How Might Adam Smith Pay Professors Today?

by

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Abstract

Adam Smith's proposal for paying professors was intended to induce increased faculty knowledge. If students have imperfect information about what they learn, and universities can only imperfectly measure the input of faculty time in student learning, publications may be used to measure faculty knowledge. If professors' ability to publish is positively related to their ability to produce student learning, which universities can imperfectly measure, publications may be necessary to attract more able professors. Since research signals faculty knowledge, schools that do not value publications *per se* could require higher publication standards and pay higher wages than schools that value only publications.

1. Introduction.

Adam Smith criticized the quality of teaching in the (allegedly) great English universities (Rosenberg, 1979). Smith believed professorial pay should be based on student assessment of teaching quality (Rosen, 1987). When he taught at the University of Glasgow, professors were paid a fixed annual salary and also received fees collected by the faculty from students.[1] The objective in this paper is to consider pay schemes a university might use to induce professors to allocate their time to maximize a university's objective function that includes the level of student knowledge created. We consider a university's optimal choice of teaching and publication standards, how these choices are affected by a school's valuation of publications *per se* versus student learning, and what these choices imply regarding wages and time spent at work at different types of school. With Smith's critique in mind, several points are noteworthy.

First, although Smith endorsed the payment of fees by students to professors, this specific method of pay is not what is important. Currently, many universities base faculty pay raises on student evaluations, which can accomplish Smith's objective of tying faculty pay to student input. Making professors' pay sensitive to student assessment of teaching does not require the explicit payment of fees from students to faculty.[2]

Second, in Smith's time, education was basically a consumption good. In the US, from 1636 until the late nineteenth century, universities were small and supplied ministers and "gentlemen" with a moral education not related to careers (McCormick and Meiners, 1988). If a student simply wishes to learn Shakespeare or a foreign language, it is relatively easy for the student to determine how much has been learned.[3] Similarly, for narrow vocational education, it may not be difficult to test to see what students

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[1] At some point, a professor was entitled to a house that could be used to board students and earn additional income. The majority of Smith's income may have come from student fees and income from boarders. Smith's salary in 1764 was 44 pounds sterling. His annual income appears to have ranged from 150 to 300 pounds sterling, about 100 pounds of which came from fees, and, as much as 100 pounds of which came from boarders. See Scott (1937).

[2] Rosen (1987) argued education now reflects a complex bundling and certification problem, so there is no reason for the payment of fees by individuals to instructors. Also, he believed the real problem in British universities was the absence of competition. These reasons notwithstanding, faculty performance should be a function of the method by which they are paid, and, thus the extent to which student input determines faculty pay may be important.

[3] "When a young man goes to a fencing or a dancing school, he does not, indeed, always learn to fence or to dance well; but he seldom fails of learning to fence or dance" (Smith, 1976, p.764). One wonders if Smith read Benjamin Franklin, who, using the

have learned. For the broader learning generally obtained at modern universities, it may be more difficult for students to measure what they have learned and to accurately communicate this information to academic administrators.

Third, Smith was apparently not just concerned with what one might call *teaching*---communicating knowledge possessed by a professor. He seems to have been interested in the level of faculty knowledge, which shall be referred to herein as *scholarship*.[4] When Smith bemoaned the poor quality of teaching in English universities, he noted the low level of intellectual inquiry in those schools (Rosenberg, 1979). He believed schools with smaller endowments that depended on their reputations for subsistence were "...obliged to pay more attention to the current opinions of the world."[5] Further, Smith argued (regarding the faculty at well-endowed universities): "If the teacher happens to be a man of sense, it must be an unpleasant thing to him to be conscious, while he is lecturing his students, that he is either speaking or reading nonsense..."[6]

In the modern university, students and employers have incomplete knowledge of what students have learned. In order to ensure faculty maintain their level of knowledge (scholarship), universities that cannot directly observe scholarship may base faculty pay in part on peer evaluation of a measure of scholarship---publications. Diamond (1993) suggests university students are not capable of judging what or how they should be taught. Lazear (1976) argues publish or perish is a rational response to the inability to measure teaching. Paul and Rubin (1984) suggest publications signal faculty knowledge. Siow (1997) provides evidence more research serves as a signal of faculty quality and attracts more able students. Becker, Lindsay, and Grizzle (2003) demonstrate students pay more to attend schools in which faculty engage in research. The latter find more able students are more sensitive to academic quality; thus a higher level of publications at a school generates more able student applicants.

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pseudonym Silence Dogood, wrote in 1722 about Harvard: "where...they learn little more than how to carry themselves handsomely, and enter a Room genteely, (which might as well be acguir'd at a Dancing-School,)..."

[4] As defined in the American Heritage Dictionary (1991, p.1098), scholarship is the "knowledge resulting from study and research in a particular field."

[5] Smith, 1976, p.773.

[6] Smith, 1976, p.763.

Consider the evolution of North American universities as described by Siow (1998). Antebellum universities offered a liberal education with few electives and little specialization; teaching was all that mattered. Throughout the nineteenth century, there was a shift away from the classics towards science. Research-oriented universities were founded in the latter part of the century (John Hopkins in 1879, Clark in 1888, and the University of Chicago in 1891). State and land-grant universities emphasized practical and technical education and research. Given the changes in higher education since Adam Smith's era, and given Smith's concern with the level of professorial scholarship, one who supports Smith's critique of higher education might believe professorial pay should be based on student input, to the extent students can at least judge teaching in the narrow sense, and on peer-reviewed publications, which serve as a measure of scholarship.

Although, as discussed above, several authors have suggested publications may signal faculty knowledge or scholarship, none has considered a model in which professors spend time in both teaching and scholarship when both are inputs into student learning and scholarship is also required for publications. Thus, the focus of the rest of this paper is on a model of educational production when teaching is imperfectly measured, universities cannot directly observe scholarship, and publications may be used as a measure of scholarship.

The rest of the paper proceeds as follows. In Section 2, a model is developed in which both student learning and faculty publications are produced in universities (henceforth referred to as schools). In this model (used through Section 6), it is assumed schools can not measure (even imperfectly) whether students learn; schools <u>can</u> measure (imperfectly) the input of professors in teaching. To highlight differences between schools that emphasize either publications or student learning, in Section 3, schools are assumed to produce either publications or student learning *(research* or *teaching* schools), but not both. The case of either research or teaching schools is further examined in Section 4, where professors are assumed to differ in publication productivity. In Section 5, the choice between "piece rates" for publications and publication standards is considered. Professorial influence activity is introduced in Section 6. In Section 7, the possibility schools can measure (imperfectly) student learning is examined.

This case is extended in Section 8 by allowing those who are better in producing publications to also be better in producing student human capital. Concluding remarks are contained in Section 9.

