Raiding and Signaling in the Academic Labor Market

by

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Revised June 07, 2006

Abstract

Publications signal a professor's productivity and may lead to raids by other universities. Professors attach different values to non-wage benefits at a raiding university, and will quit only if benefits elsewhere are relatively high. The social value of these benefits means research may increase welfare *even without a direct social value from research*. Other results are: welfare would be reduced if a university committed to not make counteroffers; signaling occurs even if its cost is independent of individual productivity; and a school may preempt signaling by paying a higher wage, but will only do so when signaling increases welfare.

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I particularly thank Todd Kendall for detailed comments on an earlier version of this paper. I also thank Kyung Baik, Don Parsons, and participants in a workshop at Appalachian State University for their comments.

JEL classifications: D82, J44, J62

Key words: raids, signaling

1. Introduction.

In the last two decades, academicians in the U.S. have been criticized by state legislators, journalists, and foundations for allegedly emphasizing research over undergraduate education.[1] A series of books including *Profscam* (1988), *Imposters in the Temple* (1992), and *Inside American Education* (1993) was part of the chorus of criticism. Attempts to justify research usually involve an emphasis on the creation of knowledge that results from research and publication. However, critics of research can counter by referring to the citation literature, which suggests few articles are cited and even fewer have a significant effect on one's profession.[2]

The purpose of this paper is to consider whether time spent in research by faculty may enhance social welfare *even if there is no direct social value from research*. Note, the argument herein is not research has no direct social value. Rather, if, absent a direct social value from it, research may increase welfare, the possibility of a direct social value for research would then enhance the justification for research.[3]

The outline of the rest of this paper is as follows. In Section 2, possible welfare effects of research are considered. In Section 3, the analysis herein is contrasted with that in related papers. In Section 4, a model of signaling and raiding is developed. In Section 5, whether a university can profitably preempt raids by paying a higher wage is examined. In Section 6, other extensions to the basic model are considered. A direct (social and private) value for publications is considered in Section 7. Concluding remarks are contained in Section 8.

[1] Nobel laureate Merton Miller cited a week-long series of articles in the Chicago Tribune suggesting the University of Illinois reduce spending on research (Miller, 1992). In North Carolina, the John Locke Foundation produced reports critical of research at the University of North Carolina (Sykes, 1992). A segment on *Sixty Minutes* (February 26, 1995) considered teaching and research at the University of Arizona.

[2] Laband (1986) examined articles cited from 1977 through 1982, which were published in the previous thirty years in forty economics journals. Only one tenth of one percent had two hundred or more citations in this period.

[3] Salter and Martin (2001) examine recent economic analysis of the optimality of basic research. They note the traditional market failure argument fails to recognize "...the extent to which knowledge is embodied in specific researchers..." and "Scientific knowledge is not freely available to all..." (p.512). Other recent papers (Aghion *et al.*, 2005, and Lacetera, 2005) focus on whether research should be undertaken in academia or in the for-profit sector.

2. Welfare effects of research

Consider possible reasons the level of academic research may be inefficient. First, there is the traditional argument involving externalities from knowledge creation (Nelson, 1959, and Arrow, 1962), which implies too little research may occur. However, the extensive government funding for research in the US might yield too much research. A different externality may also imply an inefficiently large level of research occurs. Siow (1995, 1998) notes a professor who publishes is more visible and thus is more likely to receive an outside offer. Siow argues a professor's private gain from research---the prospect of a higher salary---exceeds the social gain from research. Thus a professor will devote an inefficiently large amount of time to research.

Second, suppose, as does Siow (1995, 1998), research has social value because it enhances a professor's knowledge. However, if the more visible a professor the higher the wage the university must pay, then, contrary to Siow's argument, too little research may occur. A similar phenomenon was considered by Waldman (1984). He found firms might promote an inefficiently small number of individuals because promotion provides information to other firms regarding the productivity of those promoted.[4]

Third, suppose research does not enhance anyone's knowledge (nor does it make professors better teachers), so there is no direct social value from research. If more able individuals are also more capable in research, publications may serve as a signal of a professor's productivity[5] and lead to raids by other universities.

Coupé *et al*. (forthcoming) suggest some aspects of faculty performance or ability may not be observable to others. These include teaching quality and the beneficial effects of one faculty member on the research of others. Herein, it is assumed universities desire higher ability professors. They might value more able professors because: a) they produce more (and higher quality) publications; b) their higher

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[4] Golan (2005) shows the matching of outside offers by a raided firm can induce efficient job assignment. Ishida (2004) demonstrates signaling may induce more promotions, thereby reducing the welfare loss from inefficient job assignment.

[5] The possibility publications may signal the productivity of professors was considered by Paul and Rubin (1984), Forbes and Paul (1991), and Siow (1997). However, they did not consider the welfare effects of publishing as a signal.

ability implies more learning by students; or c) both a) and b) are true. However, as noted above, it is not clear what the social value of publications is relative to their private value. Thus, in order to minimize the likelihood research activity is socially desirable, in the basic model herein, it is assumed there is no direct social (or private) value from publications. The question then is: can research be socially desirable?

