + \frac{3\gamma}{8}(1-\rho)(1-r\lambda_1)^2 + \frac{3\rho(1-\gamma)}{8}.$$

Finally, if  $\rho > (1-r\lambda_1)^2$ , then both types of firms offer the same wage (0). Production only occurs when the union has a low reservation wage and we have expected welfare of

$$(18) \quad EW_I^F = \frac{3\rho}{8}.$$

Straightforward comparisons of (7) and (16)-(18) reveal that in all three cases  $EW_C^F > EW_I^F$ . We summarize our results in Proposition 1.

**Proposition 1:** *If the firm sets the wage, then (a) the union is not willing to unilaterally share information; (b) the firm wants to share information and can afford to pay the union a large enough*

*up front fee to induce information revelation; and, (c) social welfare is higher with information sharing.*

Note that Proposition 1 is an interim result: a characterization of the two sides' preferences towards information sharing. What occurs in equilibrium at the initial contracting stage is straightforward, though it depends on if side-payments are possible.<sup>17</sup> If side-payments are not possible, then the firm cannot compensate the union for its expected loss and so in equilibrium the union does not share information to society's loss.

Proposition 1 is consistent with the intuition laid out at the end of Section 2. When the firm has the bargaining power, the wage it sets under complete information leads to an efficient outcome. It follows that it is possible to find a way to make all agents better off when they commit ex ante to an information sharing agreement. As we show in the next section, this is not always the case when the union has the bargaining power.

#### 4. The Union Sets the Wage

We now turn to the case in which the union makes the wage offer. If the firm agrees to the union's wage demand, then employment, profits and the wage bill are still given by (1)-(3), since the union's reservation wage plays no role in the firm's employment decision. As for the wage offer, which clearly does depend upon the reservation wage, we begin with the case in which the union has complete information about the productivity parameter. Maximizing (3) with respect to  $w$  yields the following optimal wage offer

$$(19) \quad w_C^U(\lambda) = \frac{v}{2} + \frac{1}{2\lambda}$$

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<sup>17</sup> One possible way for the firm to bribe the union is for them to agree to pay a wage premium with the stipulation that employment will be based on the opportunity cost of labor. The key assumption would be that the union wage does not affect the firm's employment decision – rather it is a rent-sharing device that supports information sharing. There is a small empirical literature that has attempted to test this assumption; but, the data seems more supportive of the view that employment is determined more by the contract wage than by proxies for the opportunity cost of labor (although the evidence was inconclusive). See, for example, Ashenfelter and Brown (1986) and McCurdy and Pencavel (1986). We thank an anonymous referee for pointing us to this literature.



This wage leads to an (ex ante) expected wage bill, profit, total surplus and social welfare of

$$(20) \quad E\theta_C^U = (1/8)[r(1-\rho)(r\lambda_e^2 - 2\lambda_e) + 1]$$

$$(21) \quad E\pi_C^U = (1/16)[r(1-\rho)(r\lambda_e^2 - 2\lambda_e) + 1]$$

$$(22) \quad ES_C^U = (3/16)[r(1-\rho)(r\lambda_e^2 - 2\lambda_e) + 1]$$

$$(23) \quad EW_C^U = (7/32)[r(1-\rho)(r\lambda_e^2 - 2\lambda_e) + 1]$$

where  $\lambda_e \equiv \gamma\lambda_1 + (1-\gamma)\lambda_2$  denotes the mean of  $\lambda$  and  $\lambda_e^2 \equiv \gamma\lambda_1^2 + (1-\gamma)\lambda_2^2$  denotes the expectation of  $\lambda^2$ .

Note that in (19)-(24) the superscript  $U$  denotes that union is making the wage offer and the subscript  $C$  is used to represent that the offer is made with complete information.

Now, suppose that the union does not know  $\lambda$  (of course, at the time that it makes its wage offer it *does* know  $v$ ). Thus, for any given  $v$ , the expected wage bill is given by

$$(24) \quad E\theta(v) = \begin{cases} .5(w-v)[\gamma\lambda_1(1-w\lambda_1) + (1-\gamma)\lambda_2(1-w\lambda_2)] & \text{if } w \leq 1/\lambda_2 \\ .5\gamma\lambda_1(1-w\lambda_1)(w-v) & \text{if } w \in [1/\lambda_2, 1/\lambda_1] \end{cases}$$

This follows directly from the fact that a firm with productivity of  $\lambda_i$  accepts any wage offer  $w$  such that  $w \leq 1/\lambda_i$ . Note that both portions of (24) are concave. To simplify what follows, we now introduce some new notation: we use  $w(\lambda_1, v)$  to denote the  $w$  that maximizes  $.5\gamma\lambda_1(1-w\lambda_1)(w-v)$  subject to  $w \in [1/\lambda_2, 1/\lambda_1]$  and we use  $w(\lambda, v)$  to denote the wage that maximizes  $.5(w-v)[\gamma\lambda_1(1-w\lambda_1) + (1-\gamma)\lambda_2(1-w\lambda_2)]$  subject to  $w \leq 1/\lambda_2$ . From (24) we obtain

$$(25) \quad w(\lambda, v) = \min\left[\frac{v}{2} + \frac{\lambda_e}{2\lambda_e^2}, \frac{1}{\lambda_2}\right] \quad \text{and} \quad w(\lambda_1, v) = \max\left[\frac{v}{2} + \frac{1}{2\lambda_1}, \frac{1}{\lambda_2}\right]$$

Substitution of (25) into (24) yields the expected wage bill from the two wage offers, which can be used to determine the optimal wage offer. Substituting (25) into (24) and comparing the outcomes yields the following result

**Lemma 1:** If we define  $\hat{\gamma}(v) \equiv \frac{\lambda_2(1-v\lambda_2)^2}{(\lambda_2 - \lambda_1)[v(\lambda_1 + \lambda_2)(v\lambda_2 - 2) + 2]}$ , then if  $\gamma \leq \hat{\gamma}(v)$  the optimal wage offer is

$w(\lambda, v)$ ; otherwise, the optimal wage offer is  $w(\lambda_1, v)$ .

It is straightforward to check that  $\hat{\gamma}$  is decreasing in  $v$ , so that  $\hat{\gamma}(r) < \hat{\gamma}(0)$ . This implies that there are three cases to consider. In the first case,  $\gamma \leq \hat{\gamma}(r)$  so there is high probability that the union is facing a low-productivity firm (i.e., a firm with  $\lambda = \lambda_2$ ). This leads the union to always offer  $w(\lambda, v)$ , which the firm always accepts. It follows that in this case production always occurs, regardless of the union and firm types. In the second case,  $\hat{\gamma}(r) < \gamma < \hat{\gamma}(0)$  so that a low reservation wage union offers  $w(\lambda, v)$  and settles with the firm regardless of its type; while a high reservation wage union offers  $w(\lambda_1, v)$  knowing that only a high productivity firm would accept. In this case, production occurs unless we have a dominant union. Finally, in the third case,  $\gamma \geq \hat{\gamma}(0)$ , so that there is a high probability that the union is facing a high-productivity firm. In this case, the union always offers  $w(\lambda_1, v)$  and production only occurs if the firm is highly productive.