2. A model in which schools value student learning and publications.

In this section, a simple model is developed in which a school employs professors to teach and to do research. Human capital of students, H, is produced using faculty time spent in the classroom, preparing lectures, etc. Such time is denoted by "t". The amount of student human capital produced also depends on the knowledge of professors, which is assumed to be a function of the time spent by professors in scholarship, y. A simple human capital production function is used:

$$H = \alpha t + (1-\alpha)y. \qquad (1)$$

The assumed human capital production function allows us to ignore complementarities between t and y; neither is necessary for some learning to take place, but, as long as $0 < \alpha < 1$, both will be used to produce H.[7] Schools value the amount of human capital produced and the number of publications by the faculty[8], q. Herein, H and q are joint products of y, the time spent by a professor in scholarship. For want of a better objective function, a school is assumed to be a profit-maximizing entity.[9] Let the number of students and faculty both be normalized to one, and the school's payment to a professor equal W. A school then wishes to maximize:

$$\delta H + \beta q - W. \qquad (2)$$

A increase in δ implies an increase in the value of student learning relative to publications; similarly an increase in β implies publications are valued more relative to student learning. Assume

[7] The initial level of faculty knowledge is suppressed. With the assumed human capital production function, one could argue the ability to produce some student human capital, even if y = 0, implies some initial level of faculty knowledge. Note, faculty knowledge depreciates fairly rapidly. McDowell (1982) finds a depreciation rate of about 13% for three year intervals, based on referencing patterns in economics journals. Presumably, for much of one's teaching career, some current faculty scholarship (which does not mean publication) is necessary for students to learn the accepted wisdom of a discipline. Lower depreciation rates were found by McDowell for other social sciences, with higher rates found for physical and biological sciences.

[8] 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.

[9] Hosios (2003) models a university run by scholars who (by majority rule) choose compensation and performance evaluation rules. He assumes scholars' ability is known. In order to deal herein with the information problem universities face when trying to judge what students have learned, it is more convenient to focus on university administrators choosing compensation schemes and performance standards.

publications are produced by the simple production function $q = by$, $b > 0$. Time spent by a professor in scholarship becomes relatively more important in producing publications than it is in student learning the larger are b and α. For now assume only one type of professor.[10]

Using teaching evaluations, peer review, and informal feedback, a school can imperfectly measure teaching. Forbes and Paul (1991) argue the widespread use of student evaluation of teaching is due to the ability of such instruments to measure "delivery". They argue students have a difficult time measuring faculty knowledge. In the context of the model herein, this argument suggests it is much easier for students to measure t than it is for them to measure H. Assume there is an imperfect measure of t, denoted by s, which shall be referred to as student evaluation, although, as suggested above, peer evaluations and other mechanisms may contribute to s. The following relationship is assumed:

$$s = \lambda t + (1-\lambda)z, \tag{3}$$

where $0 \leq \lambda \leq 1$ and z is some measure independent of t and H. Initially, z is assumed to be exogenous and, as demonstrated below, plays no significant role for now. Later we will consider the cases when a professor can affect z, and when there are exogenous differences in z among professors.

Since a school can not directly measure t or y, it can not base pay on either of these variables. However, t can be inferred from s, and y can be inferred from q, so a school can base pay on s and q. Ignoring more complicated pay schemes, and setting alternative professor earnings equal to zero, there are two basic methods a school can employ. First, it can set a standard for faculty in terms of an acceptable level of the number of publications and of the rating in student evaluations of teaching; call these levels Q and S, respectively. Alternatively, the school can pay per unit of q and s. For example, if W_q and W_s are the wage rates per unit of q and s respectively, then a professor's wage equals $W_q q + W_s s$. Although both methods yield similar results, if a school knows the cost function for professor effort, the second approach

[10]Additional time required to transform scholarship into publications is ignored. See the discussion in Section 8.

is more expensive because a professor earns rent on infra-marginal units of t and y. It is cheaper for a school to infer t and y, and then compensate a professor for the cost of effort.[11]

Let the cost of professor effort be given by C, $C = C(t,y)$. If $\frac{\partial^2 C}{\partial t \partial y} > 0$, then an increasing amount of time in one activity increases the marginal cost of the other activity. If, however, activities differ enough so an increase in the level of one has no effect on the marginal cost of the other,[12] then $\frac{\partial^2 C}{\partial t \partial y} = 0$. Either approach is reasonable, but the latter allows for less ambiguous results. Thus, assume $\frac{\partial^2 C}{\partial t \partial y} = 0$. Specifically, let $C = t^2 + y^2$.

A school infers t from S and y from Q:

$$t = \frac{S-(1-\lambda)z}{\lambda}, \tag{4}$$

$$y = \frac{Q}{b}. \tag{5}$$

Now a school maximizes $\{\delta H + \beta q - W\}$ subject to eqs.(1), (4), and (5), and $W = t^2 + y^2$. With a professor setting $q = Q$, the f.o.c. yield:

$$S = \frac{\lambda\alpha\delta}{2} + (1-\lambda)z, \tag{6}$$

$$Q = \frac{b}{2}\left[b\beta + (1-\alpha)\delta\right]. \tag{7}$$

Consider the effect of the six exogenous variables---z, λ, α, b, β, and δ---on a school's optimal choice of S and Q.

A change in the amount of "error" in evaluating teaching

[11] Chen and Ferris (1999) model a school that does not value publications *per se*, but uses publications as a standard for tenure in order to measure faculty human capital. However, pay is not based on publications, so there is no way to measure faculty knowledge post-tenure. They argue faculty do not like publication-based pay because of randomness in the publication process. However, they use a two-period model; in a multi-period model, randomness will be less important as good years cancel out bad ones. Herein, the tenure process is ignored, and the focus is on how pay can motivate faculty to continuously maintain their knowledge.

[12] If increasing time spent in either activity becomes tiresome, independent of the total time spent at work, t+y, then $\frac{\partial^2 C}{\partial t \partial y} = 0$.

An increase in z, given λ, implies more error[13] in the evaluation of teaching, s. We have: $\frac{\partial S}{\partial z} > 0$, and $\frac{\partial Q}{\partial z} = 0$. Since a school can infer t from s, and pays a wage that simply compensates for the effort cost of teaching and scholarship, there is no cost to a school from a higher value of z. To offset an increase in z, a school simply raises S, keeping t unchanged (see below). Since a larger value of z does not change the optimal (to a school) level of t, it is not surprising the optimal publication standard is also unaffected by z.

A change in the accuracy of evaluating teaching

If λ increases, the evaluation of teaching is more accurate. We have: $\frac{\partial Q}{\partial \lambda} = 0$, and $\frac{\partial S}{\partial \lambda} = \frac{\alpha\delta}{2} - z \lesseqgtr 0$. A change in λ has no impact on the optimal publication standard, and it has an uncertain impact on the optimal teaching standard. The first effect of an increase in λ on S is a larger weight for t in s implies S is more valuable. However, a lower weight for z in s means a smaller S is required to induce a given value of t.

A change in the weight of teaching vs. scholarship in human capital production

If α increases, teaching becomes more valuable relative to scholarship in student learning. Not surprisingly, a larger α implies a higher teaching standard and a lower standard for publications: $\frac{\partial S}{\partial \alpha} > 0$, and $\frac{\partial Q}{\partial \alpha} < 0$.

A change in the marginal product of scholarship in publication

An increase in b means the marginal product of scholarship (y) in publications is higher. This should have no impact on the teaching standard, but should induce a school to raise the publication

[13]Again, z is not an "error" in the sense of a random variable; it is constant and---for now---exogenous and identical for all professors.

standard since a larger b implies less scholarship is required to produce any level of publications. Indeed: $\frac{\partial S}{\partial b} = 0$, and $\frac{\partial Q}{\partial b} > 0$.

A change in the relative value of student learning vs. publications

If β increases, the value of publications to a school increases relative to the value of student learning; there is no change in the teaching standard, and the publication standard increases. If δ increases, the value of student learning increases relative to the value of publications, and S and Q both increase since the time faculty spend in both teaching and scholarship are more valuable.

