In this supplemental Appendix, we re-examine our model when, following Oswald (1993), the union maximizes the wage of the median union worker instead of the wage bill. Although Oswald notes (see p. 108) that his model of union preferences should not be used in environments in which there is uncertainty about the level of employment (which is precisely the case in our model – more on this below), we still find this a useful exercise because, as we show below, the results derived using Oswald’s modeling of union preferences are essentially consistent with the results that we derive when the union maximizes the wage bill (as in the text of our paper). Thus, carrying out this exercise provides support for our claim that our results are quite general.

In Oswald’s model the union votes on the wage contract and the contract is implemented when a majority of the union members vote in favor of approval. Thus, the median union member’s preferences are decisive. It is assumed that layoffs are by seniority and the initial size of the union is set exogenously. As a result, the union acts as if its goal is to maximize the wage subject to the constraint that the median union member remains employed. To be a bit more precise, as long as the median union member is employed, his/her indifference curves in wage-employment space are horizontal, indicating that all that matters is the wage (see Oswald’s Figure 2). Oswald therefore sometimes refers to this as the “flat indifference curve model.”

With respect to the firm, following McDonald and Solow (1981), Oswald assumes a reduced form profit function with iso-profit curves in wage-employment space that are strictly concave in employment. For a fixed level of profit, Oswald distinguishes between two cases: one in which all workers with seniority less than the median union member are laid-off (the corner solution) and one in which employment remains above this level (the interior solution). Most of the focus in Oswald’s paper is (quite naturally) on the interior solution. In this case, the contract is efficient as the iso-profit curve is tangent to the median union member’s indifference curve (see Oswald’s Figure 3).
The corner solution, in which employment is equal to half of the union membership, yields a contract that is almost always inefficient (see Oswald’s Figure 4).

This brings us to the first problem that arises when we try to use Oswald’s model of the union in our setting. With a downstream monopolist, the contract that is adopted is always the Oswald corner solution. That is, the contract that maximizes the wage of the median union member is the contract that results in exactly half the union members being employed. To see this (we show this formally below) note that the union is constrained in that it cannot drive the firm’s profit below zero. Since, for a given employment level, the wage is inversely related to the firm’s profit, a wage-maximizing union will choose along the wage/employment loci where profits are zero. However, in that case, the firm’s iso-profit contour is not strictly concave, but rather linear and strictly decreasing everywhere in employment. As a result, employment is exactly half the size of the union (as long as the wage that results in this level of employment is strictly greater than the workers’ reservation wage). As Oswald notes, when equilibrium is characterized by a corner solution, a serious problem arises since in the future the union would reach a new contract in which half of the remaining members would be laid-off. In the long-run, employment would continue to shrink until only one union member is left. Thus, Oswald concludes that the corner solution “could not be a long-run equilibrium.”

Perhaps the most critical problem that makes Oswald’s model poorly suited for our framework is that our focus is on the effects of uncertainty. Specifically, the trade off between sharing and not sharing information is partly driven by the possibility that no production occurs when information is not shared (and thus, employment drops to zero). As Oswald notes (p. 108) when

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There is a related issue here in that we have assumed that workers may have a positive reservation wage. Thus, the union cannot be so large that when half are employed, the resulting wage is below the reservation wage of r. In such a case, the solution to Oswald’s approach is not identifiable as there does not exist a wage that both the median worker and the firm would accept. Oswald does not specify a mechanism for such a contingency.
“median-seniority workers’ jobs are at risk, [...] the flat indifference curve model should not apply.” Nevertheless, for completeness we continue with an analysis of our model when the union’s preferences are as assumed in Oswald’s paper. To do so, we assume the workers are risk-neutral.