Lemma 1 and the wage offers in (25) allow us to solve for the expected wage bill, profit, and welfare for any given  $v$ . We obtain

$$(26) \quad E\theta(v) = \begin{cases} (1/8)\{v\lambda_e^2 - 2\lambda_e\} - (\sigma_\lambda^2 / \lambda_e^2) + 1 & \text{if } \gamma \leq \hat{\gamma}(v) \\ (\gamma/8)(1 - v\lambda_1)^2 & \text{if } \gamma > \hat{\gamma}(v) \end{cases}$$

$$(27) \quad E\pi(v) = \begin{cases} (1/16)\{v\lambda_e^2 - 2\lambda_e\} + 3(\sigma_\lambda^2 / \lambda_e^2) + 1 & \text{if } \gamma \leq \hat{\gamma}(v) \\ (\gamma/16)(1 - v\lambda_1)^2 & \text{if } \gamma > \hat{\gamma}(v) \end{cases}$$

$$(28) \quad EW(v) = \begin{cases} (1/32)\{7v\lambda_e^2 - 2\lambda_e\} + 5(\sigma_\lambda^2 / \lambda_e^2) + 7 & \text{if } \gamma \leq \hat{\gamma}(v) \\ (7\gamma/32)(1 - v\lambda_1)^2 & \text{if } \gamma > \hat{\gamma}(v) \end{cases}$$

where  $\sigma_\lambda^2 \equiv \lambda_e^2 - [\lambda_e]^2$  denotes the variance of  $\lambda$ . Equations (26)-(28) provide sufficient information to allow us to compare the outcomes under complete and incomplete information. The results are easier to follow if we consider the three cases described above separately.

Case 1 (production always occurs): We start with the case in which  $\gamma \leq \hat{\gamma}(r)$  so that the union always offers  $w(\lambda, v)$  and the firm always accepts. In this case, the ex ante expected wage bill is given by  $\rho E\theta(0) + (1 - \rho)E\theta(r)$ , which, from (26), is

$$(29) \quad E\theta_I^U = (1/8)\{(1 - \rho)r(r\lambda_e^2 - 2\lambda_e) - (\sigma_\lambda^2 / \lambda_e^2) + 1\}$$

Comparing (16a) with (20a) we find that  $E\theta_C^U - E\theta_I^U = (\sigma_\lambda^2 / 8\lambda_e^2) > 0$ , so that the union always prefers to share information. This result is as expected: when one side has all the bargaining power, the agent with that bargaining power prefers to be completely informed.

For the firm, ex ante expected profits are  $\rho E\pi(0) + (1 - \rho)E\pi(r)$ , which, from (27) is

$$(30) \quad E\pi_I^U = (1/16)\{(1 - \rho)r(r\lambda_e^2 - 2\lambda_e) + 3(\sigma_\lambda^2 / \lambda_e^2) + 1\}$$

Comparing (21) with (30) yields  $E\pi_C^U - E\pi_I^U = -(3\sigma_\lambda^2 / 16\lambda_e^2) < 0$ . So, unless the union offers the firm a bribe, the firm is not willing to agree ex ante to reveal its private information. Again, this result is as expected; however, what is perhaps surprising is that the union cannot afford a large enough bribe to induce an information sharing agreement. To show this, we can add (29) and (30) to find the ex ante expected joint surplus under incomplete information,  $ES_I^U$ , and then compare this value with (22). We obtain:  $ES_C^U - ES_I^U = -(\sigma_\lambda^2 / 16\lambda_e^2) < 0$ .

Finally, we turn to social welfare. Applying the same method of solution to (22) and (28) yields  $EW_C^U - EW_I^U = -(5\sigma_\lambda^2 / 32\lambda_e^2) < 0$ ; so that social welfare is higher if the agents do not share information. We summarize our findings for this case in Proposition 2.

**Proposition 2:** *If the union sets the wage and  $\gamma \leq \hat{\gamma}(r)$ , then (a) the firm is not willing to unilaterally share information; (b) the union prefers complete information, but cannot afford to pay the firm a large enough up-front fee to induce information revelation; and, (c) social welfare is lower with information sharing.*

Proposition 2 provides us with our first main result: an agreement by the agents to reveal their private information may lead to a *decrease* in the joint surplus *and* welfare. The intuition behind this result is easy to provide. Efficiency requires that the wage be set equal to the union's reservation wage. When the union uses its bargaining power, it attempts to increase its expected wage bill by asking for a wage above this level, and this creates deadweight loss. With incomplete information, the union worries that if it asks for too high a wage, a low productivity firm will reject the wage offer. Thus, it shades its wage offer down below what it would ask for with complete information in order to ensure that will production will take place. This reduction in the wage offer reduces the deadweight loss and increases the joint surplus earned by the firm and union. The implication for the first stage equilibrium is straightforward: no sharing occurs.

The fact that producer welfare is greater without sharing can be interpreted of as an application of the theorem of the second best (Lipsey and Lancaster 1956). Specifically, there are two distortions here: union power in setting wages and incomplete information. In this case, the existence of the second distortion (incomplete information) counteracts the inefficiency generated by the first distortion (union power). And, since producer welfare is greater with incomplete information, it is not possible to come to an agreement to share information. As we show below, there are other circumstances in which the second distortion does not counteract the inefficiency generated by the first distortion. And, it is in those cases that an agreement to share information may emerge as an equilibrium outcome.<sup>18</sup>

Case 3 (production only occurs when the firm is highly productive): We now turn to case 3, in which  $\gamma \geq \hat{\gamma}(0)$ , leaving the complex case 2 for last. With  $\gamma \geq \hat{\gamma}(0)$ , the union always offers  $w(\lambda_1, v)$  and production only occurs if the firm is highly productive. The fact that with incomplete information production will not occur if the firm is unlucky and draws a low value for productivity makes the prospect of sharing information more appealing to the firm. To see this, we follow the same approach as in case 1 to determine the preferences of the union, firm and society with respect to information sharing.

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<sup>18</sup>A similar analysis can be applied to social welfare, which can be at odds to the effect on producer welfare (see Proposition 4.c below). We thank an anonymous referee for pointing out this interpretation to us.

For the union, (26) implies that

$$(31) \quad E\theta_I^U = (\gamma/8)\{\rho + (1-\rho)(1-r\lambda_1)^2\}$$

Comparing (20) and (31) reveals that  $E\theta_C^U - E\theta_I^U = [(1-\gamma)/8]\{\rho + (1-\rho)(1-r\lambda_2)^2\} > 0$ ; so, as expected, the union prefers complete information

For the firm, (19b) yields

$$(32) \quad E\pi_I^U = (\gamma/16)\{\rho + (1-\rho)(1-r\lambda_1)^2\}$$

Comparing (21) with (32) reveals that  $E\pi_C^U - E\pi_I^U = [(1-\gamma)/16]\{\rho + (1-\rho)(1-r\lambda_2)^2\} > 0$ , so that the prospect of no production is sufficiently troubling that the firm now wants to share information as well. Of course, since the firm and union are both better off when they agree to reveal their information, their joint surplus must be higher as well.

Finally, turn to social welfare. From (28) we obtain

$$(33) \quad EW_I^U = (7\gamma/32)\{\rho + (1-\rho)(1-r\lambda_1)^2\}$$

Comparing (23) with (33) reveals that Social Welfare is higher with information sharing as well:

$EW_C^U - EW_I^U = [7(1-\gamma)/32]\{\rho + (1-\rho)(1-r\lambda_2)^2\} > 0$ . Given the preferences of the firm, this is not surprising since consumers are harmed when production breaks down as well. In summary we have:

**Proposition 3:** *If the union sets the wage and  $\gamma \geq \hat{\gamma}(0)$ , then (a) the firm is willing to unilaterally share information; (b) the union prefers complete information; and (c) social welfare is higher with information sharing.*

Proposition 3 provides us with our second main result: even though the firm has no bargaining power, it is unilaterally willing to unilaterally share information with the union. The result that an agent is willing to unilaterally share information is not new – however, as far as we know, this has never been

shown to be the case when the agent has no bargaining power.<sup>19</sup> Note also that Proposition 3 provides an explanation for practices such as the continuous replenishment program (described in the introduction) in which only one side of the market provides information. Moving back to the first stage, it is clear that in equilibrium we have information sharing with or without side-payments.

