Royalty Sharing and Technology Licensing in Universities [1,2]

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Abstract

Using data for 102 U.S. universities, we show that royalty sharing arrangements (cash flow rights) vary substantially across universities and that they are largely unrelated to most observed university characteristics including faculty size, quality, research funding, technology mix of the faculty, and size of the technology licensing office. However, higher inventors' royalty shares are associated with higher licensing income at the university, controlling for other factors. The results suggest that monetary incentives from inventions have real effects in the university sector.

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1 Introduction

By the end of the 1990's, universities accounted for about 50 percent of all basic research in the U.S. (National Science Board, 2000). This academic research has had real effects on the economy by increasing the productivity of private sector R&D and the growth in total factor productivity (Jaffe, 1989; Adams, 1990; and Henderson, Jaffe and Trajtenberg, 1998). These benefits work through direct knowledge spillovers and the licensing of university-owned inventions to private firms. Technology licensing activity has grown dramatically in the past two decades.[1] Over the period 1982-2000, the number of U.S. patents grants to university inventors rose from 500 to almost 3,800. The number of licenses executed on university inventions grew more than three-fold during the last decade alone, from 1,278 to 4,362, and gross licensing revenues increased nearly seven-fold, from $186 million to $1.26 billion.

In the United States university intellectual property policies typically grant the university exclusive control rights over inventions. However, in all U.S. research universities the cash flow rights from licensing inventions are shared between the inventor and various parts of the university according to specified royalty sharing schedules. In this paper we first show that monetary incentives – in the form of royalty sharing arrangements – vary widely across universities in the U.S., yet surprisingly this variation does not appear to be related to observed university characteristics. We then use this variation to estimate the effect of royalty incentives on inventive output. We find that universities with higher royalty shares for inventors generate significantly higher levels of license income, controlling for a variety of other determinants, including university size, quality and R&D funding, This finding shows that intellectual property arrangements can have real effects in the university sector, and their design deserves more attention than they have thus far received.

Section 2 provides a detailed description of royalty sharing arrangements. Section 3 investigates the determinants of these arrangements. Section 4 shows that the variation in

[1] Part of this rapid growth in university innovation and licensing activity is due to the passage of the Bayh-Dole Act of 1980 (Patent and Trademarks Amendments Act, PL 965-17) which gave universities the right to patent and a mandate to license discoveries made with federally sponsored research to the private sector. By the year 2000, nearly all American research universities had established, or expanded, technology licensing offices and introduced explicit intellectual property policies and royalty sharing arrangements for academic scientists.

Empirical studies of technology transfer include Jensen and Thursby (2001), Thursby, Jensen and Thursby (2001), Thursby and Kemp (2002), and Siegel, Waldman and Link (2003).

royalty sharing rates is significantly related to technology licensing outcomes,controlling for other relevant factors. We close with some directions for future research.

2 Variation in Royalty Sharing Rates

In the United States, universities retain exclusive control rights (unless expressly waived) over the inventions generated by their faculty. When these university inventions are licensed, however, the income generated by the licenses is shared between faculty scientists and the university. We first analyze how these cash flow rights are distributed between inventors and the university and then investigate the determinants of these arrangements.

Information on royalty sharing arrangements was downloaded from the websites of individual technology licensing offices during the summer of 2001. We restricted the sample of universities to the 102 institutions for which we collected additional data from other sources needed for the empirical analysis (described below).

The intellectual property policies at the universities usually state that a percentage of the net income received by the university from licensing an invention is retained by the inventor and the rest is allocated to the inventor's lab, department and college and to the university administration. The criterion we use for identifying the inventor share is that the inventor must gain either cash flow rights or direct control rights over the income. Thus, when the university IP policy states that the share accruing to the lab was under the control of the inventor, we added it to the inventor's share, but otherwise we did not. We call this the inventor's "royalty share."[2]

The observed royalties shares were those in effect (and posted) in 2001. Because we will examine the effect of these royalties shares on inventive outcomes, we were concerned by our inability to identify any changes that might have occurred in these shares during the 1991-1999 period (when outcomes measures are available). We conducted an e-mail survey of the TLO's in the sample and found that, of the 53 TLO's that responded, 70 percent did not change their royalty distribution during 1991-1999. Thus, for most universities the royalty sharing rates remained unchanged during the sample period. In fact, in many cases the arrangements were