The level of time spent in teaching and scholarship

Using eqs.(4) - (7), we have:

$$t = \frac{\alpha\delta}{2}, \tag{8}$$

$$y = \frac{1}{2}\left[b\beta + (1-\alpha)\delta\right]. \tag{9}$$

Clearly, t is positively related to α and δ. Also, y is positively related to b and δ, and is negatively related to α. The total time spent on teaching and research, $t+y \equiv \tau$, is:

$$\tau = \frac{1}{2}\left[b\beta + \delta\right]. \tag{10}$$

For simplicity, normalize total time available to one. Thus, for a professor to not spend all available time at work, $\tau < 1$, or $b\beta + \delta < 2$, which is assumed to be true in the rest of the paper.

3. Teaching and research schools.

Consider schools that face different prices for teaching and publications, possibly because they attract different types of students. In order to illuminate differences in behavior between schools with different emphases on student learning and publications, suppose a *teaching* school has β = 0 and δ = 1, and a *research* school has β = 1 and δ = 0. Thus, the market values the production of one unit of student human capital at a teaching school by the same amount it values one unit of publications at a research school---one dollar. For now suppose there is one type of professor. In the next section, professors will be allowed to differ in their ability to produce research.

A research school will maximize $\{q-W_{res}\}$, with W_{res} the wage paid. With no teaching, the school must compensate professors for the time spent in scholarship, so $W_{res} = y^2 = \frac{q^2}{b^2}$. A research school maximizes $\left\{q - \frac{q^2}{b^2}\right\}$ with respect to Q_{res}, subject to $q = Q_{res}$, so:

$$Q_{res} = \min\left(\frac{b^2}{2}, b\right). \tag{11}$$

If $b \leq 2$, $Q_{res} = \frac{b^2}{2}$. If $b > 2$, $Q_{res} = b$ since this entails a corner solution with $y = 1$. Note $y = \min\left(\frac{b}{2},1\right)$ for a research school. With $\beta = 1$ and $\delta = 0$ for a research school, the assumption earlier $bB + \delta < 2$ now requires $b < 2$; thus $y = \frac{b}{2}$ and $W_{res} = \frac{b^2}{4}$. The results for a teaching school are identical to those in Section 2 with $\beta = 0$ and $\delta = 1$. Using eqs.(6) and (7):

$$S_{teach} = \frac{\lambda\alpha}{2} + (1-\lambda)z, \tag{12}$$

$$Q_{teach} = \frac{b}{2}(1-\alpha). \tag{13}$$

From eqs.(8) and (9), a teaching school has $t = \frac{\alpha}{2}$ and $y = \frac{(1-\alpha)}{2}$, so $\tau_{teach} = ½$ and $\tau_{res} = y_{res} = \frac{b}{2}$. For research schools to require a greater time input from faculty than teaching schools, b (the marginal product of scholarship in publications) has to exceed one---the marginal value of a unit of human capital.

Finally, note $Q_{res} > Q_{teach}$ only if $b > 1-\alpha$: the publication standard at a research school exceeds that at a teaching school only if the marginal product of a professor’s scholarship in publications at a research school exceeds the marginal value of scholarship in producing student human capital at a teaching school.

4. Different types of professors.

If professors differ in relevant characteristics, they may sort between schools that place different emphasis on teaching and publications. As in the previous section, suppose research schools have β equal to one and δ equal to zero, and teaching schools have β equal to zero and δ equal to one. Two types of professors are assumed. Type One professors (T1s) have $b = b_1$, and Type Twos (T2s) have $b = b_2 < b_1$. If a teaching school could sort individual professors by type, it would be indifferent to hiring either type. Relative to hiring T2s, if it hired T1s, a teaching school would simply raise the publication standard to obtain the desired level of scholarship. It could obtain the same scholarship and pay the same wage, but with different publication standards, hiring either all T1s or all T2s.

A research school prefers to hire T1s because such a school is interested in publications and not scholarship *per se*. If T1s are relatively scarce, research schools will bid for them, T1s will collect all of the schools' rent, and W_{res} will equal $\frac{b_1^2}{2}$. A more interesting (and possibly more plausible) case is when T1s are relatively abundant, so some of them work at teaching schools. Now the wage at research schools will equal an amount to compensate T1s for their effort, $\frac{b_1^2}{4}$, plus an amount equal to the rent a T1 could earn at a teaching school. Before determining the extent of such rent, if the wage at research schools is bid up in order to compete with teaching schools, it is possible T2s may wish to apply to research schools. To reduce the possible cases to be considered, suppose:

$$Q_{res} = \frac{b_1^2}{2} > b_2 . \tag{14}$$

Thus, a T2 who set y equal to one could not reach the publication standard at a research school, and would not apply to such a school.

Now, unless teaching schools can identify a professor's type, such schools will attract both T1s and T2s. Let f equal the fraction of T1s on a faculty at a teaching school. If a teaching school sets a publication standard Q_{teach}, it will induce an average level of scholarship equal to $\bar{y}$:

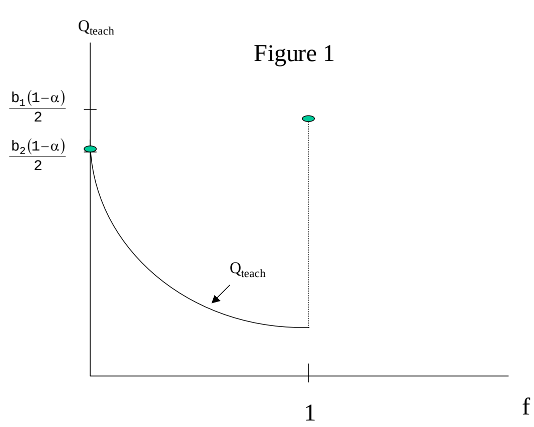
$$\bar{y} = \frac{(1-f)Q_{teach}}{b_2} + \frac{fQ_{teach}}{b_1}. \tag{15}$$

Both types of professors will spend the same amount of time in teaching to obtain the level of S set by a teaching school. However, T2s must use more time in scholarship to produce a given level of publications than T1s, so the former are the marginal job applicants. Unless there are enough T1s to satisfy demand at teaching schools, W_{teach} must compensate T2s for both t and y. Since T1s use less y than T2s to obtain any Q, the former earn rent at teaching schools. Also, if $0 < f < 1$, teaching schools prefer f to be as small as possible (that is prefer hiring T2s to T1s), since such schools desire as high a y as possible, given the wage they pay, and are not interested in publications *per se*. With $W_{teach} = t^2 + y_2^2$, and $\bar{y}$ given by eq.(15), a teaching school that maximizes {H-W_{teach}} chooses S_{teach} as found in eq.(12). A teaching school chooses Q_{teach} optimally by maximizing {H-W_{teach}}, given $H = \alpha t + (1-\alpha)\bar{y}$ and $W_{teach} = t^2 + \frac{Q_{teach}^2}{b_2^2}$, which yields:

$$Q_{teach} = \frac{b_2^2}{2}(1-\alpha)\left[\frac{(1-f)}{b_2} + \frac{f}{b_1}\right]. \tag{16}$$

Note eq.(16) only holds for $f < 1$. If $f = 1$, T1s are the marginal labor suppliers, and a teaching school sets Q_{teach} and W_{teach} to attract them. If $f = 1$, $Q_{teach} = \frac{b_1(1-\alpha)}{2}$. If $f = 0$, $Q_{teach} = \frac{b_2(1-\alpha)}{2}$. For $f < 1$, $\frac{\partial Q_{teach}}{\partial f} < 0$ (Figure 1).