More formally, we know from the text that the firm’s profits are given by \( \pi = (1 - q - w\lambda)q \). Rewriting this in terms of employment, we have \( \pi = (1 - (L/\lambda) - w\lambda)(L/\lambda) \). For any given \( \pi \), the highest wage that the median union member could obtain and still be employed is given by \( w(L) = (L\lambda - L^2 - \pi \lambda^3)/(L\lambda^2) \). Note that for \( \pi > 0 \), \( w(L) \) is strictly concave. However, since \( w(L) \) is decreasing in \( \pi \), the union will choose \( \pi = 0 \) and thus \( w(L) = (\lambda - L)/\lambda^2 \), which is clearly linear and strictly decreasing in \( L \) (since \( w'(L) = -1/\lambda^2 \)). It follows that the contract that is adopted is characterized a corner solution. Furthermore, we must also assume that the union size (denoted by \( L_U \)) satisfies \( L_U < 2\lambda_2(1 - r\lambda_2) \) so that \( w(L_U^-/2) > r \). If this does not hold, then the median union member is unemployed (i.e., the firm earns negative profits if it pays the reservation wage to \( L_U^-/2 \) workers).

We start with the complete information case. From above, the wage is \( w(\lambda) = (2\lambda - L_U)/2\lambda^2 \). Thus, the expected net wage for the median union member (ex ante – that is, before its type is determined) is given by \( E[w] = \gamma(2\lambda_1 - L_U)/2\lambda_1^2 + (1 - \gamma)(2\lambda_2 - L_U)/2\lambda_2^2 - (1 - \rho)r \). In this case, the downstream firm’s expected profit is zero. Thus, the firm will never strictly prefer sharing.

We now turn to the incomplete information case with risk neutral workers. In this case, the determination of the optimal wage for the median union member follows the same logic as in the main text of our paper. That is, the wage is either given by \( w(\lambda_1, v) = (2\lambda_1 - L_U)/2\lambda_1^2 \) or \( w(\lambda, v) = (2\lambda_2 - L_U)/2\lambda_2^2 \). If \( w(\lambda_1, v) \) is offered, then the downstream firm’s profits are zero as either it rejects the offer if it is a low-productivity firm (as it would earn negative profits) or it accepts the offer and earns zero. Thus, the expected net wage for the median worker would be \( \{\gamma(2\lambda_1 - L_U^v)/2\lambda_1^2 - r\} \). If
\( w(\lambda,v) \) is offered, then a low-productivity firm produces but earns zero. A high-productivity firm also accepts a wage offer of \( w(\lambda,v) \) but it earns a positive profit. Thus, if \( w(\lambda,v) \) is offered the expected net wage for the median workers is \( \left\{ \frac{(2\lambda_1 - L^U)}{2\lambda_1^2} - r \right\} \).

It is straightforward to show that for the median union member the critical value of \( \gamma \) is given by \( \hat{\gamma}(v) = \frac{\lambda_1^2[2\lambda_2 - L^U - 2v\lambda_2^2]}{\lambda_2^2[2\lambda_1 - L^U - 2v\lambda_1^2]} \), which is decreasing in \( v \) (as before). Moreover, we know that \( \hat{\gamma}(v) > 0 \) by the condition on \( L^u \) and \( \hat{\gamma}(v) < 1 \) since \( \lambda_1 < \lambda_2 \). If \( \gamma > \hat{\gamma}(v) \), then the median union member votes for \( w(\lambda_1,v) \). Otherwise, the union chooses \( w(\lambda,v) \). This leaves us with the same three cases that we covered in the main text. To allow for a full comparison to our earlier results, we must consider how one side can offer side payments to the other to induce sharing. Given the union’s objective, it is not clear how to proceed (for example, if the union offers the firm a side payment, how does its financing affect the payoff to the median union member?). To address this issue, we proceed by asking whether the workers who are guaranteed of employment would be willing to forgo an amount of \( x \) each in their wage to pay the firm \( x(L^u/2) \) (as we show below, since the median union worker prefers complete information, the payment must go from the union to the firm). Our analysis follows the main body and divides it into the three cases. As we show, despite the differences in the settings, our results generalize.

**Case 1 (production always occurs).** As in the text, this case occurs when \( \gamma \leq \hat{\gamma}(r) \) so that the union always offers \( w(\lambda,v) \) and the firm always accepts. A low-productivity firm earns zero either with or without information sharing; whereas a high-productivity firm earns zero profit with complete information but positive profit with incomplete information. Thus, the firm prefers incomplete information ex ante.