The results reported in Proposition 3 contrast sharply with those in Proposition 2. The reason is simple: If  $\gamma$  is sufficiently high, the union makes no attempt to settle with a low-productivity firm and tries to extract as much as possible from a high-productivity firm. Thus, the presence of incomplete information does not lead the union to shade down its wage offer as it did in case 1. This means that the main difference between the complete and incomplete information cases is that the union and firm may fail to settle under incomplete information – an outcome that benefits no one. As a result, the union, firm and society as a whole are better off with information sharing.

Case 2 (production occurs unless we have a dominant union): We now turn to the case in which  $\hat{\gamma}(r) < \gamma < \hat{\gamma}(0)$ . This means that a low-reservation wage union offers  $w(\lambda, 0)$  and settles with the firm regardless of its productivity level, and a high-reservation wage offers  $w(\lambda_1, r)$  which is rejected by a firm with low productivity. Thus, as in case 1, incomplete information will lead a low-reservation wage union to shade its offer and this will reduce deadweight loss. But, as in case 3, a high-reservation wage union will not even try and settle with a low-productivity firm; and, the possibility that production might break down makes information sharing more appealing to all parties. The fact that two forces that work in opposite directions are both present suggests that this case might be quite complex. As we show below, this is indeed the case.

We start with the union's preferences. From (26) we obtain

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<sup>19</sup> One possible exception can be found in section 5 of Milgrom (1981). In that section, Milgrom analyzes what he refers to as a "persuasion game" in which "one or more interested parties provide information to a decision-maker in an attempt to influence his decision." A good example of this would be a meeting between a used car salesman and a potential buyer in which the salesman reveals information about the car for sale. Milgrom's main objective is to determine what type of information the informed party will chose to reveal. His main result is given in his Proposition 6 in which he shows that in every sequential equilibrium of the game the informed party uses a strategy of full disclosure. We thank an anonymous referee for pointing this out to us.

$$(34) \quad E\theta_I^U = (1/8)\{\rho[1 - (\sigma_\lambda^2 / \lambda_e^2)] + (1 - \rho)\gamma(1 - r\lambda_1)^2\}$$

Comparing (20) with (34) we have  $E\theta_C^U - E\theta_I^U = (1/8)\{\rho(\sigma_\lambda^2 / \lambda_e^2) + (1 - \rho)(1 - \gamma)(1 - r\lambda_2)^2\} > 0$ ; so, just as in our two previous cases, the union prefers information sharing.

For the firm, (27) implies that

$$(35) \quad E\pi_I^U = (1/16)\{\rho[1 + (3\sigma_\lambda^2 / \lambda_e^2)] + (1 - \rho)\gamma(1 - r\lambda_1)^2\}.$$

Comparing (21) with (35) yields

$$(36) \quad E\pi_C^U - E\pi_I^U = (1/16)\{(1 - \rho)(1 - \gamma)(1 - r\lambda_2)^2 - \rho(3\sigma_\lambda^2 / \lambda_e^2)\}.$$

The right-hand-side of (36) is convex in  $\gamma$  with two roots, one of which is  $\gamma = 1$ .<sup>20</sup> Moreover, at  $\gamma = 0$  the expression is positive and decreasing in  $\gamma$ . Thus, the firm is willing to share information if  $\gamma$  is low; in

particular, if  $\gamma \leq \gamma_\Pi \equiv \frac{(1 - \rho)(1 - r\lambda_2)^2 \lambda_2^2}{(\lambda_2 - \lambda_1)[3\rho(\lambda_2 - \lambda_1) + (1 - \rho)(\lambda_2 + \lambda_1)(1 - r\lambda_2)^2]}$

If we sum expected profits and the expected wage bill in the two cases and compare the results, we find that

$$(37) \quad ES_C^U - ES_I^U = (1/16)\{3(1 - \rho)(1 - \gamma)(1 - r\lambda_2)^2 - \rho(\sigma_\lambda^2 / \lambda_e^2)\}$$

The right-hand-side of (37) is convex in  $\gamma$ , positive and decreasing at  $\gamma = 0$ , and has two roots (one of which is  $\gamma = 1$ ). The joint surplus will be higher with information sharing if

$$\gamma \leq \gamma_S \equiv \frac{3(1 - \rho)(1 - r\lambda_2)^2 \lambda_2^2}{(\lambda_2 - \lambda_1)[\rho(\lambda_2 - \lambda_1) + 3(1 - \rho)(\lambda_2 + \lambda_1)(1 - r\lambda_2)^2]}$$

Comparing  $\gamma_S$  to  $\gamma_\Pi$ , it is immediate that  $\gamma_S > \gamma_\Pi$ .

Finally, we turn to social welfare. From (19c) we obtain

$$(38) \quad EW_I^U = (1/32)\{\rho[5(\sigma_\lambda^2 / \lambda_e^2) + 7] + 7(1 - \rho)(1 - r\lambda_1)^2\}$$

Comparing (16c) with (22c) yields

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<sup>20</sup> Recall that  $\sigma_\lambda^2 \equiv \gamma(1 - \gamma)[\lambda_2 - \lambda_1]^2$ .

$$(39) \quad ES_C^U - ES_I^U = (1/32)\{7(1-\rho)(1-\gamma)(1-r\lambda_2)^2 - 5\rho(\sigma_\lambda^2 / \lambda_e^2)\}$$

As with (36) and (37), the right-hand-side of (39) is convex in  $\gamma$ , positive and decreasing at  $\gamma = 0$ , and has two roots. Expected social welfare will be higher with information sharing if

$$\gamma \leq \gamma_W \equiv \frac{7(1-\rho)(1-r\lambda_2)^2 \lambda_2^2}{(\lambda_2 - \lambda_1)[5\rho(\lambda_2 - \lambda_1) + 7(1-\rho)(\lambda_2 + \lambda_1)(1-r\lambda_2)^2]}$$

It is straightforward to show that  $\gamma_\Pi < \gamma_W < \gamma_S$ . This implies that there are values of  $\gamma$  in which the union could bribe the firm into sharing, but this agreement would reduce welfare (if  $\gamma_W < \gamma < \gamma_S$ ). In addition, there are cases in which the union and society as a whole prefer that information be shared, but the firm would be unwilling to do so unless the union were to offer a sufficiently high up-front payment (if  $\gamma_\Pi < \gamma < \gamma_W$ ). However, it is important to note that the union can afford such a bribe (since  $\gamma_W < \gamma_S$ ).

Although we know that  $\gamma_\Pi < \gamma_W < \gamma_S$  and  $\hat{\gamma}(r) < \hat{\gamma}(0)$ , summarizing case 2 is not easy since the signs of  $\hat{\gamma}(r) - \gamma_\Pi$  and  $\gamma_S - \hat{\gamma}(0)$  are not clear. For completeness, in Proposition 4 we report the results for the most general case – the one in which  $\hat{\gamma}(r) < \gamma_\Pi < \gamma_W < \gamma_S < \hat{\gamma}(0)$ . It is straightforward to show that a sufficient condition for this ranking to hold for some  $\rho$  is that  $r\lambda_2 > 2/3$ ;<sup>21</sup> however, even if this ranking does not hold, the general flavor of Proposition 4 remains, the only difference is that some of the sub-cases listed are simply empty.