[2]Shares are computed out of *net income* after deducting direct licensing expenses from gross income. We also made an adjustment for the TLO's overhead rate, when it was reported.

set in the early 1980s and never changed. Only 16 universities reported a change in royalty shares during the 1991-1999 period.[3]

In 58 universities the inventor royalty share is a fixed percentage of the license income generated by an invention (we call these *linear* schedules). Interestingly, in the other 44 universities these royalty shares vary with the level of license income (*non-linear* schedules). Because the income intervals differ across universities, for these royalty schemes we divided the license income into seven intervals based on the most frequently observed structure (in US$): 0-10,000, 10,000-50,000, 50,000-100,000, 100,000-300,000, 300,000-0.5 million, 0.5-1.0 million, and over 1 million.

Table 1 presents the main features of the royalty data.

Table 1. Distribution of Inventor Royalty Shares (percent)

Income Interval	*Mean*	*25%*	*50%*	*75%*	*Min*	*Max*
Linear Schedules (No. universities=58)	41	33	40	50	21	65
0-10,000	53	43	50	50	20	100
10,000-50,000	45	40	50	50	20	93
50,000-100,000	42	33	44	50	20	85
100,000-300,000	35	29	33	40	20	85
300,000-500,000	33	25	30	40	20	85
500,000-1 million	32	25	30	35	20	85
Over 1 million	30	25	30	34	15	85
Nonlinear Schedules: Expected Royalty Share (No. universities=44)	51	42	49	49	20	97

The mean inventor's share is 41 percent among the 58 universities using linear royalty schedules, but there is substantial cross-sectional variation. About 25 percent of these universities have royalty shares lower than a third, while the top 25 percent have royalty shares larger than 50 percent. The royalty shares in the 44 universities with non-linear schedules display even larger cross-sectional variability within each license income interval. Thus, the observed royalty shares exhibit considerable variation across universities.

[3] But only 11 reported the old and new royalty sharing agreements. In these cases, we averaged their reported shares. In the remaining 5 universities, we used the shares reported in 2001.

Before we examine the determinants of this variation, we computed an "expected" royalty share for the non-linear royalty schedules by weighting the share in each income interval by the probability of observing license income in that interval. These probabilities were estimated non-parametrically from the distribution of license income per disclosure over all years in the AUTM sample. Let v_{it} denote license income per disclosure in university i in year t. There are 723 different values for v in the pooled sample. We first estimated the density $f(v_{it})$ by kernel methods at these values, and then computed an average royalty share for each value of v using the royalty schedule for each university, taking into account the varying marginal royalty rates. Letting $\bar{\alpha}(v)$ denote the average share, the expected royalty share is $\Sigma_v \bar{\alpha}(v)\widehat{f}(v)$.[4] When the royalty schedule is linear, the expected royalty rate is simply the reported (constant) share.

The distribution of license income per invention disclosure (not shown) is highly skewed to the right.[5] Nearly all of the weight is on the first two income intervals–50.2 percent in the 0-\$10,000 interval and 46.1 in the \$10,000-\$50,000 bracket. This feature shows that taking a simple average of all sharing rates in a nonlinear schedule would be inappropriate. In fact, for practical purposes a good approximation is simply to average the first two sharing rates. Using the kernel estimates, the 'expected royalty share' averages to 51 percent across universities (last row of Table 1), which is higher than the average royalty share in the universities having linear schedules.

Figure 1 shows the histogram and a kernel estimate of the distribution of the expected royalty share. Their variability across universities is quite remarkable.

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[4] For example, with three marginal rates

$$\overline{\alpha}(v) = \frac{\alpha_1 v}{v} I(0 \leq v \leq v_1) + \frac{\alpha_1 v_1 + \alpha_2 (v - v_1)}{v} I(v_1 < v \leq v_2) + \frac{\alpha_1 v_1 + \alpha_2 v_2 + \alpha_3 (v - v_2) I(v > v_2)}{v}$$

where $I(\cdot)$ is an indicator function.