Consider the value of non-wage aspects of employment at universities. These include teaching loads and schedules, research support, and the environment in a department. These job benefits (other than salary) will be referred to as *job satisfaction*. Job satisfaction is idiosyncratic: professors differ in the value they attach to job satisfaction at any school. The social benefit from job satisfaction results because a raided professor has an *option value*. A professor whose satisfaction is relatively high elsewhere may quit, even with a counteroffer from the professor's current employer. *Option value* equals the probability one quits if raided multiplied by the conditional expected job satisfaction of a quitter.[6] Since option value is a social benefit from being raided, and a raid occurs only if the more able signal their ability via publications, it is possible option value exceeds the cost of signaling, in which case signaling is socially desirable.[7]

3. Comparisons to related work

Observations of raids in academia suggest the following occurs.

- Those who publish the most are the ones who may be raided.
- Not all raided individuals quit.
- Counteroffers often occur, but do not necessarily match outside offers.
- One's current employer may know more about one's productivity than a raider does.

Lazear (1986) considered raids with offer matching in a model in which there is match-specific productivity analogous to job satisfaction herein. In his model, the employer and the raider have some

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[6] As noted below (Section 4), it is assumed job satisfaction at one's current employer is normalized to zero.

[7] A different type of option value in the labor market was analyzed by Lazear (1998). He demonstrated a firm might prefer to hire risky workers if the firm could truncate its losses by firing workers who are found to have relatively low productivity.

exogenous probability of learning an individual's productivity. In most of Lazear's analysis, he assumed the raider and the employer had the same probability of being informed regarding worker productivity. One result is the best workers are raided. Herein, it is *assumed* those believed to be the most productive are raided.

Siow (1998) argued faculty slots are scarce, and used this observation to explain up-or-out rules in academia. Accordingly, scarce slots suggest universities desire the best workers they can attract, so raids are directed towards high productivity individuals. In contrast to Lazear's model, herein it is assumed one's employer has more knowledge than does a raider regarding an individual's productivity. Also, herein individuals expend resources to signal their productivity. This occurs via publications. Lazear did not consider the possibility of signaling by those raided, and thus did not examine the efficiency implications of raids.

Banerjee and Gaston (2004) consider a model of signaling and job turnover. In their model, (1) a noisy, costless, and exogenous signal of productivity occurs; (2) the employer knows more about a worker's productivity than does a raider; (3) raiders suffer at least a partial winner's curse; (4) counteroffers are costly; (5) an employer knows a worker's cost of job switching; (6) the less productive workers are more likely to turnover; and (7) equilibria exist in which there is no turnover. In the model herein, (1') signaling is costly, and its level is determined by what is necessary to deter the less productive from mimicking the more productive, as in Spence (1974); (2') the employer knows more about a worker's productivity than does a raider; (3') no winner's curse results because it is anticipated by raiders; (4') counteroffers are costless; (5') an employer does not know a worker's cost of *and* benefit from job switching, the net amount of which is called job satisfaction; (6') the more productive workers are the only individuals who quit;[8] and (7') zero turnover is possible. Other than assumption (2) and result (7), the model herein differs in the seven assumptions and results listed above from Banerjee and Gaston.

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[8] In the model developed in the next section, if low productivity individuals *were* to mimic the level of publications of those with high productivity, then low productivity individuals would have a higher probability of quitting than those with high productivity. In the signaling equilibrium, low productivity individuals do not turn over.

Also, result (6) does not seem consistent with the academic labor market in which good workers are raided.

Postel-Vinay and Robin (2004) argue workers may search too much when search is costly to firms. They consider when firms may commit to matching offers *or* to never matching offers. Herein, it is assumed counteroffers are not costly to firms other than, of course, the private cost of paying a higher wage. In Section 6, I consider the effects of a school's commitment to not match outside offers.

Barron, Berger, and Black (2004) assume firms can not credibly commit to not match *or* to match outside offers. As opposed to Postel-Vinay and Robin, Barron *et al*. assume private information on reservation values. Both papers focus on the optimality of search intensity of workers. Also, in Barron *et al*., non-wage benefits at one's employer are known only by the employee. Herein, the counterpart of search intensity is signaling via publications. A university's choice of the wage can affect whether signaling will occur (Section 5). Also, the value of non-wage benefits or job satisfaction at a raiding school is assumed unknown to all except the raided professor.

Finally, the paper closest in spirit to this paper is that of Pitchik (2006). In her model, an individual divides time between two activities, "visible" and "invisible," which will be denoted by v and i respectively. In a university, v might represent research activity, and i might represent teaching. One's time is allocated between these two activities, with t the time spent in v and 1-t the time spent in i. Denote an individual's output by Φ, and let the maximum of Φ with respect to t equal Φ^*. Pitchik argues an individual has an incentive to invest too much in v, so $\Phi < \Phi^*$, but an appropriate contract can result in $\Phi = \Phi^*$. In her model, a raiding firm may have superior knowledge regarding one's productivity than does one's employer, a raid reveals Φ to the employer, and those who choose too high a level of t receive a relatively low outside offer---because $\Phi < \Phi^*$.

The most important difference between the model in Pitchik and that herein is the argument in Pitchik output does not increase monotonically in v. Although it might be reasonable to believe too little time spent in teaching would imply lower output, empirically it does not appear those who publish the most receive lower wages. The reason is those who publish more can do so by reducing time in other activities (leisure) without reducing teaching time below the point where Φ is reduced. Although the effect of research on productivity is suppressed in the formal model herein (except in Section 7), in the standard signaling model in which the signal also directly affects productivity (*e.g.* Spence, 2002) , it is assumed output increases monotonically in the signal.[9]

Thus, although there are some similarities between the model herein and those in the papers discussed in this section, there are also significant differences, particularly in the focus herein on costly signaling of productivity, and on the efficiency implications of signaling and turnover.