**Proposition 4:** *If the union sets the wage and  $\hat{\gamma}(r) < \gamma < \hat{\gamma}(0)$ , then the union always prefers complete information. In addition,*

- (a) *If  $\gamma < \gamma_\Pi$ , the firm is unilaterally willing to share information and social welfare is higher with information sharing.*

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<sup>21</sup> We note that there *always* exists a  $\rho$  such that  $\hat{\gamma}(r) < \gamma_W < \gamma_S < \hat{\gamma}(0)$ .



- (b) If  $\gamma_{\Pi} < \gamma < \gamma_W$ , then the firm is not willing to unilaterally share information. The union can afford to pay an upfront fee that is sufficient to induce an information sharing agreement and social welfare is increased by such an agreement.*
- (c) If  $\gamma_W < \gamma < \gamma_S$ , then the firm is not willing to unilaterally share information. The union can afford to pay an upfront fee that is sufficient to induce an information sharing agreement but social welfare is lower by such an agreement.*
- (d) If  $\gamma > \gamma_S$ , then the firm is not willing to unilaterally share information. Moreover, the union cannot afford to pay an upfront fee sufficient to induce an information sharing agreement. In this case, social welfare would be lowered by such an agreement.*

Proposition 4 indicates that there are many possible outcomes, some of which are surprising. For example, when  $\gamma \in [\gamma_W, \hat{\gamma}(0)]$ , ex ante expected welfare is higher with incomplete information even though there is a positive probability that the agents will fail to reach an agreement and production will be disrupted. This result emerges in spite of the fact that we have assumed that it is common knowledge that there are always gains from trade. Moreover, when  $\gamma \in [\gamma_W, \gamma_S]$ , the union and firm are likely to agree to share information, this agreement will ensure that production will always occur, and yet, this agreement will lower ex ante expected welfare!

Proposition 4 also reveals some unexpected non-monotonicities in the agents' preferences. Consider, for example, how the firm's willingness to unilaterally share information varies with  $\gamma$ . Then, for  $\gamma \leq \hat{\gamma}(r)$ , the firm is unwilling to unilaterally share its private information. However, if  $\gamma$  rises above  $\hat{\gamma}(r)$  and remains below  $\gamma_{\Pi}$ , the firm switches its preference and is now willing to unilaterally share information. Yet, if  $\gamma$  increases further such that  $\gamma_{\Pi} < \gamma < \hat{\gamma}(0)$ , the firm switches back and is once again unwilling to unilaterally share information. Finally, if  $\gamma$  rises above  $\hat{\gamma}(0)$ , the firm is once again willing to unilaterally share information! A similar pattern is present for social welfare. When  $\gamma \leq \hat{\gamma}(r)$

and  $\gamma_w < \gamma < \hat{\gamma}(0)$ , social welfare is higher *without* sharing; but, when  $\hat{\gamma}(r) < \gamma < \gamma_w$  and  $\gamma \geq \hat{\gamma}(0)$ , social welfare is higher *with* sharing.

To provide some intuition for these results, we start by considering the situation when  $\gamma$  is very low (i.e.,  $\gamma \leq \hat{\gamma}(r)$ ). In this case, the union knows that there is a high probability that it will be dealing with a low-productivity firm and thus, with incomplete information, it always shades down its wage offer to make sure that an agreement will be reached. This benefits the firm and hence the firm is unwilling to unilaterally share information. Now, suppose that  $\hat{\gamma}(r) < \gamma < \hat{\gamma}(0)$ . Under incomplete information a low-reservation wage union continues to shade its offer down to guarantee agreement, while a high-reservation wage union offers a wage that it knows will be rejected by a low-productivity firm. The first effect increases the firm's ex ante expected profits (over what it would earn with complete information), while the second effect lowers it (since production would always occur with complete information). If  $\gamma$  is relatively low, then the firm knows that it is likely to draw the low-productivity parameter and the fact that production will not occur if it faces a high-reservation wage union looms large. As a result, the second effect dominates and the firm prefers complete information. But, as  $\gamma$  increases, the first effect eventually dominates and the firm switches back to preferring incomplete information. Finally, if  $\gamma \geq \hat{\gamma}(0)$ , the firm knows that under incomplete information it would never get to produce if it draws the low-productivity parameter. Moreover, the wage that it would get if it draws the high-productivity parameter would be roughly the same with and without sharing. Thus, to avoid an inefficient disruption of production, the firm wants to unilaterally share its private information. A similar rationale can be provided for the changes in society's preferences as  $\gamma$  increases.

Finally, it should be clear that all of our propositions are interim results characterizing the two sides' preferences towards information sharing. What occurs at the initial contracting stage will then depend on whether or not side-payments are possible. First, if side-payments are not possible, then only if  $\gamma < \gamma_{\Pi}$ , does information sharing arise in equilibrium. In this case, if  $\gamma \in (\gamma_{\Pi}, \gamma_S)$ , then welfare would have increased had side-payments been available. Second if side-payments are possible, then only if  $\gamma <$

$\gamma_S$  does information sharing arise in equilibrium. In this case if,  $\gamma \in (\gamma_W, \gamma_S)$ , then the ability of firms to use side-payments results in information sharing and this reduces welfare.

### 5. Extensions, Part I: Employee Stock Ownership Plans

Our first extension concerns the incentives to share information when the union has an equity stake in the firm.<sup>22</sup> As noted by Cramton, Mehran and Tracy (2005), a growing number of unions were given an equity stake in their firm in the late 1980s. This took place through the adoption of employee stock ownership plans (ESOP). With an ESOP in place, the union receives a portion of its overall return through its equity stake and thus, rather than having its entire return take the form of a union wage premium, the union also cares about the firm's profits. Even though the typical union ESOP involves a non-controlling ownership stake in the firm, even small equity stakes may significantly alter incentives to share information. Intuitively, tying the union's reward to the firm's profits makes the interests of two agents more closely aligned and should make it *easier* for them to agree to share their private information. Moreover, as the equity share rises, the union's payoff approaches producer surplus and thus, the union's preference moves towards the sharing arrangement that maximizes the joint surplus. One might therefore expect an ESOP to generate two new effects that both make information sharing easier. First, the union now internalizes the firm's benefit from information sharing and this should make the union more likely to unilaterally accept sharing. Second, the union should be more likely to unilaterally share information when doing so maximizes producer surplus, and this should decrease the need for the firm to pay an upfront fee to induce sharing. However, we show in this section that this is not always the case – that is, we show that the adoption of an ESOP might make information sharing *less* likely. The reason for this is that the ESOP also has an indirect effect in that it alters the optimal wage offer for each agent. And, we find that it is possible for this indirect effect to dominate, making it harder to support sharing agreements.

To show this, let  $e \in [0, 1]$  represent the union's equity share in the firm. This implies that the union's objective function is now  $\theta + e\pi$ . In all other respects, the environment remains the same; in

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<sup>22</sup> We thank an anonymous for suggesting this extension.

particular, the firm's goal is still to maximize  $\pi$  (even though its payoff is now  $(1 - e)\pi$ ) and producer surplus remains equal to  $\theta + \pi$ . We therefore restrict attention to how an ESOP changes the union's incentives to share information and how this affects the likelihood that sharing arises in equilibrium. We present the results in the text with the calculations relegated to the Appendix. Since the derivations are analogous to those in Sections 3 and 4, only an outline is provided.