[5] Such skewness is typical of distributions of the returns to innovation (Schankerman, 1998; Harhoff, Narin, Scherer and Vopel, 1999).

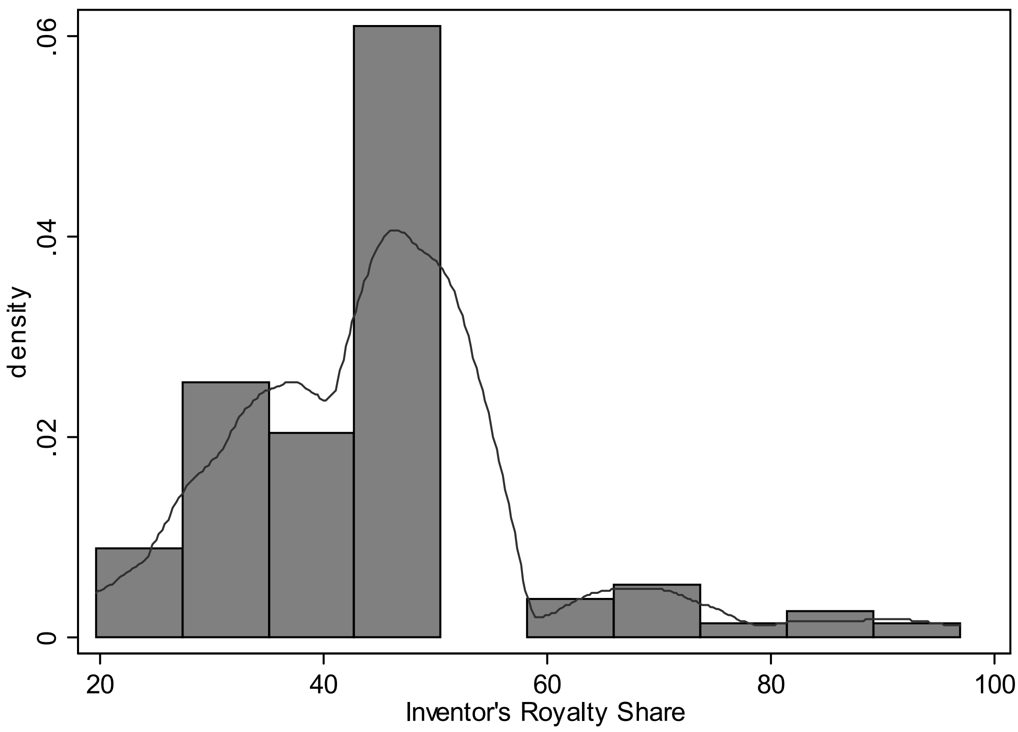

Figure 1: Distribution of expected inventor's royalty shares

Another striking feature in Table 1 is that inventor royalty shares are either constant or decline in the level of license income per invention– royalty retention is regressive (equivalently, the university 'tax' on inventors is progressive). On average, they start at 53 percent in the lowest interval and decline to 30 percent for inventions generating over $1 million. This feature holds in every quartile of the cross-sectional distribution and, in fact, it holds for *every* university in our sample.

We next relate the variation in expected royalty rates to university characteristics. We first describe the sources for this additional data. >From the Association of University Technology Managers (annual surveys), we obtained annual data for the period 1991-1999 on the number of inventions disclosed to the university TLO and total licensing income (there is no breakdown of this information by technology field), as well as R&D funding and the size and age of the TLO. We also have data for a single year (1993) on faculty size and on measures of university quality from the 1993 National Survey of Graduate Faculty, conducted by the National Research Council (NRC). We measure university size as the total number of faculty members in the doctoral programs in twenty-three fields of science. We aggregated these fields into six technology fields – biomedical and genetics, other biological sciences, computer science, chemical science (including chemical engineering), engineering, and physical sciences - and use the shares of faculty employed in each field to proxy for the research orientation of the university. We use three measures of university quality: a scholarly quality rating score between zero ("not sufficient for doctoral education") and five ("distinguished"), the number of publications per faculty, and the number of citations per faculty. The NRC reports these variables at the program level. For this analysis we aggregate them to the university level using faculty size weights.