Figure 1



As f increases, the marginal benefit of increasing Q_{teach} is reduced. With a larger fraction of T1s (who use less y to produce any Q_{teach}), there is a smaller increase in $\bar{y}$ associated with an increase in Q_{teach}, but a school must set the wage to compensate the marginal professors, T2s, even though these individuals are a smaller percentage of the faculty as f increases. However, if f = 1, a school only must set Q_{teach} and W_{teach} to induce effort from and attract T1s.

Although it may seem strange an increase in the fraction of more able publishers would *reduce* the publication standard, the reasons for this result are simple. First, this is not a problem in which a school optimally chooses a larger percentage faculty who are more able publishers. Herein, an increase in f is a constraint for a school. Second, teaching schools are assumed to place no value on publications *per se*. Third, publication productivity and the ability to produce student learning are independent. In Section 8, we consider the case when those who are more productive in publications also are more valuable in producing student learning.

Which type of school sets the higher publication standard?

Could teaching schools---which hire those who are, on average, less productive in publications if f < 1---set a higher research standard than that set by research schools? Since $\frac{\partial Q_{teach}}{\partial f} < 0$ for f < 1, consider the possibilities when f equals either zero or one, recalling $Q_{res} = \frac{b_1^2}{2}$. If f = 0, $Q_{res} > Q_{teach}$ if $b_1^2 > (1-\alpha)b_2$, which clearly holds if $b_1 \geq 1-\alpha$. Also, the condition for no T2s to apply to research schools (ineq.(14)) implies $b_1^2 > 2b_2$, so, this condition ensures $Q_{res} > Q_{teach}$ when f = 0, and this holds *a fortiari* for all f < 1. If f = 1, $Q_{res} > Q_{teach}$ if $b_1 > 1-\alpha$, the logic of which result was explained at the end of Section 3. Thus, assuming the condition for no T2s to apply to a research school holds, unless teaching schools attract only the same type of professors as research schools, the former will set a lower publication standard than the latter,[14] and, if $b_1 > 1-\alpha$, research schools set a higher publication standard than teaching schools regardless of the value of f, and independent of the condition for no T2s to apply to research schools.

Time inputs at different schools

Using eqs.(12) and (16), at a teaching school:

$$t = \frac{\alpha}{2}, \tag{17}$$

$$y_1 = \frac{b_2^2(1-\alpha)}{2b_1}\left(\frac{1-f}{b_2} + \frac{f}{b_1}\right), \tag{18}$$

$$y_2 = \frac{b_2(1-\alpha)}{2}\left(\frac{1-f}{b_2} + \frac{f}{b_1}\right). \tag{19}$$

At research schools, $t = 0$, and $y = \frac{b_1}{2}$. With $y_2 > y_1$, T2s spend more time on the job at teaching schools than T1s. T2s at teaching schools spend less time on the job than T1s at research schools if:

$$\alpha + (1-\alpha)\left(1 - f + f\,\frac{b_2}{b_1}\right) < b_1. \tag{20}$$

Note the LHS of ineq.(20) is inversely related to f. Thus, the greatest chance ineq.(20) would <u>not</u> hold---and T2s at teaching schools would spend more time at work than T1s at research schools---is when $f = 0$. If $f \rightarrow 0$, the LHS of ineq.(20)$\rightarrow 1$, so, again, $b_1 > 1$ is required for time on the job at research schools to exceed that at teaching schools. The condition $b_1 > 1$ implies the *marginal product* of scholarship in publications exceeds the *marginal value* of a unit of student learning, H; only if $b_1 < 1$ would faculty at teaching schools spend more time on the job than the faculty at research schools.

Wages at different schools

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[14] Of course, this result depends on the assumption a research school values an additional unit of publications by the same amount a teaching school values an additional unit of student human capital.

A teaching school pays a wage that just compensates a T2 for teaching and scholarship. This wage also just compensates a T1 for teaching, but implies rent for such an individual since a T1 uses less time to produce any Q than does a T2. The amount of this rent is given by:

$$rent = \left(\frac{Q_{teach}}{b_2}\right)^2 - \left(\frac{Q_{teach}}{b_1}\right)^2 = \frac{b_2^2(1-\alpha)^2}{4}\left(1-\frac{b_2^2}{b_1^2}\right)\left(\frac{1-f}{b_2}+\frac{f}{b_1}\right)^2. \tag{21}$$

Now, in order to attract a T1 to a research school, W_{res} must compensate a T1 for both the effort cost of producing publications, $\frac{b_1^2}{4}$, and the rent a T1 could earn at a teaching school. Since $\frac{\partial(rent)}{\partial f} < 0$, the more T1s who can not find employment in research schools and are employed in teaching schools ($df > 0$), the lower is W_{res}. We have:

$$W_{res} = \frac{1}{4}\left[\left(\frac{1-f}{b_2}+\frac{f}{b_1}\right)^2\left(1-\frac{b_2^2}{b_1^2}\right)b_2^2(1-\alpha)^2 + b_1^2\right]. \tag{22}$$

For a teaching school, $W_{teach} = t^2 + y_2^2$. Using eqs.(12), (15), and (16), we have:

$$W_{teach} = \frac{1}{4}\left[\left(\frac{1-f}{b_2}+\frac{f}{b_1}\right)^2 b_2^2(1-\alpha)^2 + \alpha^2\right]. \tag{23}$$

Note $\frac{\partial W_{teach}}{\partial f}$ and $\frac{\partial W_{res}}{\partial f}$ are both negative and $\left|\frac{\partial W_{teach}}{\partial f}\right| > \left|\frac{\partial W_{res}}{\partial f}\right|$, so a decrease in f increases W_{teach} more than W_{res}. Now $W_{res} > W_{teach}$ if:

$$b_1^2 - \left(\frac{1-f}{b_2}+\frac{f}{b_1}\right)^2 \frac{b_2^4}{b_1^2}(1-\alpha)^2 > \alpha^2. \tag{24}$$

The LHS of ineq.(24) is a positive function of f. To understate the possibility $W_{res} > W_{teach}$, evaluate ineq.(24) when $f = 0$. We have:

$$b_1^4 > \alpha^2 b_1^2 + (1-\alpha)^2 b_2^2. \tag{24'}$$

Clearly ineq.(24') holds if $b_1 \geq 1$. Otherwise, it is possible teaching schools pay more than research schools, but this requires $b_1 < 1$, and is more likely the larger is b_2, given b_1. Thus, if the difference between professor types in the marginal product of scholarship in publications is small enough---so rent for the more able publishers at teaching schools (and thus the wage for these individuals at research schools) is small enough---it is possible teaching schools pay more than research schools.