Regarding the four bulleted items at the beginning of this section: in the model herein, the first and fourth items are assumptions, and the second and third items are results. Thus, the model seems to describe the academic labor market reasonably well.

4. The model

A. Essentials

Consider a world in which a university, U, employs professors who are of two possible types: high productivity, H, and low productivity, L, with productivity denoted by x_H and x_L. Higher productivity means some professors can transmit more knowledge to students. A direct value for publications by universities is ignored until Section 7. U knows a professor's type, but other universities do not have this information. For reasons given in the next sub-section, professors who do not signal via publications are all paid a wage equal to x_L. Let job satisfaction at U equal zero. Satisfaction elsewhere equals S and is person specific.[10]

Rothschild and White (1995) note the difficulty in determining what universities maximize, and proceed to consider how profit-maximizing universities would behave. Cowen and Papenfuss (1997) argue non-profit universities maximize the efficiency of reputational certification---that is, they certify the

[9] Although output may increase monotonically in the signal, output less signaling cost will not do so. Thus, inefficient signaling may occur.
[10] One can think of S as job satisfaction elsewhere minus moving cost.

reputations of more able students and faculty. Since it is not the objective of this paper to consider what universities maximize, for want of a better objective function, it is assumed universities maximize profit.[11] The timeline of the model is as follows:

i) U offers the same wage to all professors.

ii) Hs may signal via the number of publications produced; if they signal, they attract outside offers. The possibility not all who signal receive an outside offer is considered in Section 6.

iii) Two or more identical outside universities bid in Bertrand fashion for a professor who signals. The professor randomly chooses to consider one of the identical offers. Outside firms are referred to as the market, M. Competition between raiders (M) raises the outside offer to x_H for those who signal, since M believes---correctly in a signaling equilibrium---anyone who publishes a certain amount is an H.

iv) U chooses a counteroffer, W_C. An H's utility at U is W_C minus signaling cost.

v) An H decides whether to quit or accept the counteroffer. An H's utility at M is x_H + S minus signaling cost.

Note, when the terms "outside offer" and "counteroffer" are used herein, they refer only to the monetary compensation for professors.

B. The wage for those who do not signal

Those who do not signal are paid x_L. Consider why this will be true. One argument is, if M does not know an individual professor's productivity, but knows the percentage of Hs at U will tend to equal λ, then M might offer anyone at U a wage equal to the expected productivity of these professors, E(x), with $E(x) = \lambda x_H + (1-\lambda)x_L$. However, U would not make counteroffers to Ls, so M would suffer a complete winner's curse, attracting only Ls. Thus M would only offer x_L to a professor at U.

[11] The assumption of profit-maximizing behavior *might* be problematic if one considered who to admit to a university. Profit-maximizing schools may be less inclined than non-profit-maximizing schools to enroll good students with limited financial resources.

The winner's curse argument in the preceding paragraph is not sufficient to ensure those who do not signal will be paid x_L. With job satisfaction elsewhere equal to S, not all Hs would be retained at U by a counteroffer, nor would all of the Ls leave. Thus, the complete winner's curse would not occur, and M might break even with a raid, provided its wage offer adjusted to reflect the actual combination of Ls and Hs it would expect to attract. However, one still would find only x_L offered by M to professors at U if: a) faculty slots are scarce so M will not make an offer unless it believes the individual is an H; or b) what has been called job satisfaction herein, S, represents non-wage aspects of employment at M that are costly for M to provide, so S will only be offered to those believed to be an H.

For now, assume S is costless, and scarce faculty slots result in a wage of x_L for those who do not signal. In Section 6, the case of a positive marginal cost for S is considered.

C. The quit decision

A professor who signals and attracts an outside offer may receive a counteroffer, and then must decide whether to quit. As is the case in any signaling equilibrium (Spence, 1974), an L must not want to produce the same number of publications,[12] q, as an H. Thus, in order to ensure an L will not mimic an H, one must consider the signaling and quit decisions of an L. An L who signals (and is believed to be an H) will receive an outside offer of x_H. Since U knows the productivity of its professors, U will not make a counteroffer, and an L who does not quit will be paid x_L. With S equal to job satisfaction at a raiding school, let E(S) equal zero, with S distributed on $[-\Delta, \Delta]$ with a density of $\frac{1}{2\Delta}$. A uniform distribution is assumed in order to obtain an explicit solution for the counteroffer for Hs, W_C. Let $m \equiv x_H - x_L$.

Assumption One. $\frac{\Delta}{2} < m < \Delta$.

[12] Clearly q can be thought of as some observable measure of both quantity and quality of publications, where the latter could be measured by citations. For brevity, q will be referred to as the number of publications.

As demonstrated below, if m $\geq \Delta$, an L who mimics an H will always quit when raided. In this case, the worst possible draw of job satisfaction, $-\Delta$, is not large enough to offset the wage gain, m, from quitting. The assumption m < Δ is made to allow for the possibility an L might not quit if raided. It will be shown the results herein do not depend on this assumption. If $m < \frac{\Delta}{2}$, the probability a raided H will quit is low enough so the counteroffer, W_C, will be less than x_L. Since a counteroffer lower than one's current wage is not usually (ever?) observed, for the sake of realism, it is assumed $m > \frac{\Delta}{2}$.