Table 2 is a first attempt to relate the variation in expected royalty rates to university characteristics. We split the sample into two halves: large and small universities, high and low quality, etc. and computed the mean royalty share in each subsample.

Table 2. Inventor Royalty Shares (percent)
by University Characteristics

	Faculty size	*University quality index*	*Publications per faculty*	*Citations per faculty*	*TLO size*
Bottom half	47	46	46	45	46
Top half	44	44	44	45	44
p-value of t-test	0.24	0.38	0.49	0.87	0.53

It is interesting to note that royalty shares are not related to observed university characteristics such as faculty size, university quality, the number of publications and citations per faculty, and the size of the TLO office measured by the number of TLO professionals (averaged over 1991-99). Furthermore, the average share in private universities is 44 percent whereas in public universities it is slightly higher at 46 percent. Their difference is significant only at a 48 percent significance level or higher.

Table 2 shows that there is no significant correlation between royalty shares and a variety of university characteristics, taken individually. Of course partial correlations may be different. Table 3 present the results from regressing the royalty shares on the above characteristics and additional controls.

Table 3. Determinants of Inventor Royalty Shares

	dependent variable: expected royalty share ($\times100$)				
Constant	56.4*	54.3*	58.9*	57.4*	58.4*
	(10.7)	(10.7)	(9.94)	(13.2)	(13.3)
Faculty size('00s)	-0.23	-0.52	-0.77	-1.27	-0.61
	(.31)	(.40)	(.77)	(.86)	(.69)
Quality index	-2.59	-2.56	-3.24	-1.28	-0.98
	(2.28)	(3.67)	(2.06)	(2.45)	(2.33)
Private	-1.97	-1.16	-2.32	-3.18	-0.39
	(2.84)	(2.91)	(2.93)	(2.97)	(2.87)
Publications/fac	–	0.93	–	–	–
		(0.97)			
Citations/fac	–	-0.14	–	–	–
		(.08)			
Biomedical	2.40	0.28	1.94	0.21	-3.52
	(9.66)	(9.77)	(9.37)	(11.6)	(12.9)
Other Biological	-4.28	-6.42	-5.47	-4.83	-5.65
	(9.34)	(9.41)	(9.13)	(11.2)	(12.8)
Computer Science	56.7	54.1	56.1	50.1	53.4
	(41.6)	(38.1)	(40.9)	(42.1)	(39.7)
Chemical Science	-15.3	-17.9	-16.43	-16.1	-17.1
	(10.2)	(9.66)	(9.66)	(12.0)	(12.1)
Engineering	-13.9	-13.8	-15.20	-10.7	-14.6
	(13.6)	(13.2)	(12.9)	(15.5)	(15.2)
R&D	–	–	0.015	0.008	-0.007
			(.016)	(.016)	(.012)
TLO size	–	–	–	0.91	0.89**
				(.64)	(.52)
TLO age	–	–	–	-0.38*	-0.34*
				(.10)	(.11)
High-tech index					-0.93*
					(.47)
R^2	0.10	0.12	0.11	0.19	0.23
F-test: $p - value$	0.10	0.05	0.03	0.01	0.03
No. obs.	102	102	102	99	86

Notes: Heteroskedaticty-robust s.e. in parenthesis.* (resp. **) indicates significance at the 5% (resp. 10%) level. Technology field variables measure the percentage of faculty in each field. Physical sciences is the reference group. R&D denotes R&D funding from all sources (in millions). TLO size is the number of full-time equivalent (FTE) professionals in the TLO. To compute TLO age, the initial year is taken as the first year in which there is at least 0.5 FTE in the TLO. Variables are averaged for 1991-99.