To get right to the bottom-line, here is a summary of the results for this case: **The firm prefers**

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\(^2\) This is not an issue that Oswald deals with.
incomplete information while the union prefers complete information. In addition, the union either cannot induce the firm to share information or is indifferent to it, and social welfare is weakly lower with information sharing. This is (weakly) the same set of results summarized in Proposition 2, which characterizes the outcome in case 1 when the union sets the wage to maximize the wage bill.

As we noted above, the firm earns zero in each state with complete information. To see what occurs with incomplete information, it is easiest to initially assume that the firm must employ exactly \( L_u/2 \) workers. In this case, with incomplete information a low-productivity firm still earns zero while a high-productivity firm earns a positive profit (regardless of the union’s type). However, the firm’s expected reward exactly equals the union’s expected loss from incomplete information since the employment levels are held constant. Thus, the union members would be indifferent between giving the bribe sufficient to make the firms indifferent between sharing and not sharing information.

Now, allow a high-productivity firm to increase its employment beyond \( L_u/2 \) if it so desires. Since \( w(\lambda, v) \) and \( L_u^U/2 \) are both exogenous to a high-productivity firm, it is possible that the profit-maximizing employment level given \( w(\lambda, v) \) could be greater than or less than \( L_u^U/2 \) (see Figure 1). Since the median union member would reject any contract in which he/she is unemployed, the relevant case is the one in which the firm would want to employ more than \( L_u^U/2 \) workers. Specifically, if \( L_u \) is sufficiently small, then a high-productivity firm wants to employ more than \( L_u^U/2 \) workers when the wage is \( w(\lambda, v) \) and hence its gain from incomplete information is greater than it would be if it were constrained to keep employment at \( L_u^U/2 \).\(^3\) However, the median union member’s wage does not change. It follows that if a high-productivity firm sets employment above \( L_u^U/2 \), its gain from incomplete information will exceed the union’s loss. This implies that the median union

\(^3\) Straightforward algebra gives the condition as \( L_u < 2\lambda_2\lambda_1/(\lambda_2 - \lambda_1)/(4\lambda_2^2 - \lambda_1^2) \). To see this intuitively note that if \( L_u \) is arbitrarily close to zero, then the firm would employ more than \( L_u^U/2 \) workers. See figure 1 below.
worker and the other union members who would remain employed would not be willing to pay what it would take to get the firm to agree to share information. Finally, since wages are above the reservation wage, the increase in output implies that total welfare is greater with incomplete information in this case.

Case 3. As in the text, this case occurs when \( \gamma \geq \hat{\gamma}(0) \). This implies that the union always offers \( w(\lambda, \nu) \) and production only occurs if the firm is highly productive.

Here is a summary of our results for this case: The firm is indifferent between sharing information and not sharing; the union prefers complete information and can induce the firm to share information. Social welfare is greater with information sharing (weakly, as in Proposition 3 in our paper). In this case, the firm’s expected profit with both complete and incomplete information is zero because only a high-productivity firm operates with incomplete information and in that case the wage is set so that its expected profit is zero. The median union member’s expected wage is higher with complete information (as he/she receives a positive net wage from a low-productivity firm with complete information and nothing with incomplete information). Since the firm’s expected profits are always zero, the gain from complete information to those employed is greater than the firm’s loss. Since the firm is indifferent, the median union member would be willing to vote for a contract giving the firm a fixed amount (lowering its expected wage but still keeping it above its expected wage with incomplete information) to share information. Since with complete information production occurs with a low productivity firm, social welfare is greater with information sharing.

Case 2. As in the text, this case occurs when \( \hat{\gamma}(r) < \gamma < \hat{\gamma}(0) \). Thus, a union with a low reservation wage offers \( w(\lambda, 0) \), while a union with a high reservation wage offers \( w(\lambda, r) \). The firm always accepts \( w(\lambda, 0) \) if it is offered, but if \( w(\lambda, r) \) is offered instead, only a high-productivity firm accepts.
Here is a summary of our results for this case: **The firm prefers incomplete information while the union prefers complete information.** In this case, the union may be able to bribe the firm and information sharing may increase or reduce social welfare, much like in Case 2 in the main body of our paper (see Proposition 4).