An L who mimics an H by publishing and is offered x_H will quit if $x_H + S \geq x_L$, or if $S \geq -m$. Let p_L = the probability an L who signals and is raided will quit. We have:

$$p_L = 1 - \frac{1}{2\Delta}\int_{-\Delta}^{-m} dS = \frac{\Delta + m}{2\Delta}, \tag{1}$$

with $p_L < 1$ by Assumption One. An L who quits will have conditional expected job satisfaction, $\overline{S}_L$, equal to:

$$\overline{S}_L = \frac{\frac{1}{2\Delta}\int_{-m}^{\Delta} S dS}{\frac{1}{2\Delta}\int_{-m}^{\Delta} dS} = \frac{\Delta - m}{2}. \tag{2}$$

Similarly, one can derive the quit probability, p_H, and the conditional expected job satisfaction, $\overline{S}_H$, for an H, the only difference being an H who is raided is offered W_C instead of x_L by U.

$$p_H = \frac{\Delta + x_H - W_C}{2\Delta}, \tag{3}$$

$$\overline{S}_H = \frac{\Delta + W_C - x_H}{2}. \tag{4}$$

Using eqs.(1) - (4), it is clear $p_L > p_H$ and $\overline{S}_H > \overline{S}_L$. Also, as shown in the Appendix, *for any continuous distribution of S*, $p_H \overline{S}_H > p_L \overline{S}_L$. Now $p_H \overline{S}_H$ is the expected gain in job satisfaction for an H who quits, and $p_L \overline{S}_L$ is the same thing for an L. For brevity, this shall be referred to as the *option value* of signaling and quitting. A higher option value for Hs than for Ls is important for the results derived below.

D. The optimal counteroffer

An L who mimics an H in publications and is raided will not receive a counteroffer, and will only receive the original wage, x_L. An H will receive a counteroffer, W_C, that maximizes the expected profit for U:

$$\max_{W_C} \{(x_H - W_C)(1 - p_H)\},$$

which yields:

$$W_C = x_H - \frac{\Delta}{2}. \qquad (5)$$

From eq.(5), it is clear $W_C > x_L$ only if $m > \frac{\Delta}{2}$, as discussed above. Using eqs.(3) - (5), $p_H = ¾$ and $\overline{S}_H = \frac{\Delta}{4}$, so option value for an H equals $\frac{3\Delta}{16}$. Thus, with a uniform distribution for S, a raided H quits 75% of the time in this model.

E. Signaling via publications

A simple production process is assumed for publications. With the input of effort, y, an L can produce publications, q, with q = y. For an H, q = by, with $b \geq 1$. Let the effort cost of publishing equal y^2 for either an H or an L. Thus, in order to produce q publications, an L has cost of q^2, and an H has cost of $\frac{q^2}{b^2}$. In the typical signaling model, b would have to exceed one in order for an L not to mimic an H.

Proposition One. Ignoring for now the possibility of a higher wage preempting signaling, signaling will always occur, even if b = 1.

Proof. Let the net payoff from signaling for an L and an H be denoted by I_L and I_H respectively. An L who signals (mimics an H in publications) will quit with a probability of p_L and have a wage plus conditional expected satisfaction of $x_H + \overline{S}_L$. With a probability of $1-p_L$, an L will remain at U and be paid x_L. The cost of signaling for an L is q^2. Using eqs.(1) and (2):

$$I_L = \frac{(m+\Delta)^2}{4\Delta} + x_L - q^2. \qquad (6)$$

An H who signals will quit with a probability of ¾ , and will then receive a wage of x_H and conditional expected satisfaction of $\frac{\Delta}{4}$. An H who does not quit will be paid $W_C = x_H - \frac{\Delta}{2}$. Signaling cost for an H is $\frac{q^2}{b^2}$. Thus:

$$I_H = x_H + \frac{\Delta}{16} - \frac{q^2}{b^2}. \qquad (7)$$

Suppose b = 1. Then $I_H > I_L$ if:

$$m + \frac{\Delta}{16} > \frac{(m+\Delta)^2}{4\Delta}, \text{ or}$$

$$-4m^2 + 8\Delta m - 3\Delta^2 > 0. \qquad (8)$$

If $m \to \frac{\Delta}{2}$, the LHS of ineq.(8) $\to 0$. Also, $\frac{\partial LHS}{\partial m} = 8(\Delta\text{-}m) > 0$ by Assumption One. Thus, for $m > \frac{\Delta}{2}$, $I_H > I_L$ when b = 1. A larger b makes I_H even larger. As noted above, the assumption $p_L < 1$ does not change anything of consequence. Suppose $p_L = 1$. Now an L who signals always quits, so $\overline{S}_L = 0$ (the population mean of S), and $I_L = x_H - q^2$, which is clearly less than I_H for $b \geq 1$. To complete the proof, note $I_L > x_L$ for a small enough (less than $\frac{(m+\Delta)^2}{4\Delta}$) effort expenditure by an L on publications, with x_L the payoff to one who does not signal. Thus, assuming an indifferent L will not signal, with q^2 an L's cost of publishing, an L will prefer not to mimic an H if $q \geq \frac{m+\Delta}{2\Delta^{1/2}}$. The Riley outcome (Riley, 1979) is the least-cost level of the signal, call it q_R, that yields a separating equilibrium. Then:

$$q_R = \frac{m + \Delta}{2\Delta^{1/2}}. \tag{9}$$

Since q_R just makes an L indifferent to signaling, and $I_H > I_L$, $I_H > \frac{q_R^2}{b^2}$ for $b \geq 1$, and signaling occurs. ■

Why is $I_L < I_H$, even if $b = 1$, so Hs and Ls have the same cost of signaling? An apparent explanation is an H has a higher return than an L from signaling because an H whose S is relatively low and does not quit is paid more than an L who does not quit, W_C versus x_L. However, as was shown, even if an L will *always* quit, $I_L < I_H$. Thus, the fact an H who does not quit earns more than an L who does the same is not *directly* responsible for $I_H > I_L$.