In the first column the royalty share is regressed on the faculty size, the university scholarly quality index, a private ownership dummy, and the scientific composition of the faculty. No individual regressor is significant, and the p-value of the F-test for the overall regression is only 10 percent. Also note that the scientific composition of the faculty does not have a significant effect on inventor's shares. This is interesting, since academic scientists usually sit on the governance committees that set these rates. Adding additional measures of academic quality (column 2) or R&D funding (column 3) does not change the conclusions, even though it makes the overall regression more significant.[6]

There is some evidence that royalty shares are positively related to the TLO size, and negatively related to the age of the TLO. This is consistent with the hypothesis that universities that place greater emphasis on technology licensing (as indicated by the size of the TLO) also introduce more high powered incentives to their academic inventors. The negative correlation with TLO age may simply indicate that awareness of the need for such incentives has been growing over time, so younger TLO's tend to have higher royalty shares. Whatever the explanations, we should not put too much emphasis on this finding because the quantitative effects are very small. An increase in the TLO size of one full-time professional (about a 33 percent increase) is associated with a rise in the royalty share of less than one percentage point while a one-year increase in TLO age is associated with a decline in royalty share of a third of a percentage point.

Finally, we add a variable to control for differences in the value of outside options available locally to university scientists. If demand for licensing is localised, because of information or other factors, the value of outside options available to faculty is positively correlated with the level of high-tech activity in the local area. Universities located in more dense high-tech areas face stiffer competition from the private sector and may therefore allocate higher royalty shares to their faculty. We use the 1995 Milken index of high-tech activity for the area where the university is located (Friedman and Silberman, 2003). The index varies from zero to a maximum of 23.7 (for Stanford University). In doing so, we lose about 15 percent of the universities in the sample because they are located in areas where the index is not available. Royalty shares are negatively related to the Milken index of high-tech activity. Contrary to the conjecture, royalty shares are evidently *not set* in response to the value of outside options

[6]Publications and citation per faculty are jointly not significant in column 2.

available locally to university scientists.

We have shown that inventor royalty shares are essentially unrelated to key university characteristics. This negative conclusion is striking, and it raises the question of whether existing royalty distribution schemes have been set in any systematic way at all. Putting this aside, one may be tempted to conclude that these shares do not matter for academic innovation and technology licensing performance. Is royalty sharing a purely distributive matter, or does it have implications for performance? In the next section we exploit the cross-sectional variation in inventor royalty shares to identify their effect on licensing outcomes.

3 Do Royalty Sharing Rates Matter?

In Lach and Schankerman (2003) we develop a simple model in which scientists allocate effort to produce more research projects, to improve the quality of each project, and to other responsibilities (e.g., teaching). Scientists attach private value to royalty income, publications and teaching, and face shadow prices of different types of effort set by the university. The scientist may face trade-offs between producing publications and inventions that generate license income (i.e., there may be imperfect alignment between these two tasks). Under the assumption that the scientist's utility function is supermodular in the royalty share – i.e., her marginal utility of both types of research effort rises in that share – the model predicts that universities with a larger inventor royalty share should generate higher total license revenues, controlling for other relevant factors. In addition to affecting effort, a rise in the royalty sharing rate should attract more productive scientists. In short, the incentive effect can work both through raising effort and sorting.mechanisms.

To examine this prediction, let y be licensing income per faculty and α be the inventor royalty share. Since we showed that α is mostly unrelated to other observables we are arguably justified in examining the conditional expectation $E(y|\alpha)$, and interpreting this relationship as causal. The advantage of abstracting from other determinants of license income is that we can easily estimate $E(y|\alpha)$ non-parametrically, i.e., we can let the data determine the shape of the conditional expectation function, rather than imposing a linear or quadratic form. Figure 2 traces the estimated conditional expectation calculated using a Fan (1992) locally weighted regression smoother.

