Involuntary Unemployment and Intrafirm Bargaining with Replacement Workers

by

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This paper reconsiders the result of Lars Stole and Jeffrey Zwiebel (1996a, b) that when a firm bargains with its workers over the wages in non-binding contracts, the firm will over-employ workers to reduce the hold-up power of any one. This result has stood in contrast to conclusions drawn in the literature on involuntary employment that worker bargaining power would lead to under-employment. We demonstrate that the Stole-Zwiebel conclusion critically relies on the lack of replacement workers. When insiders can be easily replaced from a finite and exogenous pool of workers, then the firm chooses to under- rather than over-employ workers. Neoclassical outcomes occur as the replacement pool of workers becomes infinitely large. Moreover we demonstrate that the key driving force between the differing conclusions of these models is the impact of the firm's employment choice on the supply of skilled workers available to it. *Journal of Economic Literature* Classification Numbers: C70, D23, J41, J64.

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In a series of papers, Lars Stole and Jeffrey Zwiebel (1996a, b) developed a model of intra-firm wage bargaining that describes how a firm's employment decision can act as an instrument to control the hold-up power of workers. In their model, workers are irreplaceable in the short run, and therefore possess some bargaining power. The firm can depress the hold-up power of any one worker by choosing to expand employment ex ante. They show that the firm does indeed choose to expand employment above the level that would be chosen in the absence of hold-up power—to such an extent that bargained wages are driven down to workers' outside options. Thus there is greater equilibrium employment than would be the case in a complete contracting world.

Stole and Zwiebel's (hereafter SZ) focus on the strategic role of employment decisions on wage bargaining and how it can generate over-hiring, stands in contrast to other models of labor market bargaining that lead to involuntary unemployment.[1] For example, Avner Shaked and John Sutton (1984) focus on the bargaining power of insiders relative to outsiders (a distinction not present in SZ). Insiders consequently earn a wage premium that leads to employment rationing. Given this, we explore how the presence of outside (replacement) workers might impact on wage bargaining in an otherwise SZ environment and, in particular, on the firm's employment choice.[2]

Our main result is that, when there is a *finite* pool of outside or replacement workers available to the SZ firm, and the size of the labor pool is exogenous, there is always under-employment relative to the neoclassical benchmark. The intuition for this result is straightforward. While bringing a worker inside a firm may depress the wages of all workers, that same impact is achieved by the threat of replacement.

[1] See, for example, Carl Shapiro and Joseph Stiglitz (1984), James Malcomson (1997), and Ricardo Caballero and Mohamad Hammour (1998).

Consequently, the employment decision of the firm is simply based on a comparison of the marginal product of a worker with their bargained wage. We demonstrate that a finite pool of replacement workers leaves insiders with some hold-up power and hence, bargained wages exceed their reservation wages. The inflated wages lead a firm to under-hire. Moreover, we demonstrate that as the number of replacement workers becomes infinitely large, neoclassical levels of wages and employment are restored.

Our amendment of SZ to take into account the existence of a replacement pool serves as a basis for making empirical predictions regarding the employment impact of wage bargaining. We demonstrate that our under-hiring result applies in the case in which the total pool of workers is exogenously fixed, as is the case with a fixed regional or educational pool. However, when the firm's employment decisions affect the size of the total pool, over-hiring is possible even in the presence of perfectly substitutable replacements. For instance, this might emerge when employment gives workers important experience that is transferable across firms. That is, workers in comparable positions in the same industry might acquire industry-specific skills that were of (equal or lesser) value to other firms. In this sense, the available pool would be the set of all workers employed in comparable positions in the industry. Thus, our model provides a more general characterization of SZ's conclusions (who assumed that useful skills could only be provided through employment at the firm).

Following the set-up of the model and derivation of our main result (in Section I), Section II presents a framework for empirical predictions, including the generalization of SZ's over-hiring result. A final section concludes.

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[2] The SZ environment is likely to yield somewhat different outcomes from Shaked and Sutton, given that the source of workers' bargaining power is not time costs but the risk of losing workers; only the latter source of bargaining power is influenced by the availability of workers.