We begin with the case in which the firm sets the wage. As before, we solve for equilibrium by backwards induction. In the last stage, when the firm sets employment, the wage is already set and thus, the environment is unchanged. It follows that profit maximizing output is still given by (1) and profits  $\pi$  are still given by (2). The union's payoff, which we now denote by  $\hat{\theta}$ , is given by

$$(40) \quad \hat{\theta}(e, \lambda, w) = \frac{\lambda}{2}(1 - w\lambda)(w - v) + e \frac{(1 - w\lambda)^2}{4}.$$

We turn next the wage setting stage. When choosing the optimal wage, the firm now takes into account the fact that the union has an equity stake in the firm. Thus, the firm attempts to maximize profits (or expected profits) subject to  $\hat{\theta} \geq 0$ . If the firm knows  $v$ , maximizing (2) subject to this constraint leads to an optimal wage of  $w = (2\lambda v - e)/(2 - e)\lambda$ . Note that, as expected, this wage is decreasing in the equity stake  $e$ . Profits and the union's payoff are given by

$$(41) \quad \pi_C^F(\lambda) = \frac{(1 - v\lambda)^2}{(2 - e)^2} \quad \hat{\theta}_C^F(\lambda) = 0.$$

where, as in section 3, the super-script F denotes that the firm is setting the wage and the sub-script C denotes that the firm has complete information. Note that the (ex ante) expected joint surplus is the sum of profits and wage bill which yields

$$(42) \quad ES_C^F = \frac{(1 - e)}{(2 - e)^2} \{ \rho + (1 - \rho)[\gamma(1 - r\lambda_1)^2 + (1 - \gamma)(1 - r\lambda_2)^2] \}.$$

If the firm does not know  $v$ , then it will choose  $w$  to maximize expected profits. As we show in the Appendix, the optimal wage is now given by

$$(43) \quad w_I^F(\lambda) = \begin{cases} \frac{-e}{(2-e)\lambda} & \text{if } \rho \geq (1-r\lambda)^2 \\ \frac{(2\lambda r - e)}{(2-e)\lambda} & \text{otherwise} \end{cases}$$

There are several interesting features to note in (43). First, as in Section 3, there are two critical wages: the lowest wage that a union with  $v = 0$  would accept and the lowest wage that a union with  $v = r$  would accept. Second, these critical wages are both lower than their counterparts in Section 3, since an ESOP creates an incentive for the union to accept lower wages (to increase profits). Third, the critical condition on  $\rho$  is identical to the one in Section 3: for any given  $\lambda$ , the firm chooses the wage based on whether  $\rho$  is greater or less than  $(1 - r\lambda)^2$ . Finally, and perhaps most importantly for the later discussion, as with the complete information case discussed above, the optimal wage offer is decreasing in the equity stake.

As in Section 3, from (43) the firm's wage offer can be determined. Note that now when  $\rho < (1-r\lambda_2)^2$ , then the firm's wage offer depends on its type. Using (43) the expected profits under incomplete information can be determined:

$$(44) \quad E\pi_I^F(\lambda) = \begin{cases} \frac{\rho}{(2-x)^2} & \text{if } \rho \geq (1-r\lambda)^2 \\ \frac{(1-r\lambda)^2}{(2-x)^2} & \text{otherwise} \end{cases}$$

For the union, its expected payoff depends on  $\lambda$ , which it does not know. For a union with  $v = 0$ , we have

$$(45) \quad E\hat{\theta}_I^F(0) = \begin{cases} \frac{r\gamma\lambda_1(1-r\lambda_1)}{(2-x)} + \frac{r(1-\gamma)\lambda_2(1-r\lambda_2)}{(2-x)} & \text{if } \rho \leq (1-r\lambda_2)^2 \\ \frac{r\gamma\lambda_1(1-r\lambda_1)}{(2-x)} & \text{if } \rho \in [(1-r\lambda_2)^2, (1-r\lambda_1)^2] \\ 0 & \text{otherwise} \end{cases}$$

For a union with  $v = r$ , we obtain:

$$(46) \quad E\hat{\theta}_I^F(r) = 0$$

Following the logic in section 3, it is straightforward to show that, as in proposition 1, the union always prefers incomplete information and the firm always prefers complete information. The

introduction of equity stakes has no effect on those results because the firm sets the wage so that the union's complete information payoff is always zero. However, it may no longer be possible for the firm to offer the union an upfront bribe that is sufficient to get them to commit to revealing their reservation wage. That is, producer surplus may now *decrease* with information sharing. We summarize this new result in Proposition (5) with a sketch of the proof provided in the Appendix.

***Proposition 5: If the firm sets the wage and  $\rho < (1 - r\lambda)^2$ , then there exists an equity stake  $e^* \in (0,1)$  in the firm such that for any  $e \geq e^*$  the firm cannot afford to pay the union a large enough up front fee to induce information revelation.***

Proposition 5 indicates that when the firm sets the wage and the union holds an equity stake in the firm, producer surplus may decrease with information sharing. This implies that an ESOP can actually discourage information sharing! There is a clear reason for this result: an ESOP generates inefficiency and this inefficiency can be greater with complete information. Specifically, recall that the wage is decreasing in the equity stake. Moreover, with complete information and no ESOP, the firm's optimal wage offer also maximizes producer surplus (i.e., the contract is efficient). It follows that with complete information, producer surplus is decreasing in the equity stake. Specifically, from (42), as the equity stake goes to 1, producer surplus goes to zero. However, with incomplete information, in some states the wage is above the complete information wage and so expected producer surplus is greater.

We now turn to the case in which the union sets the wage. The last stage, when employment is set after the wage has been determined, is no different than it is when the firm sets the wage. Thus, employment, profits and the union's payoff are still given by (1), (2) and (40). When the union has complete information about the productivity parameter, the wage that maximizes its payoff in (40) is

$$(47) \quad w_C^U(\lambda) = \frac{v}{2-e} + \frac{1-e}{\lambda(2-e)}$$

Note that, as expected, an increase in  $e$  results in a lower wage: as the union's equity stake rises, the optimal wage offer decreases in order to increase downstream profits. In fact, when  $e = 1$ , the union's payoff equals producer surplus and thus it sets the wage equal to  $v$ , resulting in the efficient outcome.

With (47) we can calculate the (ex ante) expected payoff to the union, profit and producer surplus. We obtain:

$$(48) \quad E\hat{\theta}_C^U = \frac{r(1-\rho)(r\lambda_e^2 - 2\lambda_e) + 1}{4(2-e)}$$

$$(49) \quad E\pi_C^U = \frac{r(1-\rho)(r\lambda_e^2 - 2\lambda_e) + 1}{4(2-e)^2}$$

$$(50) \quad ES_C^U = \frac{[r(1-\rho)(r\lambda_e^2 - 2\lambda_e) + 1](3-2e)}{4(2-e)^2}$$

where  $\lambda_e$  and  $\lambda_e^2$  are as defined in Section 4. Note that all three expressions are increasing in  $e$  since an increase in  $e$  results in a lower wage offer by the union, which enhances efficiency.

