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How do patent incentives affect university researchers?☆

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ABSTRACT

Universities and other beneficiaries of public funding for scientific research are encouraged to patent resulting inventions under the Bayh–Dole Act. This controversial framework gives academic grant recipients a direct financial stake in the success of their inventions by requiring universities to share the resulting patent royalties with inventors. This incentive for grant recipients might help justify Bayh–Dole patents when the conventional justification for exclusivity—that it is necessary for commercialization—fails to hold. But there is little evidence as to whether it works.

This article examines how one aspect of the patent incentive—the prospect of royalties—affects the behavior of university researchers. Fortuitously, different schools offer inventors different shares of patent revenue. We have created a dataset of royalty-sharing policies from 152 universities, which shows substantial variation across universities and time. (For example, Caltech switched from sharing 15 %–25 % of net income in 1994, the University of Washington switched from sharing 100 % of initial revenues to a flat rate of 33 % in 2004, and the University of Iowa switched from 25 % to 100 % of initial patent revenues in 2005.) Although prior work has reported that higher inventor royalties lead to more university licensing income, we show that this result was driven by coding errors. We also extend prior work by examining more years, doing a more convincing panel data analysis, using additional outcome variables, and looking at lateral moves by the most active patenters. In all of these analyses we find no compelling empirical evidence that increasing university inventors' royalty share has a significant effect on any of the outcomes one would expect to be most affected.

These results do not imply that patents provide no incentives to university researchers. They may provide reputational benefits or encourage faculty-run spin-offs, or even provide financial incentives that are not captured by our statistics. But the lack of a measurable impact of higher royalty shares on patenting activity suggests that, from a social welfare perspective, it may be preferable for a larger share of royalties to be retained by universities, which are then required by Bayh–Dole to reinvest this money in science research and education. In any event, our analysis raises promising questions for future research and calls into question the existing view that increasing the inventor's share in university patent policies encourages researchers to develop and commercialize more remunerative patents.

1. Introduction

Public research funding may be the most significant legal policy tool to promote innovation: direct U.S. research funding is larger than estimates of U.S. patent rents (Hemel and Ouellette, 2013). The National Science Foundation (2016) reports that scientific researchers at universities, other nonprofits, and government laboratories conduct over 75 % of all basic research and over 40 % of all applied research in the United States—the majority of which is funded by the federal government. In total, U.S. taxpayers provide over $100 billion in direct research funding each year—nearly one quarter of all U.S. research spending. This funding is a complement to the patent system, not a substitute. Under the Bayh–Dole Act of

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1980, institutions receiving federal research support can patent and license any resulting inventions, and the Stevenson–Wydler Act of 1980 sets similar rules for inventions at national laboratories.

The optimal allocation of intellectual property rights for government-funded researchers is a problem of substantial economic importance and global interest (Hvide and Jones, 2018; Czarnitzki et al., 2016; Azoulay et al., 2009; Jaffe et al., 2007). Proponents of the Bayh–Dole framework contend that academic patent licensing has created enormous economic benefits, including new life-saving products, hundreds of thousands of new jobs, and an increase of up to $30 billion per year in U.S. GDP (Pressman et al., 2017). But empirical support for the causal nature of these claims is thin, and Bayh–Dole's detractors contend that the significant costs that patents impose—including raising the price of knowledge goods for both consumers and follow-on innovators, many of whom already paid for the initial research through U.S. taxes—outweigh any benefits (for a review, see Ouellette and Weires (2020)).

Although the traditional justification for patents is that they increase ex ante incentives to create new inventions, the publicly funded researchers who might be influenced by these incentives have played only a small role in Bayh–Dole debates. Instead, as Eisenberg (1996) has explained, Bayh–Dole proponents "shift the focus from the initial costs of making an invention to the subsequent costs of developing an existing invention into a commercial product." Thus, the primary justification for Bayh–Dole patents today is that they encourage grant recipients to commercialize research results. But while this "commercialization theory" is convincing for some Bayh–Dole patents, it cannot support the Act's present scope. As we explain in Section 2, there are many inventions for which exclusivity is *not* necessary for commercialization. For such patents, it is particularly important to scrutinize other evidence of their benefits and costs—including the effect on the individual researchers who create the inventions in the first place.