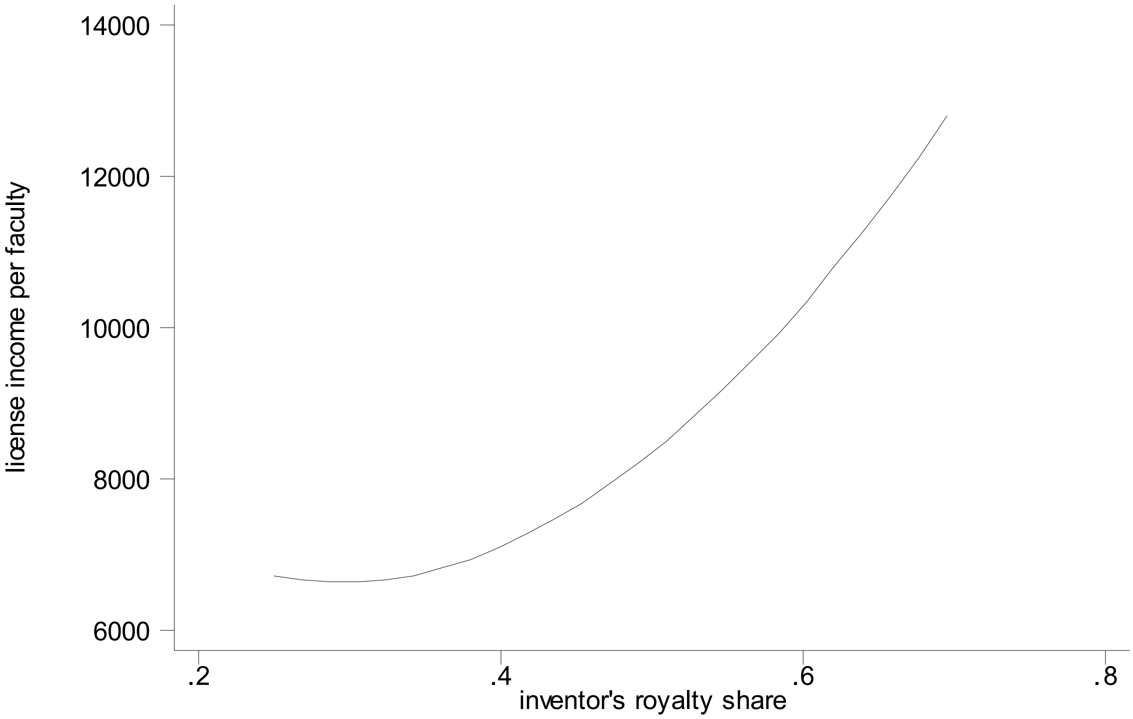

Figure 2: Expected license income per faculty given the royalty share

This relationship is clearly increasing and somewhat non-linear: although income is not very responsive to economic incentives at the low range of the royalty shares this is strikingly reversed at shares above 35-40 percent. From Table 1 we know that approximately 75 percent of the universities have expected royalty shares above 40 percent.

In order to get some quantitative assessment of this estimated relationship, as well as an idea of its precision, we estimated a loglinear model. We regressed log license income on the log of faculty size, the quality index, the log of R&D funding, the number of TLO professionals, the age of the TLO and on the scientific composition of the faculty (the same controls used in Table 3). Because identification of the inventor's royalty share effect is based on cross-sectional variation, we average the available time-series data (license income, TLO size, R&D) and estimate a simple cross-sectional model by OLS with robust standard errors.[7] Table 4 present the results.

[7] Four universities reported zero license income, and were exlcuded from the regressions.

Table 4. License Revenues and University Characteristics

dependent variable: log license income

Royalty share (×100)	0.023*	0.021*	0.024*
	(.011)	(.010)	(.012)
Log faculty size	0.92*	0.25	0.61*
	(.19)	(.30)	(.25)
Quality	0.64*	-0.15	-0.04
	(.28)	(.31)	(.30)
Private	0.22	0.52**	0.58**
	(.43)	(.31)	(.33)
Biomedical	-1.02	-0.76	0.12
	(1.23)	(1.36)	(1.31)
Other Biological	–0.70	-1.07	-0.25
	(.98)	(1.24)	(1.29)
Computer Science	0.20	0.03	1.42
	(2.46)	(2.68)	(2.64)
Chemical Science	-0.95	-1.17	-0.32
	(1.07)	(1.72)	(1.55)
Engineering	0.49	-0.35	0.05
	(1.07)	(1.42)	(1.43)
Log *R&D*	–	1.15*	0.64*
		(.38)	(.28)
TLO size	–	0.013	0.007
		(.021)	(.019)
TLO age	–	0.027*	0.040*
		(.008)	(.009)
High-tech index			0.071
			(.035)*
R^2	0.48	0.66	0.66
No. obs.	98	97	85

Notes: see notes to Table 3.