From ineq.(14), $b_2 < \frac{b_1^2}{2}$ for T2s not to apply to research schools. Since a larger value for b_2 implies the smallest possibility $W_{res} > W_{teach}$, suppose $b_2 = \frac{b_1^2}{2}$. Then ineq.(24') becomes:

$$b_1^2 > \frac{\alpha^2}{1 - \frac{(1-\alpha)^2}{4}}. \tag{24''}$$

Ineq.(24") illustrates what is sufficient for $W_{res} > W_{teach}$ if b_2 is as large and f is as small as possible. If, for example, $\alpha = .5$, so teaching and faculty scholarship have equal value in student human capital production, $W_{res} > W_{teach}$ if $b_1 > .516$. If $\alpha = .75$, b_1 must exceed .756 in order for W_{res} to exceed W_{teach}. If $\alpha = .25$, b_1 must exceed .27 for $W_{res} > W_{teach}$. Thus, as a rough approximation, a sufficient condition for research schools to pay a higher wage than teaching schools is the marginal product of scholarship in publications at research schools, b_1, exceeds the marginal value of teaching in human capital production at teaching schools, α. Combined with our earlier results---research schools set higher publication standards than teaching schools with two types of professors---elite undergraduate institutions (those with a high value for α) that would fit our definition of a teaching school might pay high salaries relative to research schools and base pay in part on publications, even though they place little or no value on publications *per se*.

Profit at research schools

If somehow teaching schools could sort out T1s from T2s, they would hire only one type of professor. If only T1s were hired, they would earn no rent at teaching schools. Thus, as shown before, a research school would pay a wage equal to $\frac{b_1^2}{4}$, and have Q equal to $\frac{b_1^2}{2}$, and profit equal to $\frac{b_1^2}{4}$. With T1s mixed with T2s at teaching schools ($0 < f < 1$), research schools must pay a wage that reflects the rent earned by T1s at teaching schools. It has not been demonstrated it is profitable for a research school to operate when it must compensate its faculty for the rent they could earn at a teaching school. Using eq.(22) profit at a research school is:

$$\pi_{res} = \frac{1}{4}\left[b_1^2 - b_2^2\left(1-\frac{b_2^2}{b_1^2}\right)\left(\frac{1-f}{b_2}+\frac{f}{b_1}\right)^2(1-\alpha)^2\right]. \tag{25}$$

Since π_{res} is positively related to both f and α, if $\pi_{res}|_{f=\alpha=0} \geq 0$, then $\pi_{res} \geq 0$ for all values of f and α. We have:

$$\pi_{res}|_{f=\alpha=0} = \frac{1}{4}\left[b_1^2 - \left(1-\frac{b_2^2}{b_1^2}\right)\right]. \tag{25'}$$

If $b_1 \geq 1$, $\pi_{res}|_{f=\alpha=0} \geq 0$. In general, if $b_2 = \gamma b_1$, with $\gamma < 1$, $\pi_{res}|_{f=\alpha=0} \geq 0$ if $b_1^2 + \gamma^2 \geq 1$. A larger value for γ implies a smaller gap between b_1 and b_2, which, as shown above, means a lower W_{res} due to less rent for T1s at teaching schools.

5. Will teaching schools use "piece rates" for research?[15]

In Section 2, it was argued paying a "piece rate"---a per unit payment for s and q---was dominated by requiring a standard for s and q and compensating professors for the effort required to reach those standards. Paying a piece rate for either s or q implies infra-marginal rent for professors. However, that argument applied to the case when only one type of professor was employed at a school. In the last section, teaching schools employed two types of professors, T1 and T2. In that case, T1s earned rent with a publication standard. Compensation for teaching effort was just sufficient to cover the effort cost for either type of professor. The question considered now is whether a piece rate for publications could dominate a publication standard when two types of professors are employed at a teaching school.

[15] Since, by assumption (ineq.(14)), research schools only attract one type of professor (T1s), for those schools, a piece rate is dominated by a publication standard, as explained in Section 3.

It is easy to show the teaching standard will be the same as before (eq.(12)). Using eqs.(12), (15), and (16), and the fact $y_1 = \frac{q}{b_1}$, and $y_2 = \frac{q}{b_2}$, a teaching school's optimal choice of S and Q yields t, y_1, y_2, and $\pi_{\mathtt{teach}}\big|_{S,Q}$:

$$t = \frac{\alpha}{2}, \tag{26}$$

$$y_1 = \frac{b_2^2(1-\alpha)}{2b_1}\left(\frac{1-f}{b_2} + \frac{f}{b_1}\right), \tag{27}$$

$$y_2 = \frac{b_2(1-\alpha)}{2}\left(\frac{1-f}{b_2} + \frac{f}{b_1}\right), \tag{28}$$

$$\pi_{\text{teach}}\big|_{S,Q} = \frac{1}{4}\left[\alpha^2 + (1-\alpha)^2 b_2^2\left(\frac{1-f}{b_2} + \frac{f}{b_1}\right)^2\right]. \tag{29}$$

A teaching school using a piece rate for q will set the same level of S as it would using a performance standard for publications (eq.(12)), which results in $t = \frac{\alpha}{2}$. With W_q paid per publication, a professor of type "j", j =1,2, will choose y_j to maximize $\{W_q b_j y_j - y_j^2\}$, so $q_j = \frac{W_q b_j^2}{2}$, and $\bar{y} = \frac{W_q}{2}\left[f b_1 + (1-f) b_2\right]$. Maximizing $\pi_{\text{teach}}\big|_{S,W_q}$ with respect to W_q yields:

$$W_q = \frac{(1-\alpha)}{2}\frac{\left[f b_1 + (1-f) b_2\right]}{\left[f b_1^2 + (1-f) b_2^2\right]}, \tag{30}$$

$$\pi_{\text{teach}}\big|_{S,W_q} = \frac{1}{4}\left\{\alpha^2 + \frac{(1-\alpha)^2}{2}\frac{\left[f b_1 + (1-f) b_2\right]^2}{\left[f b_1^2 + (1-f) b_2^2\right]}\right\}. \tag{31}$$

Using eqs.(29) and (31), $\pi_{\mathtt{teach}}\big|_{S,Q} < \pi_{\mathtt{teach}}\big|_{S,W_q}$ if:

$$2b_2^2\left(\frac{1-f}{b_2} + \frac{f}{b_1}\right)^2 < \frac{\left[(1-f) b_2 + f b_1\right]^2}{\left[(1-f) b_2^2 + f b_1^2\right]}. \tag{32}$$

If there are few T1s at teaching schools, paying a piece rate is less likely to dominate a publication standard. If f = 0, ineq.(32) becomes 2 < 1, so a piece rate is not more profitable than a publication standard. If f$\rightarrow$1, the LHS of ineq.(32)$\rightarrow \frac{2b_2^2}{b_1^2}$, and the RHS of ineq.(32)$\rightarrow$1. If $b_1^2 > 2b_2^2$, paying a piece rate dominates a publication standard.[16] From ineq.(14), $b_1^2 > 2b_2$ for no T2s to apply to research schools. Thus, if $b_2 \leq 1$, ineq.(32) holds, and a piece rate dominates a publication standard with a large enough fraction of T1s at teaching schools.[17] However, if $b_2 > 1$, it is possible to have ineq.(14) hold---so no T2s apply to research schools---and not have ineq.(32) hold---so piece rates would not dominate a publication standard at teaching schools regardless of the fraction of T1s at teaching schools.[18] A larger value of b_2, given b_1, implies less rent for T1s at teaching schools when the publication standard is used, and thus less likelihood a piece rate is more profitable than a publication standard.