Section 3 provides an overview of the economics of science and engineering research at universities.[2] We then draw from the qualitative and quantitative literature to develop an empirically grounded framework for understanding the effects of patent incentives on university researchers. This article focuses on whether there is rigorous evidence showing an incentive benefit from the *financial* effect of patent royalties, but as we explain, patents may have other effects on ex ante incentives that our analysis cannot capture. For example, patents might create an incentive benefit from the *reputational* effect of receiving credit for a novel idea. The patent incentive might also have *negative* incentive effects, such as a shift in research focus away from more socially valuable but unpatentable ideas. Survey work suggests that financial returns are a relatively small part of faculty incentives to patent, although surveys present the usual difficulties with self-reported motivations. Efforts to study the impact of Bayh–Dole on more quantitative metrics of university research suggest that patents are not substituting for publications or causing a marked shift in research focus, but it is difficult to disentangle the effect of Bayh–Dole's enactment from related trends in university research.

The most significant effort to isolate the effect of the financial incentive from patent royalties for individual researchers comes from economists Saul Lach and Mark Schankerman, who took advantage of variation in the royalty share provided to inventors at different universities (Lach and Schankerman, 2004, 2008). Universities are required under the Bayh–Dole Act to share some portion of patent income with inventors, but there is substantial variation in these royalty-sharing policies. Based on data from the 1990s, Lach and Schankerman (2004) concluded that "inventor royalty shares are essentially unrelated to key university characteristics" such as faculty size and quality, and that patent "licensing income is significantly increased when the direct monetary rewards to the inventor, in the form of royalties, are raised." Their two papers on this effect, both based on the same underlying data, have been cited over 700 times, including to support the argument that ownership of federally sponsored patents should vest entirely in individual inventors (Clements, 2009). For example, one highly cited review states that this work shows "the importance of [the inventor's] share in securing researchers' cooperation in technology licensing" (Siegel et al., 2007).

Lach and Schankerman's pioneering work identified a valuable source of empirical variation for studying the effect of patent royalties on academics. But we find that their statistically significant results stem from errors coding some university policies: 42 out of 101 universities involve an error of at least five percentage points.[3] No such correlation exists in their own dataset when these errors are corrected.[4] Additionally, the results we present in Section 4 cast further doubt on the empirical conclusion that higher inventor royalty shares lead to greater licensing income. We use the same data sources for outcome and control variables as Lach and Schankerman, but with an expanded range of years (1991–2013) and additional outcome variables: the number of invention disclosures filed with university technology transfer offices (TTOs) each year, and the number of patents filed and received by each TTO. These outcomes are all imperfect (or even negative) measures of *social* welfare, but they are the outcomes one would expect to be most directly responsive to financial patent incentives. We also use a larger number of universities, based on our hand-compiled dataset of patent royalty-sharing policies, which shows substantial variation across both universities and time. We conduct cross-sectional analyses based on the approach of Lach and Schankerman (including a restriction to the same 1991–99 period) as well as panel data analyses with university and year fixed effects. None of these analyses support the claim that increasing the inventor's share of patent licensing revenue in official royalty-sharing policies causes academics to increase their patent-related activity.

As an additional check, we examined moves between universities by the most active university patenters: faculty with at least ten patents in the ten years prior to 2016. Based on 133 lateral moves for which we had calculated an expected share at both the old and new institution at the time of the move, we did not find that these high-patenting faculty tended to move to schools with a higher expected share.