Turn next to the case in which the union does not know  $\lambda$  when it sets the wage. Then, for a given  $v$ , the union's expected payoff is given by

$$(51) \quad E\hat{\theta}(v) = \begin{cases} (w-v)[\gamma\psi(\lambda_1) + (1-\gamma)\psi(\lambda_2)]/2 & \text{if } w \leq 1/\lambda_2 \\ (w-v)\gamma\psi(\lambda_1)/2 & \text{if } w \in [1/\lambda_2, 1/\lambda_1] \end{cases}$$

where  $\psi(\lambda_j) \equiv (1-w\lambda_j)[\lambda_j + (e/4)(1-w\lambda_j)]$ . The logic used to derive (51) is identical to that used to derive (17) in Section 4, since the firm's objective has not changed: it still wants to maximize profits. As before, portions of (51) are concave and maximizing (51) over  $w$  yields the following two potentially optimal wage offers (note that we continue to employ the same notation as in Section 4):

$$(52) \quad w(\lambda, v) = \min \left[ \frac{v}{2-e} + \frac{\lambda_e(1-e)}{2\lambda_e^e(2-e)^2}, \frac{1}{\lambda_2} \right] \text{ and } w(\lambda_1, v) = \max \left[ \frac{v}{2-e} + \frac{(1-e)}{2\lambda_1(2-e)}, \frac{1}{\lambda_2} \right]$$

Substituting (52) into (51) yields the expected payoff to the union from the two wage offers, which can be used to determine the optimal wage offer. Comparing the outcomes yields the following result

Lemma 2: If we define  $\tilde{\gamma}(v, e) \equiv \frac{\lambda_2^2(1 - v\lambda_2)^2}{(\lambda_2 - \lambda_1)[v\lambda_2(\lambda_1 + \lambda_2)(v\lambda_2 - 2) - e(\lambda_2 - \lambda_1)(2 - e) + 2\lambda_2]}$ , then if

$\gamma \leq \tilde{\gamma}(v, e)$  the optimal wage offer is  $w(\lambda, v)$ ; otherwise, the optimal wage offer is  $w(\lambda_1, v)$ .

It is straightforward to check that  $\tilde{\gamma}(v, e)$  is increasing in  $e$  (since  $e \leq 1$ ), so that an increase  $e$  affects which case arises. This result is quite intuitive. An increase in  $e$  increases the union's return from the firm and thus, it becomes more important for the union to ensure that production will occur. To accomplish this, the union sets a lower wage to increase the likelihood that the low productivity firm will produce. However, as we show below, this may make information sharing less likely!

As in Section 4, for any given  $e$ , we have three cases to consider. If we suppress the  $e$  argument in our notation, then case 1 is characterized by  $\gamma < \tilde{\gamma}(r) < \tilde{\gamma}(0)$ . In this case, the union always offers  $w(\lambda, v)$  which the firm always accepts (thus, production always occurs). In case two  $\tilde{\gamma}(r) < \gamma < \tilde{\gamma}(0)$  so that a low reservation wage union offers  $w(\lambda, v)$  and a high reservation wage union offers  $w(\lambda_1, v)$ . Finally, the third case occurs when  $\gamma \geq \tilde{\gamma}(0)$ , in which case the union always offers  $w(\lambda_1, v)$  and production occurs only if the firm is highly productive.

We can now use Lemma 2 and (52) to calculate the union's expected payoff and total profit for any given  $v$ . We obtain

$$(53) \quad E\hat{\theta}(v) = \begin{cases} \{v(v\lambda_e^2 - 2\lambda_e) - [1 + e(2 - e)](\sigma_\lambda^2 / \lambda_e^2) + 1\} / 4(2 - e) & \text{if } \gamma \leq \tilde{\gamma}(v) \\ \gamma(1 - v\lambda_1)^2 / 4(2 - e) & \text{if } \gamma > \tilde{\gamma}(v) \end{cases}$$

$$(54) \quad E\pi(v) = \begin{cases} [v(v\lambda_e^2 - 2\lambda_e) + (3 + e(4 - e))(\sigma_\lambda^2 / \lambda_e^2) + 1] / 4(2 - e)^2 & \text{if } \gamma \leq \tilde{\gamma}(v) \\ \gamma(1 - v\lambda_1)^2 / 4(2 - e)^2 & \text{if } \gamma > \tilde{\gamma}(v) \end{cases}$$

where, as in Section 4,  $\sigma_\lambda^2$  denotes the variance of  $\lambda$ . From (53) and (54) the joint surplus can be calculated (for details see the Appendix). We can also use (53) and (54) and take the expectation of the union's and firm's payoffs for each of the three cases, following the same steps outlined in Section 4. We can then examine the impact of an ESOP on information sharing. As in Section 4, the results are easier to



follow if we consider the three cases separately. In particular, *within* cases 1 and 3 there are no changes. Thus, Propositions 2 and 3 remain as in Section 4.

What *does* change, however, is the *likelihood* that these cases occur. To see this, note that as  $e$  increases,  $\tilde{\gamma}(v)$  decreases. This implies that an increase in  $e$  makes case 1 more likely and case 3 less likely. Thus, in addition to lowering the wage directly, an increase in  $e$  can increase efficiency indirectly by triggering a discrete decrease in the wage. However, for the same reason, an increase in  $e$  can reduce the likelihood of information sharing. Focusing for the moment on just cases 1 and 3, note that a large increase in  $e$  could move the environment from case 3 to case 1. As a result, information sharing (which would occur in case 3) would no longer occur! Thus, as when the firm sets the wage, an ESOP could counter-intuitively make information sharing less likely. Below we show that similar results are possible when the increase in  $e$  moves the agents from case 3 to case 2 or from case 2 to case 1.

As in Section 4, case 2 is considerably more complex than cases 1 and 3. However, we can summarize the changes induced by an ESOP in a fairly straightforward manner. There is no change in the union's preference in that it still prefers complete information. The firm's preferences change only to the extent that  $\gamma_{\Pi}$  changes and likewise, the union's ability to induce the firm to share information changes only to the extent that  $\gamma_S$  changes. Thus, it is sufficient to focus on the impact of changes in  $e$  on  $\gamma_{\Pi}$  and  $\gamma_S$ . Proposition 6, which is proven in the Appendix, provides us with the necessary information.

**Proposition 6:**  $\gamma(v, e), \gamma_{\Pi}$  and  $\gamma_S$  are all increasing in  $e$ .

Combining Propositions 4 and 5 we can now examine the impact of an ESOP on information sharing if we are initially in case 2. There are several possibilities. To begin with, suppose that  $e$  increases and that we remain in case 2. Then it is possible for information sharing to become *more* likely. For example, suppose that initially  $\gamma > \gamma_{\Pi}$  and that the increase in  $e$  is sufficient to reverse the inequality; then Proposition 4 indicates that the increase in  $e$  will induce the firm to unilaterally share information. Similarly, suppose instead that initially  $\gamma > \gamma_S$  and that the increase in  $e$  is sufficient to reverse the

inequality; then Proposition 4 indicates that the increase in  $e$  will now make it possible for the union to bribe the firm to share information. Of course the increase in  $e$  could also move the agents out of case 2 to case 1. If that happens, then the increase in the equity stake may make information sharing *less* likely. To see this, suppose that we start out in case 2 with  $\gamma < \gamma_{\Pi}$  and that the increase in  $e$  moves the agents into case 1; then the increase in the equity stake will have moved us from an initial situation in which the firm was willing to share information to a new situation in which the union cannot pay a large enough upfront fee to induce sharing. A similar outcome arises when an increase in  $e$  moves the agents from case 3 to case 2. If the agents are initially in case 3, they start out willing to share. However, if the increase in  $e$  moves the agents to case 2 with  $\gamma > \gamma_S$ , Proposition 4 indicates that the sharing will cease!