I. Bargaining with Replacement

We begin by building on the SZ model in a simple way. Suppose that there is a single firm and that it if it employs n workers, its revenue (or output) is $F(n)$, a concave and non-decreasing function. The pool of potential workers is N, and each worker has a reservation wage of $\underline{w}$. As a benchmark, let n^* be the neoclassical firm's choice of employment (i.e., $F(n^*) - F(n^* - 1) \doteq \underline{w}$, where "$\doteq$" is defined as "equal within an integer").[3] We assume throughout that $n^* < N$. The wage outcome for an individual worker is $\tilde{w}_{N-n}(n)$ where the subscript indicates the number of 'outside' workers available and the number in parenthesis represents the number of 'inside' or employed workers. Finally, we preserve the key assumption of SZ that wages are non-binding and can be renegotiated any time. That is, following any breakdown in negotiations between the firm and any one 'inside' worker, all other insiders can re-open negotiations with the firm and vice versa.

A. *One Insider and One Outsider*

Suppose this pool were comprised of one worker only and that the firm and worker were to negotiate over the wage, $\tilde{w}_0(1)$, that the worker would receive. Then the firm and worker have outside options of $F(0)$ and $\underline{w}$, respectively. If they were to divide the surplus equally, this would imply that $\tilde{w}_0(1)$ satisfies:

$$F(1) - \tilde{w}_0(1) - F(0) = \tilde{w}_0(1) - \underline{w}$$

or $\tilde{w}_0(1) = \frac{1}{2}\left(F(1) - F(0) + \underline{w}\right)$.[4]

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[3] Similarly to SZ (1996a), we define the asymmetric binary relation, $y(n) \doteq z(n)$, to indicate that $y(n) - z(n) \geq 0 > y(n+1) - z(n+1)$.

[4] Recall that the SZ model (1996a) postulates pairwise bargaining with an infinitesimal probability of breakdown after each round; the outcome of such bargaining is the Nash equilibrium, an equal division of surplus.

Now suppose there was a pool of two workers, but the firm could only productively use one (i.e., $F(2)=F(1)$). The firm must choose which workers will be 'insiders.' An *insider* is a worker who can negotiate with the firm but if those negotiations were to break down, they could never be reopened. Thus, if negotiations broke down when there are two insiders (each earning $\tilde{w}_0(2)$), the remaining worker would be paid $\tilde{w}_0(1)$. Therefore $\tilde{w}_0(2)$ satisfies:

$$F(1)-2\tilde{w}_0(2)-(F(1)-\tilde{w}_0(1))=\tilde{w}_0(2)-\underline{w}$$
$$\Rightarrow \tilde{w}_0(2)=\tfrac{1}{6}\big(F(1)-F(0)\big)+\tfrac{1}{2}\underline{w}$$

So long as $F(1)-F(0)>3\underline{w}$, a SZ firm – a firm that cannot draw on an outside pool – would choose to hire two insiders rather than one.

In contrast, suppose outside workers can be brought inside at any time (at which point they too become an insider). By having a single worker inside, there is another available in the event of a breakdown in negotiations between the firm and the initial insider. In that event, the replacement worker will receive $\tilde{w}_0(1)$. When the initial insider and the firm negotiate, they would agree to a wage, $\tilde{w}_1(1)$, that satisfies:

$$F(1)-\tilde{w}_1(1)-(F(1)-\tilde{w}_0(1))=\tilde{w}_1(1)-\underline{w}$$
$$\Rightarrow \tilde{w}_1(1)=\tfrac{1}{2}\tilde{w}_0(1)+\tfrac{1}{2}\underline{w}=\tfrac{1}{4}\big(F(1)-F(0)\big)+\tfrac{3}{4}\underline{w}$$

It is easy to see that $2\tilde{w}_0(2)>\tilde{w}_1(1)$, so that it is profit maximizing to have only a single insider when replacement is possible. Note that the 'with replacement' wage $\tilde{w}_1(1)>\underline{w}$.