The reason I_H exceeds I_L is *indirectly* related to the fact W_C exceeds x_L. An H has a higher cutoff for the value of S below which one will not quit. For an H, this value is $W_C - x_H$, and for an L, the value is $-m = x_L - x_H$. This is the reason why $\overline{S}_H > \overline{S}_L$. With $p_H \overline{S}_H > p_L \overline{S}_L$ (see the Appendix), option value is what drives the result $I_H > I_L$, even if $b = 1$.

Note: Proposition One can not be proven for a general distribution of S (see the Appendix).

Proposition Two. Signaling may improve welfare but only if b is sufficiently larger than one.

Proof. The cost of signaling for an H is $\frac{q_R^2}{b^2}$. The social gain from an H signaling is the option value of satisfaction, $p_H \overline{S}_H = \frac{3\Delta}{16}$. Using eq.(9), signaling improves welfare if:

$$3b^2\Delta^2 > 4(\Delta+m)^2 \tag{10}$$

The larger is b, the lower the cost of signaling for an H. A larger m implies a larger I_L (and I_H); thus q_R increases and signaling cost rises. Signaling is most likely to improve welfare the smaller is m. If $m \to \frac{\Delta}{2}$, signaling improves welfare only if $b > \sqrt{3} \approx 1.73$. If $m \to \Delta$, signaling improves welfare only if $b > \sqrt{\frac{16}{3}} \approx 2.31$. ■

Thus signaling *may* improve welfare, but, with a uniform distribution of job satisfaction, this requires a lower cost for publishing for high productivity individuals than for those with low productivity, and is more likely to occur when the productivity difference between Hs and Ls is smaller.

Intuitively, signaling may improve welfare for the following reason. Part of the private return to signaling is also a social return: the option value of job satisfaction. Although an L who signaled would have a net private gain just equal to cost, the net gain for an H is higher (because option value is higher), and, if b exceeds one, an H has a lower cost than an L from signaling. Thus, even though the private gain from signaling exceeds the social gain, an H has a private gain that exceeds the cost, and, for b sufficiently large, the social gain may exceed the cost.

Lazear (1998) showed a firm's expected return from hiring risky workers is positively related to the variance in worker ability. Herein, with a uniform distribution of job satisfaction, it can be shown (see the Appendix) the net social benefit from signaling is non-negatively related to the variance in job satisfaction.

5. Can signaling via publications be preempted?

Proposition One suggests signaling always occurs in this model (with S distributed uniformly). However, one must consider the possibility U can preempt signaling by paying all a wage that exceeds x_L.[13]

Proposition Three. There are some cases when signaling may (profitably) be preempted, but only when signaling does not improve welfare.

Proof. Normalize the number of professors (pre-raids) at one, with λ the fraction of Hs at U (pre-raids). Since U earns zero profit on Ls, its expected profit if raided, π_{raid}, is then:

$$\pi_{raid} = \lambda(1\text{-}p_H)(x_H\text{-}W_C) = \frac{\lambda\Delta}{8}, \tag{11}$$

using eq.(5) and the fact $p_H = ¾$. If U can pay $x_L + \delta$ to each professor and deter signaling, with $\delta > 0$, its profit, $\pi_{preempt}$, is:

$$\pi_{preempt} = \lambda x_H + (1\text{-}\lambda)x_L - x_L - \delta = \lambda m - \delta. \tag{12}$$

U prefers preemption to being raided if $\delta < \lambda\left(m - \frac{\Delta}{8}\right)$. Thus the most U can afford to pay to preempt raids is $x_L + \lambda\left(m - \frac{\Delta}{8}\right) \equiv W_P$. The question is whether an H will prefer to signal or to receive W_P and not signal. Since U can anticipate what an H would do, if U believes W_P will *not* deter signaling, then U will not offer this wage. Thus, *with* signaling, as in the previous section, Ls do not publish and are paid x_L; Hs publish the amount $q = q_R$ (eq.(9)), are raided, and receive a counteroffer $W_C = x_H - \frac{\Delta}{2}$. Using W_P and eqs.(7) and (9), an H prefers signaling to the preemptive wage offer if:

[13] Again, if U paid a higher wage only to Hs, this would indicate to M which professors were Hs.

$$(1-\lambda)m - \frac{(m+\Delta)^2}{4\Delta b^2} - \frac{\Delta}{8}\left(\frac{1}{2}+\lambda\right) > 0. \qquad (13)$$