To be clear, our results are only focused on the impact of a university's *official* patent policy—we cannot determine how often faculty negotiate a different royalty share. (Based on conversations with technology transfer officials, our understanding is that side deals over patent issues exist, but we have not heard of any deals focused on the royalty rate.) But as we explain, this caveat does not affect our conclusion that increasing the share for inventors in a university's standard policy does not seem to increase any of the outcomes that likely would be most affected: invention disclosures, patent applications, issued patents, or licensing income. And at the same time, increasing the inventor's share may take away money

[2] Not all university patents are Bayh–Dole patents, nor are all Bayh–Dole patents university patents, although there is significant overlap. We focus on university patenting, but we expect much of the discussion to apply in other nonprofit and government research contexts.

[3] Most notably, for Carnegie Mellon University, Lach and Schankerman used an expected share of 97%, but the university's IP policy has given the inventor 50% of net patent income since 1985. Changing this one value makes their correlation no longer statistically significant. For additional details, see the Appendix.

[4] We are grateful to Mark Schankerman for generously providing some of the data analyzed in Lach and Schankerman (2008), which facilitated this comparison.

from the university.[5] Even setting aside the more complicated issue of whether incentivizing more faculty involvement in technology licensing has a positive net *social* benefit, we do not find evidence of a potential *private* benefit to increasing the inventor's share in official policies that might justify the corresponding loss of additional R&D funding.

Policies governing university patent ownership may still have incentive effects, as illustrated by recent work on the transfer of ownership rights from professors to universities in Norway (Hvide and Jones, 2018). The failure to observe an effect stemming from variation in royalty-sharing arrangements in the United States may stem from average royalty income being low compared with other sources of income for academics (including patent-related income such as equity in start-ups and non-patent income such as the grants that must be obtained to pay part of academic scientists' salaries) and the wider variety of instruments U.S. universities might use to compensate faculty with high expected patent returns. Our key point here is simply that the historical U.S. experience currently offers no compelling empirical evidence that providing a greater financial incentive to university researchers by increasing their share of royalties has a significant effect on university licensing income.

As we conclude in Section 5, these results suggest that a rethinking of Bayh–Dole policy is in order. Overall, we hope to shift the burden to Bayh–Dole defenders to develop an evidence-based justification for those academic patents that are not justified by ex post commercialization incentives. Perhaps these patents are justified by ex ante incentives through other channels such as reputational rewards. Perhaps they are justified by their role in generating additional funding for university research or internalizing foreign benefits of U.S. science spending (Hemel and Ouellette, 2017). Given the weak evidence base, we are currently agnostic on whether any of these benefits might outweigh the costs of exclusivity, but we think these questions demand further study.

At the very least, we think our results suggest that from a social welfare perspective, most university patent royalties may not be optimally allocated. Decreasing the standard percentage of patent income provided to inventors as personal income to shares on the lower range of the policies we studied—say, 25 % of initial net royalties—seems likely to have little effect on patent-related activities by faculty. (Lowering the faculty share even further may also be beneficial, but our data reveal little about the counterfactual of a zero percent royalty share. Even if few researchers are aware of or responsive to the precise rate, they may at least be aware that they could expect *some* financial compensation for patenting.) Any other incentives that patents might provide to academics—such as reputational benefits or encouragement of faculty-run spin-offs—would not seem to be affected by such a change. At the same time, decreasing inventors' shares of patent income would increase universities' shares, which Bayh–Dole requires universities to reinvest in science research or education.

2. Can researcher incentives help justify Bayh–Dole?

Universities, other nonprofits, and government research laboratories conduct a significant fraction of U.S. research, but they rarely commercialize the results of this research themselves. Indeed, much university research is focused on basic scientific findings that are far from any practical consumer good, though they may have substantial payoffs for more applied work in the future. Thus, a NASA-funded Stanford biologist can send ants to space even though Stanford has no plans to make space-ant-related products, and researchers at the National Institutes of Health (NIH) can study the genetic causes of sleep duration in fruit flies without any immediate commercial tie-in. Unlike researchers at for-profit firms, whose work is usually funded by their firms and driven by the firms' business interests, nonprofit and government researchers are typically funded by grants and other direct support: In 2013, the federal government spent almost $50 billion funding its own research centers, and over $40 billion more on grants to universities and nonprofits (National Science Foundation, 2016).