This highlights the main difference between the SZ wage and the 'with replacement' case. Under SZ, even though it is not productive to have two workers, it may be profitable to employ two so as to depress the hold-up power of any one. Over-employment arises because the firm cannot expand its employment beyond the initial set of workers it negotiates with. In contrast, when there is an outsider, insiders can be potentially replaced. While the firm still benefits from having an alternative worker if negotiations with one worker breaks down, it need not pay two workers to have that option. Hence, there is no incentive to over-employ.

B. *Bargaining with Immediate Replacement*

When a firm can potentially replace insiders, our central result is that it will choose to under- rather than over-employ workers. To demonstrate this result we make a simplifying assumption – that we term 'immediate replacement' – that allows us to generate a closed-form solution to our bargaining game. Specifically we assume that, if negotiations break down, the firm *always* wants to replace an insider. That is, if one insider were to leave and there were some outsiders remaining, the firm would choose to bring an outsider into the firm, to maintain the same level of production. As we will demonstrate, this assumption allows us to simplify the specification of 'with replacement' wages and outcomes. However, we will describe below the (qualitatively similar, but not closed-form) outcome when immediate replacement is not imposed.[5]

Under immediate replacement, in the event that all n workers are inside, these insiders will be paid their SZ wage, $\tilde{w}_0(n)$. If there is a single outside worker and n insiders, then $\tilde{w}_1(n)$ is determined in one-on-one bargaining by equating the benefit to the firm with the benefit to an insider. If one insider were to exit, the outsider would be brought in, and all would earn SZ wages. That is,

$$F(n) - n\tilde{w}_1(n) - \left(F(n) - n\tilde{w}_0(n)\right) = \tilde{w}_1(n) - \underline{w}$$
$$\Rightarrow \tilde{w}_1(n) = \tfrac{n}{n+1}\tilde{w}_0(n) + \tfrac{1}{n+1}\underline{w}$$

If there are two outsiders, then if one insider were to exit, the remaining insiders' wages become $\tilde{w}_1(n)$. Given this, we have:

$$F(n) - n\tilde{w}_2(n) - \left(F(n) - n\tilde{w}_1(n)\right) = \tilde{w}_2(n) - \underline{w}$$
$$\Rightarrow \tilde{w}_2(n) = \tfrac{n}{n+1}\left(\tfrac{n}{n+1}\tilde{w}_0(n) + \tfrac{1}{n+1}\underline{w}\right) + \tfrac{1}{n+1}\underline{w}$$
$$\Rightarrow \tilde{w}_2(n) = \left(\tfrac{n}{n+1}\right)^2 \tilde{w}_0(n) + \left(1 - \left(\tfrac{n}{n+1}\right)^2\right)\underline{w}$$

Notice that expanding the number of outsiders depresses the insiders' wages. Indeed, for *N*-*n* outsiders, we can see that:

$$\tilde{w}_{N-n}(n) = \left(\tfrac{n}{n+1}\right)^{N-n} \tilde{w}_0(n) + \left(1 - \left(\tfrac{n}{n+1}\right)^{N-n}\right)\underline{w} \qquad (1)$$

This outcome is simply a linear combination of the SZ wage and the 'neoclassical' wage, $\underline{w}$. For any finite *N*, this negotiated wage lies above $\underline{w}$. That is, even with the possibility of replacement, some rents remain with the insider. It is only as *N* becomes infinitely large that hold-up disappears: i.e., $\lim_{N\to\infty} \tilde{w}_{N-n}(n) = \underline{w}$.[6]

Bargaining power in the SZ model is the result of a risk of breakdown in negotiations: if the firm continues to press for an agreement with a worker, it may forever lose the opportunity to negotiate with that worker. Clearly the cost of such a loss is a function of how many workers are available to the firm. Therefore, the wage in (1) is determined by the size of the pool of outsiders. If that pool is large, neoclassical outcomes result, while if that pool is small, rents remain with the worker. When that pool is finite, there is always a possibility (albeit very small) that the firm could find itself with few workers. That possibility drives the firm to pay above neoclassical wages.

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[5] A complete treatment of the general case is contained in Catherine de Fontenay and Joshua Gans (2002).