Clearly, the lower is signaling cost (the larger is b), the more likely an H prefers signaling to preemption. From ineq.(10), we can find the minimum b for which signaling improves welfare; call this b*. From ineq.(13), we have the minimum b for which Hs prefer signaling to preemption; call this b**. We have:

$$b^* = \frac{2(\Delta + m)}{\Delta\sqrt{3}}, \qquad (14)$$

$$b^{**} = \frac{\Delta + m}{2\Delta^{1/2}\left[(1-\lambda)m + \frac{\Delta}{8}\left(\frac{1}{2}+\lambda\right)\right]^{1/2}}. \qquad (15)$$

It is easy to show b** is positively related to λ, and $b^{**}|_{\lambda=1} = b^*$. Thus, for $\lambda < 1$, b** < b*, and signaling is never preempted when it improves welfare. ■

6. Other extensions

A. Commitment to not make counteroffers

As noted earlier, Postel-Vinay and Robin (2004) consider the possibility U can commit to not match outside offers. Herein, the optimal counteroffer for an H will not equal the outside offer, but (if $m > \Delta/2$) will involve an increase in pay. Suppose there is some (un-modeled) gain to U if it does not make counteroffers. In this case, an H who signals, is raided, and stays at U will only receive a wage equal to x_L. Then, if b = 1, $I_H = I_L$. Thus, for signaling to occur, b must exceed one.

Proposition Four. A policy of not making counteroffers means signaling is less likely to improve welfare.

Proof. The level of the signal required to deter Ls from mimicking Hs is the same as before (eq.(9)), but now $p_H = p_L$ and $\overline{S}_H = \overline{S}_L$ (eqs.(1) and (2) respectively). Signaling improves welfare only if:

$$b > \sqrt{\frac{\Delta + m}{\Delta - m}} \equiv b^{***} . \qquad (16)$$

With U paying W_C to Hs who signal and are raided, signaling was found to improve welfare only if $b > b^*$ (eq.(14)). Now $b^{***} > b^*$ if $4m^2 > \Delta^2$, which is true if $m > \frac{\Delta}{2}$. ■

In models of on-the-job search, it may improve welfare for a firm to commit to not match outside offers, because otherwise search may be socially excessive. However, with signaling of productivity in order to obtain an outside offer, since firms would never make counteroffers to low productivity workers, the latter's return to signaling is unaffected by a no-counteroffer policy. Thus the level of the signal required to deter low-productivity individuals from mimicking those with high productivity is also unchanged. Provided $b > 1$, Hs still prefer signaling to receiving a wage equal to x_L. All that occurs with a policy of not making counteroffers is Hs are more likely to quit, so their option value from job satisfaction is the same as that for Ls, which (see the Appendix) is lower than option value for an H with counteroffers. The social gain from signaling is reduced, and a lower cost of signaling (larger b) is required in order for signaling to improve welfare.

B. Not all who signal are raided

The scarce slots argument (Siow, 1998) suggests there may not be enough open faculty positions at raiding schools for all who signal. Suppose only the fraction ρ of those who signal are raided. The quit decisions of Ls and Hs are unaffected, but the net payoff from signaling is reduced for both. Using the analysis in Section 4, but when only ρ of those who signal are raided, we have:

$$I_H = \rho\left(m + \frac{\Delta}{16}\right) + x_L - \frac{q^2}{b^2}, \qquad (17)$$

$$I_L = \frac{\rho(m+\Delta)^2}{4\Delta} + x_L - q^2. \qquad (18)$$

Proposition Five. The condition for signaling to improve welfare is independent of the fraction of those who signal who are raided.

Proof. For b = 1, the condition for $I_H > I_L$ is exactly the same as before (ineq.(8)). The expected social gain from signaling is what it was before, except it now occurs for only ρ of Hs. Thus the expected social gain per H is $\frac{3\rho\Delta}{16}$. However, the minimum level of q that deters Ls from signaling is found where $I_L = x_L$, which yields the Riley outcome: $q_R = \frac{\rho^{1/2}(m+\Delta)}{2\Delta^{1/2}}$. Since an H's signaling cost is $\frac{q_R^2}{b^2} = \frac{\rho(m+\Delta)^2}{4b^2\Delta}$, the social cost of and benefit from signaling derived in Section 4 have both been multiplied by ρ. Thus, the condition for welfare-enhancing signaling is the same as before and is independent of ρ. ■

The only thing different when not all who signal are raided is the net social gain or loss from signaling; it is ρ times what it was before.

C. Job satisfaction is costly

As discussed in Section 4, one interpretation of satisfaction is it represents some non-wage benefits---teaching load, research assistants, etc.---that are costly for a university to provide. Suppose it costs a raider "C" per professor to provide S. The analysis is similar to that in Section 4, except now a raider offers a wage of x_H - C. In order for $I_H > I_L$ when b = 1:

$$-4m^2 + 8\Delta m - 3\Delta^2 + C(C-2\Delta) > 0. \qquad (19)$$

If $C \geq \Delta$, non-wage benefits would not be offered: the cost of providing S would at least equal the maximum value of S. If $C < \Delta$, the fourth term on the LHS of ineq.(19) is negative, and the LHS of ineq.(19) is less than the LHS of ineq.(8)---the same condition but when C = 0. It was demonstrated above ineq.(8) holds for $m > \frac{\Delta}{2}$; ineq.(19) will not hold for $m \approx \frac{\Delta}{2}$, so there is no guarantee signaling will occur if b = 1. Also, in addition to the cost of signaling, there is now the cost C per raided worker. Thus, given m, it is less likely signaling improves welfare