6. Professorial influence activity.

As discussed in Section 1**,** Adam Smith believed basing faculty pay on student fees paid directly to professors would increase the likelihood faculty would engage in scholarship. However, there is a contradiction in Smith's discussion of this issue. At one point, he seems to suggest a professor can easily convince students the professor has suitable knowledge, even if it is not the case. "The slightest degree of knowledge and application will enable him to do this without exposing himself to contempt or derision, or saying anything that is really foolish, absurd, or ridiculous."[19]

It would appear Smith believed professors could engage in *influence activity*[20] in order to affect evaluations of them. Such activity makes evaluations less valuable, and thus merits consideration. In this

[16] If f = 1, only T1s are employed at teaching schools, b_2 is replaced with b_1 in ineq.(32), and the inequality does not hold: as suggested in Section 2, a publication standard dominates a piece rate. For f < 1, an increase in f makes it more likely a piece rate dominates a publication standard.

[17] See the Appendix for a more complete proof of this argument.

[18] For example, if $b_2 = 2^{.5} = 1.414$ and $b_1 = 1.9$, $b_1^2 = 3.61$ and $2b_2 = 2.828$, so ineq.(14) holds, but $2b_2^2 = 4$, so a piece rate is dominated by a publication standard.

[19] Smith, 1976, p.763.

[20] Milgrom and Roberts (1988) were the first to analyze influence activity.

section, the possibility professors can convince students the former have provided more education than they actually have is considered.

Suppose there is one type of school, there is one type of professor, and $\beta = 0$. Thus publications have no direct value for schools. Let $z = z_0 + i$, where "i" represents faculty time in influence activity, $C = t^2 + \theta i^2 + y^2$, and $\theta < 1$. Influence activity is assumed to be less costly to a professor than either teaching or research. Now $s = \lambda t + (1-\lambda)(z_0+i)$, so $t = \frac{S-(1-\lambda)(z_0+i)}{\lambda}$. A professor will choose i to minimize $\{t^2 + \theta i^2\}$ subject to $t = t(i)$ from the previous sentence. This yields:

$$i = \frac{(1-\lambda)[S-(1-\lambda)z_0]}{\theta\lambda^2 + (1-\lambda)^2}, \tag{33}$$

$$t = \frac{\lambda\theta[S-(1-\lambda)z_0]}{\theta\lambda^2 + (1-\lambda)^2}. \tag{34}$$

Now $t > i$ only if $\theta > \frac{1-\lambda}{\lambda}$. If $\lambda \leq ½$, $\frac{1-\lambda}{\lambda} \geq 1$, so, with $\theta < 1$, we have $i > t$: if s, the evaluation of teaching is relatively inaccurate, so more weight is placed on z than on t, a professor will spend more time in influence activity than in teaching.

Maximizing profit, with the wage set to just induce professors to be willing to work here, we have $W = C = t^2+y^2+\theta i^2$. A school chooses S and Q, which, as before with one type of professor, implies $Q = \frac{b(1-\alpha)}{2}$. As in Section 2, $y = \frac{1-\alpha}{2}$. Deriving S optimally, and substituting in for t and i, we have:

$$S = \frac{\alpha[\theta\lambda^2 + (1-\lambda)^2]}{2\theta\lambda}, \tag{35}$$

$$t = \frac{\alpha}{2}, \tag{36}$$

$$i = \frac{\alpha(1-\lambda)}{2\theta\lambda}. \tag{37}$$

Both t and y are the same as if there were no influence activity---the case in Section 2 with

$\beta = 0$. With no influence activity, total time on the job, τ, equals ½. With influence activity, $\tau > ½$. If the evaluation of teaching is highly accurate ($\lambda \rightarrow 1$), then influence activity approaches zero.[21] The amount of time spent in influence activity is positively related to the weight for teaching in student human capital production (α), and is negatively related to the marginal cost of influence activity (reflected in θ) and the accuracy of the evaluation of teaching (λ).

Unless influence activity is so large the time constraint binds (see f.n.21), a school induces the same amount of teaching and scholarship it would have if there were no influence activity. However, influence activity is costly since, in order to attract professors, a school must compensate them for the effort they expend---including effort in influence activity.

7. Evaluations can measure (imprecisely) human capital.

To this point, it has been assumed imprecise evaluation of teaching was possible, but a school, using student teaching evaluations or other techniques, could not measure, even imperfectly, the amount of human capital produced. As discussed in Section 1, modern universities, in which a relatively broad set of skills is generally obtained, should find it easier to obtain some measure of professors' teaching input than to assess how much human capital has been obtained by students. However, for completeness, the possibility of imperfect measurement of human capital production at a school is considered in this section.

Consider the following case: there is one type of school and professor, $\beta = 0$, $\delta = 0$, and there is no influence activity. With $H = \alpha t + (1-\alpha)y$, the evaluation of the faculty now yields a measure s:

$$s = \psi H + (1-\psi)z = \psi\alpha t + \psi(1-\alpha)y + (1-\psi)z. \tag{38}$$

Suppose no publication standard is set by a school, but a teaching standard of S is imposed. Now a school knows a professor will minimize $C = t^2 + y^2$, subject to $s = S$. Solving S for y:

$$y = \frac{S - \psi\alpha t - (1-\psi)z}{\psi(1-\alpha)}. \tag{39}$$

[21] Note, with influence activity, $t+y+i \equiv \tau < 1$ if $\frac{\alpha(1-\lambda)}{\lambda} < \theta$. Thus, θ must be sufficiently large or the time constraint will bind.

A professor chooses t to minimize C, subject to eq.(39). This yields:

$$t = \frac{\alpha\left[S-(1-\psi)z\right]}{\psi\left[\alpha^2+(1-\alpha)^2\right]}, \tag{40}$$

$$y = \frac{(1-\alpha)\left[S-(1-\psi)z\right]}{\psi\left[\alpha^2+(1-\alpha)^2\right]}. \tag{41}$$

A school chooses S to maximize {H-W} subject to W = C and eqs.(40) and (41). This yields:

$$S = \frac{\psi}{2}\left[\alpha^2+(1-\alpha)^2\right]+(1-\psi)z. \tag{42}$$

Using eqs.(40)-(42), $t = \frac{\alpha}{2}$, and $y = \frac{1-\alpha}{2}$. Thus, when human capital produced at a school is capable of being measured, albeit imperfectly, without using a publication standard, a school is able to induce the levels of teaching and scholarship it could obtain when only teaching can be measured and a school has to use a publication standard. Without a direct value for publications ($\beta > 0$), schools would appear to have no reason to require publications when human capital production can be, even imperfectly, measured.

8. Better scholars produce more student human capital

The possibility professors differ in the ability to produce publications was considered in Sections 4 and 5 above. However, what has yet to be considered is the case when professors differ in ability as an input in student learning. Specifically, consider the possibility more able scholars are more valuable in the production of student learning. As George Stigler argued:

> A capable research scholar has a deeper knowledge than the non-scholar: one treats a subject with much more care if one’s thoughts are going to be published and reviewed by hawk-eyed colleagues. A research scholar in general has a higher level of energy than the non-scholar. Of course there are research scholars who are so magnificently incomprehensible and one-sided that in simple mercy to students they should be forbidden to enter a classroom. For ever such creature there are surely a dozen lazy, poorly informed non-research scholars. The correlation between teaching ability and research ability is imperfect but it is not negative.[22]

[22] Stigler, 1989, p.17.