[6] One convenient property of SZ is that comparable outcomes can be derived in a continuous version of their problem. With replacement, a similar derivation can be made. In de Fontenay and Gans (2002), we demonstrate that when labor is drawn from a continuous set [0, *N*],

$$\tilde{w}_{N-n}(n) = e^{-\frac{N-n}{n}} \tilde{w}_0(n) + \left(1 - e^{-\frac{N-n}{n}}\right)\underline{w}\,.$$

All of the results for the discrete case can also be easily derived when working with this continuous specification.

C. *Under-hiring*

Given this, what is the firm's choice of insiders, *n*, from a potential pool of *N*? Using (1), the profits of the firm become:

$$\tilde{\pi}_{N-n}(n) = \left(\tfrac{n}{n+1}\right)^{N-n} \tilde{\pi}_0(n) + \left(1 - \left(\tfrac{n}{n+1}\right)^{N-n}\right)\pi(n) \tag{2}$$

where $\pi(n)$ are 'neoclassical' profits and $\tilde{\pi}_0(n)$ are SZ profits ($= \tfrac{1}{n+1}\sum_{i=1}^{n}\pi(i)$). The firm will choose *n* to maximize this convex combination. This gives the marginal condition that will hold at the optimum (subject to integer constraints):

$$\begin{aligned}\tilde{\pi}_{N-n-1}(n+1) - \tilde{\pi}_{N-n}(n) &= \left(\tfrac{n+1}{n+2}\right)^{N-n-1}\left(\tilde{\pi}_0(n+1) - \tilde{\pi}_0(n)\right) \\ &\quad + \left(1 - \left(\tfrac{n+1}{n+2}\right)^{N-n-1}\right)\left(\pi(n+1) - \pi(n)\right) \\ &\quad + \left(\left(\tfrac{n+1}{n+2}\right)^{N-n-1} - \left(\tfrac{n}{n+1}\right)^{N-n}\right)\left(\tilde{\pi}_0(n) - \pi(n)\right) \doteq 0\end{aligned} \tag{3}$$

Let $\tilde{n}$ be the number of insiders that maximizes SZ profits and recall that n^* is the number that maximizes neoclassical profits. Note that if the firm were to choose $n = \tilde{n}$, the first and third terms in the left-hand side of (3) are (approximately) zero while the second is negative (SZ, 1996a, Result 4). Hence, the firm would not hire up to this level. The presence of a reserve pool depresses the inside wages so the firm does not need to have extra insiders to depress this wage.

What happens if the firm sets $n = n^*$, the neoclassical choice, when $n^* \le N$? The first term can be decomposed as follows:

$$\begin{aligned}\tilde{\pi}_0(n+1) - \tilde{\pi}_0(n) &= \tfrac{1}{n+2}\sum_{i=0}^{n+1}\pi(i) - \tfrac{1}{n+1}\sum_{i=0}^{n}\pi(i) = \left(\tfrac{1}{n+2}\right)\pi(n+1) - \tfrac{1}{(n+1)(n+2)}\sum_{i=0}^{n}\pi(i) \\ &= \left(\tfrac{1}{n+2}\right)\left[\left(\pi(n+1) - \pi(n)\right) + \left(\pi(n) - \tilde{\pi}_0(n)\right)\right]\end{aligned}$$

Substituting these into (3) and evaluating at $n = n^*$, we have:

$$\begin{aligned}&\tilde{\pi}_{N-n-1}(n+1) - \tilde{\pi}_{N-n}(n) \\ &= \left(1 - \left(\tfrac{n+1}{n+2}\right)^{N-n}\right)\underbrace{\left(\pi(n+1) - \pi(n)\right)}_{\doteq 0} + \left(\left(\tfrac{n+1}{n+2}\right)^{N-n} - \left(\tfrac{n}{n+1}\right)^{N-n}\right)\underbrace{\left(\tilde{\pi}_0(n) - \pi(n)\right)}_{<0} < 0\end{aligned}$$

Hence, the firm will wish to reduce its employment below the neoclassical level.