We start by considering the firm. With complete information, the firm (regardless of type) always earns zero profits. With incomplete information, a high-productivity firm earns positive profits when the union has a low reservation wage. Hence in expectation (before it knows its type) the firm prefers incomplete information. The implication is that when the union acts as if it maximizes the wage of its median member, the firm would never unilaterally share information. We note that the examples of unilateral information sharing that we cited in the introduction (e.g., in the auto industry with the *Harbour Report*), provide evidence against this model.

We now turn to the union. If the union is a high-reservation wage type, with incomplete information it earns zero when facing a low-productivity firm (since the firm does not produce) and it earns the same wage as it would with complete information when facing a high-productivity firm. Hence, a union with a high reservation wage prefers complete information. If the union has a low reservation wage, then the wage it receives does not depend on whether or not information is shared whenever it faces a low-productivity firm. However, if the union faces a high-productivity firm, it obtains a higher wage with complete information. Hence, the median worker’s expected wage is always greater with complete information; i.e., the union prefers complete information.

To determine if the union can induce the firm to share information, we begin by noting that when a high-reservation wage union faces a high-productivity firm or a low-reservation wage union faces a low-productivity firm, information has no effect on their joint surplus or welfare. With a high-reservation wage union and a low-productivity firm, no production occurs with incomplete information. With complete information the low-productivity firm earns zero profits and the median worker earns a positive surplus. Since the firm in this state is indifferent between complete and
incomplete information, the $L_u/2$ workers who are employed would be willing to compensate the firm for sharing information (as in case 3). Moreover, since production occurs with complete information, welfare is greater with complete information.

With a low-reservation wage union and a high-productivity firm, we begin by considering what occurs when employment is fixed at $L_u/2$. In this case, the gain to the “half employed” ($L_u/2$ times $(w(\lambda_1, 0) - w(\lambda, 0))$ from the complete information (i.e., the higher wage) exactly equals the high productivity firm’s loss. Hence, the $L_u/2$ workers are just willing to compensate the firm from its expected loss so as to induce information sharing. However, as in case 1, if $L_u$ is sufficiently low, then the firm’s profit maximizing employment level exceeds $L_u/2$.\(^4\) That is, in this state (a low-reservation wage union and a high-productivity firm) there is a loss to the firm from complete information that exceeds $(w(\lambda, 0) - w(\lambda_1, 0))\cdot L_u/2$ as it must restrict its output. Since the median worker only cares about the wage difference, the $L_u/2$ workers are not willing to compensate the firm for this loss. Finally, as in case 1, since output is greater with incomplete information, welfare is greater with incomplete information; social welfare decreases with information sharing.

To summarize, in one state (with a high-reservation wage union and a low-productivity firm) the union is willing to compensate the firm for sharing information and welfare increases with information sharing. In another state (a low-reservation wage union and a high-productivity firm), we have the opposite outcome: the union is not willing to compensate the firm for sharing information and welfare decreases with information sharing. The other two states have the same outcome with either complete or incomplete information. Hence, as in case 2 in the main body, whether information sharing occurs and whether welfare increases from sharing depends on the specific structure (i.e., parameters of the model). For example, if the gain in the expected joint

\(^4\) If $L_u$ is sufficiently high, then when with incomplete information the low reservation union meet offers the high productivity firm $w(\lambda, v)$, it is optimal for the firm to still choose $L_u$ (see figure 1 below).
surplus from information sharing in one state \{high-reservation wage union, low-productivity firm\} is greater than the loss in the expected joint surplus loss in the other state \{low-reservation wage union, high-productivity firm\}, then information sharing can arise. Moreover, as in our paper, the condition for welfare to decrease from information sharing is not the same as the condition required for the union to be able to bribe the firm. The only real difference between case 2 here and case 2 in the main body of our text is that unilateral information sharing by the firm cannot arise here. However, this outcome is driven by the assumption that the union maximizes the wage which implies that with complete information the firm always earns zero profits. In contrast, in the model in our paper the union *could* have selected a wage such that the firm would earn zero profits, but it was *never* in the union’s interest to do so because such a wage always generated a sub-optimal wage bill.


Figure 1: example of firm not increasing L when wage yields positive profits.