Following Stigler's argument, suppose we again have two types of professors, T1s and T2s, where T1s have $b = b_1$ and T2s have $b = b_2$. Further, suppose $b_1 > 1$ and $b_2 = 1$. Also, as has been assumed before, let $\beta = 0$ (so publications have no direct value to a school) and $\delta = 1$. Now the human capital production function for students is assumed to be:

$$H_j = \alpha t_j + (1-\alpha) b_j y_j, \tag{43}$$

with j = 1, 2 indexing the type of professor.[23] Thus, with the same amount of time spent in scholarship, a T1 can produce more publications *and* more student knowledge than a T2. Now a school would prefer to hire T1s than T2s. Assuming, as in the previous section, $s = \psi H + (1-\psi)z$, if a school set a standard for teaching evaluation, S, a T1 could obtain such a standard with a smaller time input. Thus, a wage that just compensated T1s for their effort would not compensate T2s, so the latter would not apply. However, since T1s have a comparative advantage in publication and in the input of their knowledge in student learning, it may be the case T2s have a comparative advantage in convincing students the latter have learned. Thus let $z_2 > z_1$. Further, to reduce notation, suppose $z_1 = 0$.

Consider a school that could distinguish T1s from T2s. A T2 faced with a standard for evaluation of teaching, S, will minimize $\{t^2+y^2\}$ with respect to t, subject to y = y(t) (eq.(39) with $z = z_2$ and $b_2 = 1$). With $s = \psi H$ for a T1, using eq.(43), a T1 minimizes $\{t^2+y^2\}$ with respect to t, subject to:

$$y = \frac{S - \psi\alpha t}{\psi(1-\alpha) b_1}. \tag{44}$$

The cost-minimizing values of t and y for a T2 are found in eqs.(40) and (41) (with $z = z_2$), and lead to a school choosing S as in eq.(42) (again with $z = z_2$). As in the previous section, a T2 would set t equal to $\frac{\alpha}{2}$ and y equal to $\frac{1-\alpha}{2}$. A school hiring only T2s would have profit, π_2, of:

$$\pi_2 = \frac{1}{4}\left[\alpha^2 + (1-\alpha)^2\right]. \tag{45}$$

[23] The assumption a T1 has the same advantage over a T2 in producing student learning as in publications was made in order to reduce the number of possibilities to consider.

A school hiring only T1s will choose a profit-maximizing S, S_1 that leads to t_1, y_1, and π_1:

$$S_1 = \frac{\psi}{2}\left[\alpha^2 + (1-\alpha)^2 b_1^2\right], \tag{46}$$

$$t_1 = \frac{\alpha}{2}, \tag{47}$$

$$y_1 = \frac{(1-\alpha)b_1}{2}, \tag{48}$$

$$\pi_1 = \frac{1}{4}\left[\alpha^2 + (1-\alpha)^2 b_1^2\right]. \tag{49}$$

With $b_1 > 1$, $\pi_1 > \pi_2$: thus a school wishes to hire only T1s. It should also be clear a school prefers all T1s to some mixture of T1s and T2s. Consider whether T2s would earn rent if a school set S to just attract T1s (eq.(46)). For a T2, $s = \psi H + (1-\psi)z_2$ and $H = \alpha t + (1-\alpha)y$. Thus, with $S = S_1$:

$$t_2 = \frac{\alpha}{\psi\left[\alpha^2 + (1-\alpha)^2\right]}\left\{\frac{\psi}{2}\left[\alpha^2 + (1-\alpha)^2 b_1^2\right] - (1-\psi)z_2\right\}, \tag{50}$$

$$y_2 = \frac{(1-\alpha)}{\psi\left[\alpha^2 + (1-\alpha)^2\right]}\left\{\frac{\psi}{2}\left[\alpha^2 + (1-\alpha)^2 b_1^2\right] - (1-\psi)z_2\right\}. \tag{51}$$

Using eqs.(47) and (48), a school that wants to attract only T1s will set a wage, W_1, to just cover the effort cost of this type of professor:

$$W_1 = \frac{1}{4}\left[\alpha^2 + (1-\alpha)^2 b_1^2\right]. \tag{52}$$

If $W_1 > t_2^2 + y_2^2$, a T2 <u>will</u> apply to a school that sets $S = S_1$ with no publication standard. Using eqs.(50)-(52), a T2 will earn rent at a school with S_1 if:

$$\psi^2 J\left[\alpha^2 + (1-\alpha)^2\right] > 4\left[\frac{\psi}{2}J - (1-\psi)z_2\right]^2, \tag{53}$$

where $J \equiv \alpha^2 + (1-\alpha)^2 b_1^2$. Now ineq.(53) is not very intuitive. However, if $b_1 \to 1 = b_2$, ineq.(53) becomes $2z_2(1-\psi) > 0$. If T2s are identical to T1s in the ability to publish and produce student learning, but T2s have $z_2 > 0 = z_1$, then T2s can obtain a given evaluation standard, S, using less time in teaching and scholarship than T1s.[24]

Since ineq.(53) holds for low enough values for b_1, T2s may earn rent at a school that sets $S = S_1$. Suppose a school also sets a publication standard $Q = b_1y_1$. With y_1 found in eq.(48), this implies $Q = \frac{(1-\alpha)b_1^2}{2}$. With $b_2 = 1$, to satisfy this publication standard, a T2 would have to set $y_2 = \frac{(1-\alpha)b_1^2}{2}$. With $s = \psi H + (1-\psi)z_2$ for a T2, to produce S_1, $t_2 = \frac{\alpha}{2} - \frac{(1-\psi)z_2}{\alpha\psi}$. Now a T2 would <u>not</u> apply to a school with $S = S_1$ and $Q = \frac{(1-\alpha)b_1^2}{2}$ if $W_1 < t_2^2 + y_2^2$, which reduces to:

$$\frac{(1-\psi)z_2}{\psi}\left[1 - \frac{(1-\psi)z_2}{\alpha^2\psi}\right] < \frac{(1-\alpha)^2 b_1^2\left(b_1^2 - 1\right)}{4}. \tag{54}$$

In general, ineq.(54) <u>may</u> hold, and is more likely to hold the larger is b_1, and when the evaluation of teaching becomes more accurate.[25] Thus, even if the evaluation of teaching may reveal (imperfectly) the amount of human capital produced, if some professors are more productive in both publication and student learning, and others are more able to "fool" evaluators (have a larger value for z), a publication standard may be required to induce the latter types not to apply. Note this result does <u>not</u> require schools place any direct value on publications ($\beta = 0$).

Consider what may be required for ineq.(54) to hold. The left hand side (LHS) of ineq.(54) is maximized when $z_2 = \frac{\alpha^2\psi}{2(1-\psi)}$. In order to minimize the probability ineq. (54) holds and the publication standard $Q = \frac{(1-\alpha)b_1^2}{2}$ deters T2s from applying, substitute into ineq.(54) using $z_2 = \frac{\alpha^2\psi}{2(1-\psi)}$ and rearrange terms:

$$\frac{\alpha^2}{(1-\alpha)^2} < b_1^4 - b_1^2. \tag{54'}$$

[24] Using eqs.(47), (48), (50), and (51), if $b_1 \to 1$, $t_2 < t_1 = \frac{\alpha}{2}$, and $y_2 < y_1 = \frac{1-\alpha}{2}$ if $z_2 > 0$.

[25] If $\psi \to 1$, the LHS of ineq.(54)$\to 0$.