The intuition for under-employment is simple. If outsiders are perfect substitutes for insiders the firm does not have to keep them inside to benefit from their influence in depressing negotiated insider wages. Put simply, the firm does not lose its option on anyone from the pool by not bringing them inside and paying them. Consequently, workers are only brought inside if their marginal product exceeds the wage the firm expects to negotiate with them. However, from (1), for a finite *N*, $\tilde{w}_{N-n}(n) > \underline{w}$, for any *n* less than the SZ choice. Therefore, at the neoclassical optimum, $w_{N-n^*}(n^*) > F'(n^*) \doteq \underline{w}$. The bargained wage always exceeds the neoclassical wage when the pool is finite, implying that there is a wage premium and also under-employment.

The result that workers are brought inside *if their marginal product exceeds their negotiated wage* is proven in the Appendix for the general case – the case that does not assume immediate replacement. At n^*, negotiated wages are above $\underline{w}$ (which equals the marginal product at n^*), so the firm will always hire less than n^*.

It is worth pointing out that the general case differs from immediate replacement because in general a firm may not choose to replace insiders immediately. Beginning from the optimal *n*, a breakdown in negotiations with an insider raises the bargaining power of all remaining insiders and outsiders, and the bargained wage of a replacement may now exceed their marginal product.

Therefore, under-hiring with the assumption of 'immediate replacement' is additionally driven by the cost of replacing immediately. The higher is the employment level *n*, the more likely it is that the firm will employ a replacement whose marginal product of the replacement is less than the wage the firm expects to pay in that situation. The firm will, therefore, decrease its hiring to reduce this possibility. Nonetheless, in general, under-hiring persists in the absence of the immediate replacement assumption for the reasons stated above.

The under-hiring result has several direct implications. First, insiders earn rents; $\tilde{w}_{N-n}(n) > \underline{w}$ for finite *N*, at the profit maximizing *n*. This stands in contrast to the SZ optimum where $\tilde{w}_0(\tilde{n}) = \underline{w}$. The fact that insiders are paid a premium suggests that outsiders would have an incentive to offer the firm some up-front payment to replace an insider. This up-front payment must be irrecoverable prior to any wage negotiations, otherwise once negotiations begin, no payment is made. SZ consider this issue:[7] in the initial stages of their game, when the firm is choosing the number of workers (i.e. before that number becomes fixed) the firm would like to commit to hire at the first best, and require an up-front fee from its workers equal to the wage premium. They rule out this possibility by assuming either that workers are unable to pay such a fee, for liquidity reasons, or that the firm is unable to commit to hiring a certain number of workers. Similarly we assume that either workers are liquidity constrained, or that the firm is unable to contractually commit to hiring a *specific* worker upon receiving her up-front payment.

The second implication is that as *N* gets very large, profits at any *n* approach their neoclassical value. Thus, the firm's profit maximizing choice of employment approaches n^*.

II. Distinguishing between Under- and Over-hiring

Because under-hiring contrasts with the broad over-hiring conclusion of SZ, it is important to identify the underlying characteristics of labor market conditions that

[7] See SZ (1996a, p.196, fn.3) for a discussion of this issue.

may support one modelling conclusion over the other. The key issue proves to be the impact of the hiring decision on the supply of skilled workers available to the firm.

SZ argued that hiring generates firm-specific skills that the firm requires to be productive.[8] Such specificity precludes the use of outside workers to discipline the hold-up power of insiders, as outsiders by definition do not possess the required skills. Indeed, SZ demonstrate that if an infinite pool of moderately inferior workers is available to the firm, the firm's incentive to over-hire is mitigated.

More generally, the employment of workers gives them productive skills. Thus, there are many situations in which the experience of employment enhances the set of skilled workers in an industry. Consider for example managerial or marketing skills. While such skills may be specific to a firm (as in SZ) it is also possible that they could be of broader applicability in industry as evidenced by the extent of corporate raiding and high mobility among senior executives in the U.S. (Edward Lazear, 1986, 1998). Thus, in many situations, the firm has available a pool of (perhaps imperfect) replacements who currently work for other firms in an industry, but the firm's hiring of workers who are new to the industry will still impact upon the overall pool of workers in a similar sense to SZ.