The royalty share coefficient is positive and significant. A 10 percentage point increase in the inventor's share should generate, on average, a 20-25 percent increase in license income. At the mean, the implied elasticity of license income with respect to royalty share is about unity. The elasticity of licence income with respect to faculty size is close to unity, but this effect is reduced significantly after accounting for the effects of R&D funding. Licensing revenue is larger for higher quality universities in the simple specification in column 1. However, the effect of university quality operates primarily by increasing the level of external (government and industrial) R&D funding (see column 2). The estimated coefficient on the private university dummy provides preliminary evidence that private universities are much more effective (50 percent, on the point estimate) at generating licensing income than public universities.[8]

In addition to R&D funding, we include the size and age of the TLO to account for differences in their effectiveness in licensing university inventions. Surprisingly, we do not find a significant effect of the number of TLO professionals, but there is a substantial return to TLO experience as measured by age. An additional year of experience translates into a 2.7 percent increase in license income. In column 3, we also add Milken's high-tech index to capture the demand side for licensing. The estimated incentive effect of royalty shares is robust to this additional control even though the sample changes (making the comparison of other estimates somewhat problematic).[9]

The parameter estimates in Table 4 imply that raising the inventor's royalty share would increase *total* license income. Denote total license income by R and the university's share by $(1-\alpha)R$. Then $\frac{d\log(1-\alpha)R}{d\alpha} = \frac{d\log R}{d\alpha} - \frac{1}{1-\alpha}$. Measuring the royalty shares as a fraction, the estimated change in *university* income is $2.1 - \frac{1}{1-\alpha}$, where α is the inventor's share and we use the estimate from column 2. This effect is positive for all universities with $\alpha < 0.52$. At these universities, there is a Laffer effect: lowering the 'tax rate' imposed by the university would actually generate higher university revenues from licensing its inventions.

There are two main, potential sources of bias in these regressions. The first is reverse causality: universities with low levels of license income may set higher inventor royalty shares to incentivise licensing. This implies a negative correlation between the error term and the royalty share, giving a *downward bias* in the estimated incentive effect. Thus this cannot explain away our central finding that royalty incentives matter. As shown in the previous section, they are almost unrelated to observable characteristics of the university. While this does not rule out correlation with unobservable characteristics, we expect any endogeneity bias to be relatively small because most royalty distribution schemes for universities in our sample were set before 1991.

[8] Adams and Griliches (1998) find that private universities produce more research output (publications and citations) per dollar of R&D.

[9] Of course, we recognise that some of these control variables may be endogenous – especially TLO size and the high technology density measure – so that their estimated coefficients may be picking up two-way causality.

The second source is a possible inventor reporting bias. A researcher has a choice between reporting the disclosure and sharing the license revenues with the university, or not reporting it and commercialising it outside (e.g., by forming a private start-up company). If misreporting error is uncorrelated with the royalty share, there is no bias in the estimated incentive effect. However, if high valued inventions are more likely to go unreported to the TLO, and if the rate of misreporting is negatively correlated with the royalty share, then our estimates would *overstate* the incentive effect of royalty sharing on license income. When the royalty share rises, part of the observed rise in license revenue would reflect inventors now reporting high-value inventions. With available data we cannot identify the size of this reporting effect but, because faculty have a contractual obligation to report invention disclosures to the TLO, it is unlikely that this bias is large enough to undo the estimated positive effect of royalty sharing rates on license income. Of course, both the incentive effect and the reporting effect of royalty shares are relevant to the university, since they jointly determine how much license income the university actually earns.

4 Concluding Remarks

University research is an important source of new technology and spillovers to the private sector. Yet not much is known about the forces driving academic research and technology licensing. In this paper we show that licensing income is significantly increased when the direct monetary rewards to the inventor, in the form of royalties, are raised. There are at least two important issues for future research. First, we would like to identify the extent to which this incentive effect works by inducing greater effort by scientists and through sorting of scientists across universities. Second, we provided preliminary evidence that private universities are more effective in licensing activity than their public counterparts. This issue warrants more attention, both to confirm the finding and to understand the underlying determinants of this difference.

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