If teaching time is much more important than faculty scholarship in student learning, α is relatively large and ineq.(54') is less likely to hold. For example, if $\alpha = .9$, b_1 must exceed 1.88 for the inequality to hold, but, if $\alpha = .1$, b_1 must only exceed 1.05 for the inequality to hold. If 50% of student learning is from teaching time, so $\alpha = ½$, then b_1 must exceed 1.27 for the inequality to hold. In this case, T1s have to be about 27% more productive in publications and student learning than T2s in order for a school's desired publication standard for T1s to deter T2s from applying.[26]

If ineq.(54) does not hold, then a school would choose between pooling---hiring both T1s and T2s---and setting an even higher publication standard in order to induce T2s not to apply. The latter scenario implies T1s separate themselves from T2s via an excessive level of publications---the classic signaling result in Spence (1974).

Ignored herein is any additional time (beyond y) required to turn scholarship into publications. If such additional time is required, the wage would have to increase to compensate professors for their additional effort, which implies a publication standard would be less profitable for a school. However, if T1s have a comparative advantage in publication time, as they do in y, additional time required for publications would be more costly for T2s than T1s, suggesting a publication standard is even more likely to deter T2s from applying.

9. Conclusion

In this paper, a model was considered in which scholarly activity by faculty is an input in student learning and may be measured by publications. A number of results were derived, only a few of which will be summarized now. With two types of professors, unless teaching schools attract only the same types of professors as research schools, the former will set a lower publication standard than the latter. Additionally, as a rough approximation, a sufficient condition for research schools to pay a higher wage than teaching schools is the marginal product of scholarship in publications at the former must exceed the

[26] Suppose $\psi = \alpha = .5$. Then the value of z_2 that maximizes the LHS of ineq.(54) is .125. If $z_2 = .125$ and b_1 is slightly larger than 1.27, ineq.(53) holds: T2s *would* apply to a school that set S to just attract T1s and did *not* set a publication standard, but the publication standard $Q = \frac{(1-\alpha)b_1^2}{2}$ *would* deter T2s from applying.

marginal value of teaching in human capital production at the latter. Thus, allowing for differences in the marginal value of teaching in schools (that is, different αs), the model herein could explain why some elite undergraduate schools might pay relatively high salaries (because α is high for them) and require publications, even though they place little or no value on publications *per se*.

In general, publications may be desired directly and to measure the knowledge (scholarship) of the faculty. If a university can only measure teaching (*i.e.* the input of the faculty into student learning), publications may be used to measure faculty knowledge for a given type of professor attracted. If a university can imperfectly measure student learning, publications may be necessary to induce less able professors not to apply.

Adam Smith was concerned with the level of faculty scholarship. His proposal---direct payment of faculty by students---may have been sensible when education was essentially a consumption good, the value of which was fairly easy to observe by students. Today, given students and employers have incomplete knowledge of what the former have learned, pay based partially on peer-reviewed publications, in order to ensure faculty maintain their level of scholarship, and on student input, to the extent students can imperfectly judge either teaching in the narrow sense or what they have learned, may be optimal to accomplish Smith’s objectives.

Appendix

A piece rate versus a publication standard for teaching schools.

Using inequality (32), differentiate the left-hand side (LHS) and the right-hand side (RHS) with respect to f:

$$\frac{\partial \text{LHS}}{\partial \text{f}} = (\text{positive}\,\#1)\left(\frac{1}{b_1} - \frac{1}{b_2}\right) < 0, \tag{A1}$$

$$\frac{\partial \text{RHS}}{\partial \text{f}} = (\text{positive}\,\#2)\left((1-f)b_2^2 + fb_1^2 - b_1 b_2\right). \tag{A2}$$

Setting $\frac{\partial \text{RHS}}{\partial \text{f}} = 0$ yields:

$$f = \frac{b_1 b_2 - b_2^2}{b_1^2 - b_2^2} = \frac{b_2(b_1 - b_2)}{(b_1 + b_2)(b_1 - b_2)} = \frac{b_2}{b_1 + b_2}. \tag{A3}$$

The second (●) term in eq.(A2) equals zero for a maximum or minimum of the RHS. Now $\frac{\partial^2 \text{RHS}}{\partial f^2} = (\text{positive}\,\#2)(b_1^2 - b_2^2) > 0$. Thus, when $f = \frac{b_2}{b_1+b_2}$, the RHS is at a minimum, and, for $f > \frac{b_2}{b_1+b_2}$, the RHS is a positive function of f. When $\frac{b_2}{b_1+b_2} < f < 1$ (with $f < 1$ implying some T2s are employed at teaching schools), an increase in f lowers the LHS and raises the RHS of ineq.(32), implying a piece rate is more likely to dominate a publication standard.

References

Becker, Elizabeth, Lindsay, Cotton M., and Grizzle, Gary. "The Derived Demand for Faculty Research." *Managerial and Decision Economics* 24 (December 2003): 549-567.

Becker, William E., and Watts, Michael. "How Departments of Economics Evaluate Teaching." *American Economic Review* 89 (May 1999): 344-349.

Chen, Zhiqi, and Ferris, J. Stephen. "A Theory of Tenure for the Teaching University." *Australian Economic Papers* 38 (March 1999): 9-25.

Diamond, Arthur M., Jr. "Economic Explanations of the Behaviour of Universities and Scholars." *Journal of Economic Studies* 20 (No.4/5 1993): 107-133.

Dogood, Silence. "To the Author of the New England Courant." *The New-England Courant* (May 14, 1722).

Forbes, Shawn M., and Paul, Chris W. "Education, Publishing, and Academic Markets." *Financial Practice and Education* 1 (Spring 1991): 21-24.

Hosios, Arthur J. "On the Distribution of Scholars and Employment Practices (incl. Tenure)." Working paper, Department of Economics, University of Toronto, January 2003.

Lazear, Edward P. Review of *An Economic Theory of Learning*. *Journal of Political Economy* 84 (February 1976): 192-194.

McCormick, Robert E., and Meiners, Roger E. "University Governance: A Property Rights Perspective." *Journal of Law and Economics* 31 (October 1988): 423-442.

McDowell, John M. "Obsolescence of Knowledge and Career Publication Profiles: Some Evidence of Differences among Fields in Costs of Interrupted Careers." *American Economic Review* 72 (September 1982): 752-768.

Milgrom, Paul, and Roberts, John. "An Economic Approach to Influence Activities in Organizations." *American Journal of Sociology* 94 (Supplement 1988): S154-S179.

Paul, Chris W., and Rubin, Paul H. "Teaching and Research: the Human Capital Paradigm." *Journal of Economic Education* 15 (Spring 1984): 142-147.

Rosen, Sherwin. "Some Economics of Teaching." *Journal of Labor Economics* 5 (October 1987): 561-575.

Rosenberg, Nathan. "Adam Smith and Laissez-Faire Revisited." Chapter 2 in *Adam Smith and Modern Political Economy*, ed. by Gerald P. O'Driscoll, Jr. Ames: Iowa State University Press, 1979.

Scott, William Robert. *Adam Smith as Student and Professor*. Glasgow: Glasgow, Jackson, Son and Company, 1937.

Siow, Aloysius. "Some Evidence on the Signalling Role of Research in Academia." *Economics Letters* 54 (July 1997): 271-276.

_____. "Tenure and other Unusual Personnel Practices in Academia." *Journal of Law, Economics, and Organization* 14 (April 1998): 152-173.

Smith, Adam. *An Inquiry into the Nature and Causes of the Wealth of Nations*. Oxford: Clarendon Press, 1976.

Spence, Michael. *Market Signaling*. Cambridge: Harvard University Press, 1974.

Stigler, George J. "The Future of Higher Education: an Economic Perspective." Center for the Study of the Economy and the State working paper #56, University of Chicago, May 1989.