It is the magnitude of this impact that proves to be critical in concluding whether under- or over-hiring is likely. To see this formally, suppose that, rather than being exogenous, N is determined by the firm's employment choice, n. In particular, suppose that the size of the replacement pool is unaltered by the firm's employment choice (i.e., $N - n$ is independent of n). In this case, the firm's first-order condition (previously, (3)) becomes:

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[8] SZ do not model the time period during which the worker develops firm-specific skills, but they are implicitly assuming that acquiring firm-specific skills takes time.

$$\tilde{\pi}_{N-n}(n+1)-\tilde{\pi}_{N-n}(n)$$
$$=\left(1-\left(\tfrac{n+1}{n+2}\right)^{N-n+1}\right)\left(\pi(n+1)-\pi(n)\right)+\left(\left(\tfrac{n+1}{n+2}\right)^{N-n+1}-\left(\tfrac{n}{n+1}\right)^{N-n}\right)\left(\tilde{\pi}_0(n)-\pi(n)\right)\doteq 0 \quad (4)$$

Note that at the SZ-optimum, $\tilde{n}$, the first term is negative while the second is zero. Therefore, over-hiring is mitigated by the pool of replacements. At the neoclassical-optimum, n^*, the first term is zero while the second is positive for low values of *N*, implying that the firm chooses to over-hire.[9] The second term is negative for large values of *N*, but this is an artifact of the assumption that the firm is committed to 'immediate replacement,' which biases results toward under-hiring.[10] Nonetheless, in de Fontenay and Gans (2002), we relax this assumption and demonstrate that there is always some over-hiring.[11]

The one-to-one effect of the firm's employment decision on the set of skilled workers restores the SZ motivation for over-hiring. That is, while outsiders still serve to depress the wages paid, insiders now function in the same way as insiders in SZ; insiders are not available to the firm unless the firm hires them, and they are

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[9] Specifically, it is positive (negative) if at $n = n^*$:

$$N \leq (>) n-1+\log[\tfrac{n}{n+1}]/\log\left[\tfrac{n(n+2)}{(n+1)^2}\right].$$

[10] As noted in Section II, under immediate replacement, there is an additional cost to hiring in that the firm commits to replace any insider with whom negotiations break down. In (4), this cost dominates the SZ benefit to over-hiring when the set of skilled workers is large as the incentive to over-hire is diminished as the 'with replacement' wage is close to the neoclassical one. When immediate replacement is not imposed there is no such additional cost to hiring workers.

[11] A hiring commitment also biases the results of Asher Wolinsky (2000) toward under-hiring, although for slightly different reasons. He models a firm that receives a new worker in each period with probability α, but must employ the worker or lose them forever. This corresponds directly to the over-hiring case described in this section: there is a pool of replacements (the set of workers arriving in the future), but every worker retained by the firm increases the pool by one. Wolinsky first restricts attention to the case in which the firm commits to hiring until it reaches a certain level of employment, $\hat{n}$, and to maintaining employment at this level; this is similar to our 'immediate replacement' assumption. If the firm can begin with $\hat{n}$ workers, it finds it optimal to choose $\hat{n} > n^*$, that is, *over-hiring*. However, if the firm begins with zero workers, the intuition is different. Workers' wages undergo a discrete drop once the firm reaches $\hat{n}$, because once at $\hat{n}$, any worker lost to a breakdown in bargaining can be replaced in the next period with probability α. (At lower levels of *n*, the firm is one worker further away from the employment level it seeks, and thus there is no replacement.) Because the first workers to join the firm have strong bargaining power, the firm has an incentive to reach $\hat{n}$ quickly and thereby depress their wages. Therefore, the firm commits to $\hat{n} < n^*$, that is, *under-hiring*, through punishment mechanisms that are typical in infinitely-repeated games. Wolinsky extends the

irreplaceable if they leave the firm. Consequently, the firm chooses to employ more workers so as to reduce the wages they pay to insiders.