To summarize this section, equity stakes can make information sharing *less* likely both when the firm sets the wage and when the union sets the wage. When the firm sets the wage, this may occur because an ESOP causes the optimal wage offer to fall *below* the efficient level. As a result, it may no longer be possible for the firm to induce the union to share information because such a sharing would reduce producer surplus! When the union sets the wage, this counter-intuitive outcome arises because an ESOP makes the wage offer at which both types of firms produce more attractive. However, it is precisely the case in which the union finds it optimal to offer this wage that information sharing cannot arise in equilibrium. Thus, the introduction of an ESOP can reduce the likelihood of information sharing.

## **6. Extensions, Part II and Discussion**

In this section we consider two additional extensions of the basic model and discuss the importance of some of our main assumptions in an attempt to explore the robustness of our results.

### **6.1 Bargaining Power**

The next extension that we consider concerns the way in which the wage is set. In sections 3 and 4 we considered the two extremes in which one side has all the bargaining power. In reality, we would expect both sides to have some influence over the wages under consideration. In order to model the

intermediate cases, we examined an extension of the model in which, after the decision on information sharing is reached, a coin is flipped to determine which side has power to set the wage. If we use  $\beta$  to denote the probability that the union wins the coin flip, then  $\beta$  serves as a measure of the union's bargaining power.<sup>23</sup> A careful reading of Propositions 1 - 4 reveals, however, that this extension has little, if any, impact on our overall message. For example, consider the case in which  $\gamma \geq \hat{\gamma}(0)$ . In this case, Propositions 1 and 3 indicate if lump sum fees are allowed, all agents and society as a whole will prefer information sharing regardless of which agent sets the wage. Thus, we would expect that regardless of the value of  $\beta$ , the agents would be able to reach an ex ante agreement to reveal their private information.

Turn next to the case in which  $\gamma \leq \hat{\gamma}(r)$ . Then Proposition 1 indicates that an agreement to share information is likely to emerge when the firm sets the wage; whereas Proposition 2 indicates that it will not be possible to induce the firm to share information when the union sets the wage. Moreover, society's preferences also depend on who has the bargaining power; so that all of the agents' preferences depend on  $\beta$ . To sort out the possibilities, we could follow the same approach adopted in case 2 of section 4 and solve for the value of  $\beta$  that makes a particular agent indifferent between complete and incomplete information. For example,  $\beta_W$  would denote the level of  $\beta$  that would make social welfare the same without and with sharing and  $\beta_\theta, \beta_\pi$ , and  $\beta_S$  would play the analogous role for the wage bill, profits and the joint surplus, respectively. The problem is that, depending upon the parameters of the model, most of the conceivable rankings of these  $\beta$ s are possible; which implies that almost any outcome is possible.<sup>24</sup> But, this is the basic message of Proposition 4 – almost any outcome is possible when the union has all the bargaining power! In fact, there is really only one new outcome that emerges when we extend the model in this manner. In section 4, we never found a situation in which the agents would

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<sup>23</sup> We thank Jennifer Reinganum for suggesting this approach.

<sup>24</sup> Details are available from the authors upon request.

prefer incomplete information while society preferred complete information.<sup>25</sup> This possibility *does* arise when  $\beta$  can take on values strictly between zero and one. It follows that extending the model in this manner would make only a small difference in our bottom line.

## 6.2 Non-linear Wage Contracts

Our last extension concerns the contract used by the union when it has all the bargaining power. We found that when the union sets the wage the agents may not be able to reach an agreement to share information and society may prefer this outcome. This follows directly from the fact that the union is restricted to a linear contract and chooses a wage that is both socially inefficient and does not maximize the joint union-firm surplus. Restricting attention to linear contracting between firms and their unions makes a great deal of sense -- this is (almost exclusively) the only type of contracting that we observe in union/firm relationships. Moreover, as we pointed out in footnote 2, linear contracting also appears to be the main form of contracting used in firm to firm vertical relationships. This point is emphasized in a recent paper by Iver and Villas-Boas (2003) who note that

in actual practice, both the magnitude and the incidence of two-part tariffs may be quite insignificant. In mainstream retail sectors such as grocery retailing or departmental stores, retailers do not seem to pay lump-sum fees to manufacturers. Even in business format franchising (in which the incidence of franchise fees is the highest), the evidence indicates that franchisors often charge negligible franchise fees compared with what they could otherwise have commanded (see Kaufman and Lafontaine 1994).

Nevertheless, to test the robustness of our results, suppose that we extend our analysis by giving the union even more power – that is, suppose that we allow the union to choose a more sophisticated contract. To make this precise, suppose that we allow the union to make the wage offer *and* dictate the price that the firm must charge in its output market (as in Rey and Tirole 1986). In the union-firm case this could be accomplished by allowing the union to determine employment. In the case of another type of input, this could be accomplished by allowing the input supplier to practice resale price maintenance (RPM). As we show in the working paper precursor to this article (Creane and Davidson 2006), if the

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<sup>25</sup> When we say that the “agents prefer incomplete information” we mean that their joint surplus is decreased by an information sharing agreement.

input supplier has this much power then with complete information it can always find a wage/price combination that maximizes the joint surplus and drives the firm's profits to zero. Moreover, this combination results in an efficient outcome. It follows that in this case the results we would obtain when the union has all the bargaining power would become analogous to the results obtained when the firm sets the wages – the agent with the bargaining power would always be able to induce the other agent to share its information and this outcome would always maximize social welfare. The reason for this is that when information is revealed and one agent can control both the wage and employment, contracts become complete and efficiency is obtained regardless of which agent has the power. We summarize our findings in this case with the following Proposition, which is completely analogous to Proposition 1.

***Proposition 6:*** *If the union sets the wage and the output price, then (a) the firm is not willing to unilaterally share information; (b) the union wants to share information and can afford to pay the firm a large enough up front fee to induce information revelation; and (c) social welfare is higher with information sharing.*

The problem with this approach and Proposition 6 is, of course, that in most union-firm relationships the union *does not* have any direct influence over employment – this decision is almost always left to the firm (see, for example, Oswald 1993 and Gahan 2002). And, with respect to resale price maintenance, while RPM is a common practice in some markets, there are many other markets in which it is not used. This may be due to the fact that the informational requirements to apply RPM effectively may be daunting or it may be due to the fact that there are many cases in which RPM is not allowed since it is viewed as a restriction on free trade. We conclude that for many situations, our analysis of a model in which the agents simply haggle over the terms of trade with the downstream firm determining the final output and product price is the more practical approach.

Finally, a brief discussion of the robustness of our results with respect to our assumptions is in order. We have made very specific assumptions about the nature of the incomplete information, adopted a specific functional forms for the demand curve and the union's cost of supplying labor (i.e., a

reservation wage that is independent of employment), and assumed that the private information is drawn from distributions with binary supports. It would not be at all surprising if changing some of these assumptions changed some of our results. For example, one could assume that the union's reservation wage is increasing in employment or that the firm's private information is tied to the level of demand. In either case, giving the firm all of the bargaining power may no longer result in an efficient outcome (Proposition 1 may not generalize). Nonetheless, it should be clear that our major insight, which is that information sharing in the presence of monopoly power with linear contracts entails a tradeoff for society, is quite general. On the one hand, information sharing reduces the distortion due to asymmetric information. On the other hand, it can increase the deadweight loss associated with monopoly pricing. While the conditions under which one effect dominates the other may depend upon specifics of the model, it should be clear that the tradeoff will always be present.