D. Matching counteroffers when turnover is costly

In the model developed in Section 4, a raided university, U, will never match an outside offer.[14] Since anecdotal evidence suggests such offers are matched some times, and, in isolated instances, are more than matched, the basic model is altered in order to introduce the possibility of counteroffers that equal or exceed x_H. Suppose when an H quits there is a cost to U from turnover equal to T. Such a cost may be due to the necessity of finding someone to teach the field courses taught by the departing professor, shifting burdens of supervising doctoral dissertations, etc. Also, because of various subsidies available, suppose the university is not constrained to have non-negative profit. Now U's expected profit equals $(x_H - W_C)(1-p_H) - p_H T$. Using eq.(3) and the new profit function, the optimal W_C is:

$$W_C = x_H + \frac{T - \Delta}{2}. \qquad (20)$$

Using eqs.(2), (3), and (20):

$$p_H = \max\left(\frac{1}{4}\left[3 - \frac{T}{\Delta}\right],\ 0\right), \qquad (21)$$

[14] The model herein suggests a profit-maximizing university chooses to balance the probability one quits with profit if one stays. This results (eq.(5)) in a counteroffer less than the value of the individual. Black and Lowenstein (1991) find a similar result when a firm makes a wage offer knowing a worker may quit.

$$\overline{S}_H = \frac{T + \Delta}{4}, \tag{22}$$

$$p_H \overline{S}_H = \frac{1}{16\Delta}(3\Delta - T)(T + \Delta), \tag{23}$$

for $p_H > 0$.

Assume $T < 3\Delta$ so $p_H > 0$. Note, using eq.(23), if $T < 2\Delta$, option value is higher with $T > 0$ than with $T = 0$.[15] Option value is maximized when $T = \Delta$. At that point, $W_C = x_H$ and $p_H = ½$. Only if $T \geq \Delta$ would $W_C \geq x_H$; profit would then clearly be negative. Not surprisingly, the higher is T, the higher is W_C and the lower is p_H. Thus, if a raided school incurs a cost when a professor leaves, and may survive with negative profit, matching or exceeding outside offers may occur if turnover is sufficiently costly.

7. Publications are valued by universities

We have shown academic publishing may improve welfare when there is no direct value of publications to universities. However, in a multi-period model, if publications *per se* are not valued by schools, a raided individual would presumably cease publishing after a raid. Although it might not be surprising to find those who are raided subsequently reduce their publication rates, it is doubtful they never publish again.

Suppose one's value to a university is θ, with $\theta = \theta(x,q)$. Further suppose $\theta = x + q$, where again there are two types of individuals, L and H, and $x_L < x_H$. In Section 4, we found signaling via publications would occur, but would not increase welfare if $b = 1$. Thus, for now assume $b = 1$. Intuitively, it is now possible signaling may enhance welfare, because there is an additional social return to publishing: the direct value of the publications.

With $b = 1$ and θ separable in x and q, the optimal value for q is independent of x and equals ½ , the value of q that maximizes $\theta - q^2$. Thus, a university will require $q = ½$, but, following the analysis in

[15] Thus, Proposition One (signaling occurs even if $b = 1$) still holds unambiguously (with a uniform distribution of job satisfaction) if $T < 2\Delta$.

sub-section 4B, will pay either type of individual $x_L + ½$. In order to receive pay commensurate with their productivity, Hs may signal via increased publications, and Ls may mimic Hs. The analysis is almost identical to that in Section 4 and need not be repeated. Now an L who signals with some level of $q = q' > ½$ will be offered $x_H + q'$ by a raider---in addition to receiving job satisfaction of S, and will be offered only his productivity, $x_L + q'$, by his employer. We again have the individual quitting only if $S \geq -m$. Hence, p_L and $\overline{S}_L$ are the same as before (eqs.(1) and (2)), and it is easy to show p_H and $\overline{S}_H$ are also the same (eqs.(3) and (4)).[16]

As before, the option value (of S) for an H = 3Δ/16. It can be shown the Riley outcome, $q' = q_R$, yields $q_R = \frac{1}{2}\left(1 + \frac{m+\Delta}{\Delta^{1/2}}\right) > 1/2$. Let q* (equal to ½) denote the level of publishing that maximizes productivity net of the cost of publishing, $\theta - q^2$, which, with $\theta = x + q$, also maximizes $q - q^2$. Clearly $q_R - (q_R)^2 < q^* - (q^*)^2$, or $q_R - q^* < (q_R)^2 - (q^*)^2$: with signaling, the addition to productivity is less than the addition to cost. However, depending on the values of m and Δ, it is possible the addition to productivity *plus* option value exceeds the addition to cost, so welfare *may* increase with signaling when b = 1.

With publications directly valued by universities, individuals who are successfully raided should continue to publish after a raid, but the apparent implication of this section is publishing would decline (to q = ½) after one's ability level, x, is revealed. However, suppose b exceeds one, so the value of q that maximizes $\theta - q^2/b^2$ for an H exceeds the value of q that maximizes $\theta - q^2$ for an L. Absent signaling, to hide Hs from raiders, a university again must set the same desired publication level for either type of individual.[17] Let q_H^* be the value of q that maximizes $\theta - q^2/b^2$, and q_L^* be the value of q that maximizes $\theta - q^2$. The university will set $q = q^+$. Presumably, q^+ will be chosen to reflect the university's mix of Hs and Ls, so $q_L^* < q^+ < q_H^*$.