This suggests that a key variable to focus upon is the firm's impact on the supply of skilled workers to the industry. If each worker hired by the firm increases the pool of skilled workers by one, there is over-hiring. If instead the pool is exogenously given, and the firm's hiring decisions have no effect on its size, there is under-hiring. Reality will fall in some intermediate range, especially if the firm is large relative to the market. In the case of industry-specific skills, the large firm's hiring decisions may induce other firms to retrench (as their pool of replacements has grown); and in the case of an apparently exogenously determined regional or educational market, the firm's hiring decision may attract more individuals into the market.

It is important to note that both under-hiring and over-hiring are mitigated by a larger-sized pool. If replacements are perfect substitutes for inside workers, then as the pool grows infinitely large, the firm's hiring choices approach the neoclassical optimum, n^*. However, if outsiders are imperfect substitutes for insiders, because industry-specific skills are not identical to firm-specific skills, or there is a cost to bringing outsiders into the firm, over-hiring will persist (see de Fontenay and Gans, 2002).

III. Conclusion

This paper has extended SZ's theoretically appealing wage bargaining model to a context where a pool of replacement workers is available to the firm. When bargaining takes place with an exogenous pool of potential hires, we demonstrate that

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analysis to find the optimal employment path (that also takes the form of a repeated-game the SZ incentive to over-employ is eliminated in favor of an incentive to under-employ common to other models in the wage bargaining literature.

Our generalization of the SZ model yields relatively clear predictions on over- and under-employment, based on the nature of workers' specific skills. Human-capital specificity is decomposed into its effect on the initial size of the pool, and the firm's impact on the size of the pool. These predictions have the potential to serve as hypotheses in future empirical research into skilled labor markets.

Our analysis is partial equilibrium in nature, as is much of the literature. We focus on the firm and explaining how offering wage premiums might minimize costs. Nonetheless, the potential endogeneity of the pool of replacement workers suggests a direction for further theoretical research.

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commitment), which builds on this insight.

Appendix

Here we derive the under-employment result for the case where replacement is credible and not necessarily immediate. Let $n(N)$ be the number of workers that maximizes the firm's profits for a given N, $\pi(n(N),N)$:

$$\max_{n(N)} \pi(n(N),N)$$

$$\text{subject to } \pi(n(N),N)-\pi(n(N-1),N-1)=\tilde{w}_{N-n(N)}(n(N))-\underline{w} \qquad (5)$$

Subgame perfection implies that profits when the pool is of size (N-1) are not influenced by the choice of $n(N)$ when the pool is of size N. This is because, after a breakdown, N falls to N-1 and never returns to N, implying that choices at N-1 will not influenced by previous choices of n. Therefore, at N we can treat $\pi(n(N-1),N-1)$ as a constant, K.

Substituting for $\pi(.)$ in (5), and setting $K=\pi(n(N-1),N-1)$, we have:

$$F(n)-n\tilde{w}_{N-n(N)}(n(N))-K=\tilde{w}_{N-n(N)}(n(N))-\underline{w}$$
$$\Rightarrow \tilde{w}_{N-n(N)}(n(N))=\tfrac{1}{n+1}\left(F(n)-K+\underline{w}\right)$$
$$\Rightarrow \pi(n(N),N)=F(n)-n\tilde{w}_{N-n(N)}(n(N))=\tfrac{1}{n+1}\left(F(n)-n(\underline{w}-K)\right)$$

Using this expression for π, any internal choice of n satisfies:

$$\frac{\Delta\pi}{\Delta n}=\frac{(n+1)F(n+1)-(n+2)F(n)-\underline{w}+K}{(n+1)(n+2)}=\frac{\left[F(n+1)-F(n)\right]-\tilde{w}(n)}{n+2}\doteq 0$$

which implies that $\tilde{w}_{N-n(N)}(n(N))\doteq\frac{\Delta F(n)}{\Delta n}$.

Therefore, whenever the boundary conditions $0 \le n \le N$ do not bind, the firm chooses n to equate the marginal product of an insider with the bargained wage that insider would be paid. Given that bargained wages do not fall to $\underline{w}$ at n^* (proven in de Fontenay and Gans 2002), the firm never hires up to n^*, as $\tilde{w}_{N-n^*}(n^*)>\underline{w}=\left.\frac{\Delta F(n)}{\Delta n}\right|_{n=n^*}$.

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