## **7. Conclusion**

When agents with monopoly power haggle over the terms of trade, asymmetric information can cause the negotiations to break down in some states if one side asks for a price that is deemed too high by the other side. One might expect that if the agents were to share their information, then trade would occur in all states and that this would increase the joint surplus to be split by the agents. Moreover, if the joint surplus were to increase, it is possible to imagine that social welfare would increase as well. Indeed, this is the motivation for much of the work in the mechanism design literature which is devoted to finding conditions under which a mechanism exists that will lead to information revelation while preserving efficiency.

However, in this paper we have emphasized that although information sharing agreements insure that efficient trade will occur, they may have additional implications for profits and welfare. The reason

is that information acquisition may lead agents to change their optimal negotiating strategy. For example, if a union is uninformed about the firm's productivity, it may shade down its wage demand in order to increase the probability that the firm will accept the offer. This reduction in wage will likely lead the firm to increase employment and this could result in an increase in the joint surplus and social welfare.

In this paper, we have provided a concrete example of a setting in which these latter *gains* in the joint surplus and welfare that are associated with *incomplete information* swamp the losses that occur when negotiations break down. As a result, we have shown that it is possible for both agents and society to prefer that bargaining take place without information sharing even though it could result in no trade when trade is ex post efficient. Of course, other outcomes are possible as well. We have shown that there are instances in which the agents will agree to share their private information and that this could lead to a decrease in welfare. Finally, we have shown that both welfare and the payoffs earned by the agents can be highly non-linear in key parameters. This suggests that determining the consequences and desirability of information sharing agreements in vertical relationships is a complex issue.

## Appendix

In this Appendix we provide the details from Section 5 in which we investigate the union's incentive to share information when the union has an equity stake in the firm.

As in the text, we begin with the case in which the firm sets the wage. First, we derive the optimal wage offer when the firm does not know  $v$ . As in Section 3, expected profit is given (8) with one small change: since the union will now accept a lower wage, the critical value for  $w$  is now  $(2\lambda r - e)/(2 - e)\lambda$  rather than  $r$ . Taking this into account and maximizing (8) yields the optimal wage as given in (43).

We next turn to the derivation of expected producer surplus when the firm does not know the value of  $v$ . Using (44, 45, 12) we find that if  $\rho \leq (1 - r\lambda_2)^2$  then the expected producer surplus is:

$$(55) \quad ES_I^F = \frac{(1-e)}{(2-e)^2} [\gamma(1-r\lambda_1)^2 + (1-\gamma)(1-r\lambda_2)^2] + \frac{\rho r}{2-x} [\gamma\lambda_1(1-r\lambda_1) + (1-\gamma)\lambda_2(1-r\lambda_2)];$$

and, if  $\rho \in [(1 - r\lambda_2)^2, (1 - r\lambda_1)^2]$  we obtain

$$(56) \quad ES_I^F = \frac{\gamma(1-e)}{(2-e)^2} (1-r\lambda_1)^2 + \frac{\rho r \gamma \lambda_1}{2} \frac{(1-r\lambda_1)}{(2-e)} + \rho(1-\gamma) \frac{(1-e)}{(2-e)^2}.$$

Finally, if  $\rho > (1 - r\lambda_1)^2$  we have

$$(57) \quad ES_I^F = \frac{\rho(1-e)}{(2-e)^2}.$$

Straightforward comparison of (6) with (55)-(57) yields the proof of proposition 5. Specifically, if  $\rho > (1 - r\lambda_1)^2$ , then a comparison of (57) with (42) shows that there does not exist an  $e^*$  such that producer surplus is greater with incomplete information. If  $\rho \in [(1 - r\lambda_2)^2, (1 - r\lambda_1)^2]$ , then a comparison of (56) with (42) shows that there does exist such an  $e^*$ , etc.

We now turn to the case in which the union sets the wage. Our main goals are to (a) show that the agents' preferences for information sharing are as described in the text and (b) derive the values of  $\gamma_\Pi$  and  $\gamma_S$  when the union owns an equity stake of  $e$  in the firm.



For case 1, though the ESOP lowers the wage both when information is and is not shared, what is critical to the decision to share is that information sharing increases the wage when the firm is of the high productivity type. Hence profits are greater with incomplete information as is producer surplus. Thus, the characterization of the agents' information sharing preferences, as summarized in Proposition 2, are not affected by the equity stake. Likewise, the impact of information sharing on producer surplus and welfare in case 1 does not change when there is an ESOP.

For analogous reasons, in case 3 the agents' preferences are also still characterized by Proposition 3: With incomplete information there is no production when the firm is of the low productivity type and the wage is the same as with complete information for a high productivity firm. Hence, the firm and union both benefit from information sharing and producer surplus and welfare increase.

For case 2, all of the outcomes summarized in Proposition 4 remain possible. However, the equity stake alters the values of  $\gamma_{\Pi}$  and  $\gamma_S$ . To derive these critical values, we need the union's expected payoff and expected profits. From (19a') and (19b') it is straightforward show that:

$$(58) \quad E\hat{\theta}_I^U = \{\rho[1 - \sigma_\lambda^2(1 + e(2 - e)/\lambda_e^2)] + (1 - \rho)\gamma(1 - r\lambda_1)^2\} / 4(2 - e)$$

$$(59) \quad E\pi_I^U = \{\rho[1 + \sigma_\lambda^2(3 - e(4 - e))/\lambda_e^2] + (1 - \rho)\gamma(1 - r\lambda_1)^2\} / 4(2 - e)^2.$$

where  $\lambda_e^2$  is the expectation of  $\lambda^2$  (and both are increasing in  $e$ ).

Using (58) and (59) we can obtain the critical value for  $\gamma$  which determines whether the firm is willing to unilaterally share information. We find that this is the case for  $\gamma$  less than

$$\gamma_{\Pi} \equiv \frac{(1 - \rho)(1 - r\lambda_2)^2 \lambda_2^2}{(\lambda_2 - \lambda_1)[3\rho(\lambda_2 - \lambda_1) + (1 - \rho)(\lambda_2 + \lambda_1)(1 - r\lambda_2)^2 - e(4 - e)\rho(\lambda_2 - \lambda_1)]}$$

Note that  $e$  is present only in the denominator of  $\gamma_{\Pi}$ . And thus, it is clear  $\gamma_{\Pi}$  is increasing in  $e$  since  $e < 1$ .

If we next use (58-59) and (48-49) to calculate producer surplus, we can solve for the critical value for  $\gamma$  which determines when the union will be able to profitably induce the firm to share information. We find that this is the case for  $\gamma$  less than

$$\gamma_S \equiv \frac{(3-2e)(1-\rho)(1-r\lambda_2)^2 \lambda_2^2}{(\lambda_2 - \lambda_1)[\rho(\lambda_2 - \lambda_1) + 3(1-\rho)(\lambda_2 + \lambda_1)(1-r\lambda_2)^2 + e[e^2\rho(\lambda_2 - \lambda_1) + 2r\lambda_2(1-\rho)(\lambda_2 + \lambda_1)(2-r\lambda_2) - 2(\lambda_2 + \lambda_1) + 4\rho\lambda_1]]}$$

By inspection, it is clear that if  $e = 0$ , then  $\gamma_S$  reduces to the value defined in Section 4. It is straightforward to calculate the derivative of  $\gamma_S$  with respect to  $e$  and to show that this derivative is positive. An increase in  $e$  makes producer surplus with complete information greater; hence  $\gamma_S$  has increased. These results are summarized by Proposition 6 in the text.

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