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[16] An H who signals now quits only if $S \geq W_C - x_H - q'$, whereas before the condition was $S \geq W_C - x_H$, but now W_C is higher than before by the amount q', so p_H and $\overline{S}_H$ are the same as before.

[17] This may be accomplished by paying only for publications up to the desired level.

Now, the larger is b, the bigger the difference in the marginal cost of publishing between Hs and Ls, and the smaller is q_R. When the signal is productive, the net-productivity-maximizing value of the signal for the more able may deter the less able from mimicking the former types (Spence, 2002). In that case, the level of the signal will be max(q_R, q^*_H). If $q_R \leq q^*_H$, then an H will set q = q^*_H to signal, and will continue to publish at this level after moving to a raiding university. If $q_R > q^*_H$, an individual's publication rate will drop from q_R to q^*_H after being successfully raided, but, with $q^*_H > q^+$, will remain above the level for those who did not signal .[18]

8. Conclusion

In the model herein, a professor who signals productivity via publishing may receive an outside offer. If job satisfaction at a raider exceeds that at the professor's current university, there is a potential social benefit from signaling, so signaling may be socially desirable *without a direct social benefit from publishing*. It was also shown commitment to not make counteroffers lowers welfare by reducing the expected gain in job satisfaction from those who quit when raided. With option value equal to the probability one quits if raided multiplied by the conditional expected job satisfaction of a quitter, option value is higher the greater a professor's productivity. Thus, unlike the usual case, signaling may occur even if the marginal cost of signaling is independent of the productivity of professors.

Coupé *et al*. (forthcoming) find turnover in economics departments does not increase after a promotion, which they conclude implies promotions in academia are not used as a signal of ability to the market (Waldman, 1984). However, they admit some aspects of a professor's ability may still be unknown to the market (but known to the employer). The results in Coupé *et al*. on promotions are not inconsistent with those herein. Universities may desire publications *per se*, and also may use publications to signal dimensions of ability unobservable to the market. If promotions are based on publications, the

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[18] Faria and Monteiro (2005) suggest tenure and academic standards may result in faculty developing habits that have a lasting effect on their publication rates, which provides another reason one's publications might not drop after signaling and being hired elsewhere.

former may provide no additional information to the market regarding a professor's ability than is learned by observing publications.

Appendix

A general distribution for job satisfaction

Let S have a density f(S) on (-∞, ∞) with a c.d.f of F(S). Following the analysis in Section 4, p_L = 1 - F(-m), and p_H = 1 - F(W_C-x_H). Note F(W_C-x_H) > F(-m) for $W_C > x_L$. We then have option value---the probability of quitting times conditional expected satisfaction of a quitter---of $p_H \overline{S}_H$ and $p_L \overline{S}_L$:

$$p_H \overline{S}_H = \int_{W_C - x_H}^{\infty} Sf(S)dS, \tag{A1}$$

$$p_L \overline{S}_L = \int_{-m}^{\infty} Sf(S)dS, \tag{A2}$$

$$p_H \overline{S}_H - p_L \overline{S}_L = -\int_{-m}^{W_C - x_H} Sf(S)dS > 0,$$

provided $W_C < x_H$. (A3)

Thus, as argued in Section 4, option value is higher for Hs than for Ls for any continuous distribution of S. Following the analysis in Section 3, we have, when b = 1:

$$I_H - I_L = \overbrace{(p_H - p_L)x_H}^{1} + \overbrace{p_H \overline{S}_H - p_L \overline{S}_L}^{2} + \overbrace{(1 - p_H)(W_C - x_L)}^{3} . \tag{A4}$$

In eq.(A4), terms {2} and {3) are positive, and term {1} is negative. Thus, signaling does not necessarily occur if b =1.

Risk and option value

With S ~ uniformly on [-Δ,Δ], the variance of S, σ^2_S, equals $\Delta^2/3$. Thus, $d\Delta > 0 \Rightarrow d\sigma^2_S > 0$. The option value for a high productivity individual (an H) = 3Δ/16, so dΔ > 0 ⇒ option value increases. However, option value for a low productivity individual (an L) also is positively related to Δ, and, since the minimum level of publications (q_R) that deters an L from signaling is derived from the point where an L's net return from signaling = x_L, signaling cost for an H also increases in Δ. With option value for an H = 3Δ/16, and signaling cost for an H = $\frac{(m+\Delta)^2}{4\Delta b^2}$, the net social benefit from signaling (NSB, which can be negative) is then:

$$NSB = \frac{3\Delta}{16} - \frac{(m+\Delta)^2}{4\Delta b^2} \tag{A5}$$

We then have:

$$\frac{\partial \text{NSB}}{\partial \Delta} = \frac{3}{16} - \frac{\left(\Delta^2 - m^2\right)}{4b^2\Delta^2} . \qquad \text{(A6)}$$

The term after the minus sign in eq.(A6) is larger the smaller is m. Thus, the greatest chance $\frac{\partial \text{NSB}}{\partial \Delta}$ is negative occurs when $m \to \Delta/2$. When this occurs, $\frac{\partial \text{NSB}}{\partial \Delta} = \frac{3}{16}\left(1 - \frac{1}{b^2}\right)$, which is positive for b > 1 and zero for b = 1. Thus NSB is non-decreasing in the variance of S.

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