Some of this publicly funded research results in inventions that meet the requirements for patentability: being patent-eligible subject matter, as well as useful, new, and nonobvious. But before 1980, the federal agencies that distributed this funding and that conducted intramural research had inconsistent policies on who, if anyone, could patent these inventions (Eisenberg, 1996). To address this uncertainty, Congress passed the Bayh–Dole Act (and the lesser-known Stevenson–Wydler Act for government labs), which established uniform rules to make it clear that institutions may patent inventions derived from government-sponsored research.

The case for patents on publicly funded knowledge goods is strongest when some additional incentive is needed to commercialize those goods for public consumption, even after their initial invention is complete. For example, if universities were not permitted to patent a promising drug candidate, it is unlikely that any pharmaceutical firm would carry out the clinical trials needed to bring the drug to market (Roin, 2009). This ex post commercialization benefit is the first-listed goal in Bayh–Dole's statutory text, and it is the foundation on which Bayh–Dole defenders rest their case today. The *Economist* called the Act "[p]ossibly the most inspired piece of legislation to be enacted in America over the past half-century" because it prevents federally funded inventions from remaining "in warehouses gathering dust" (Economist, 2002).

But as Ayres and Ouellette (2016) have explained, this commercialization benefit alone cannot justify Bayh–Dole's present scope. The promise of exclusivity is evidently not always needed to commercialize university inventions because over 60 % of patent licenses issued by universities are nonexclusive (AUTM, 2014). (In theory, a university might maximize profits through cartel rather than monopoly profits to hedge against the possibility that its first licensee turns out to be a bad commercializer, but we have not heard of any university following such a strategy.)

One well-known example in which patents were unnecessary for commercialization involves Stanford's Cohen–Boyer patents on recombinant DNA technology, which were licensed nonexclusively to over 400 firms to bring in $255 million to Stanford (Leute, 2005). It is hard to generate a theory under which these patents aided commercialization; rather, they look like a tax on the early biotechnology industry (Eisenberg, 1996). Similarly, the methods of introducing genes for foreign proteins into cells covered by Columbia's notorious Axel patents were foundational technologies that surely would have achieved widespread use even without patents—though they brought in $790 million in revenue through nonexclusive licensing to Columbia (Colaianni and Cook-Deegan, 2009). For other examples in which university patents have seemed unnecessary for commercialization, see Hemel and Ouellette (2017). If Bayh–Dole patents are justified only by their commercialization incentive, then universities and other grantees could use a "market test" to limit patents to those inventions that would not be commercialized without patents (Ayres and Ouellette, 2016).

[5] This would not be the case if universities that provide higher faculty royalty shares are able to save money by offering lower faculty salaries, as one might expect in a fully efficient labor market. Given that most university faculty never patent and that other economic concerns seem far more salient, we would not expect royalty sharing rates to have a measurable effect on salary. But our normative conclusion holds whether our null result is caused by comparatively low faculty interest in patent royalties or by offsetting policy instruments for compensating faculty.

Thus, Bayh–Dole defenders must set forth other evidence of the Act's benefits. In cases where exclusivity is unnecessary for commercialization, do patents on publicly funded knowledge goods have other benefits that outweigh their costs? For example, in an era of declining federal science funding, perhaps a tax on university-developed technologies is the most politically feasible way to fund science research and education. Raising revenue for universities is not why Bayh–Dole was enacted. As Eisenberg and Cook-Deegan (2018) summarize, "the argument was not even made," and "even now, the revenue-for-universities rationale is raised only sotto voce, if at all." But this may in fact be the best justification for Bayh–Dole patents that are unnecessary for commercialization. A related benefit—recently explored by Hemel and Ouellette (2017)—is that such patents allow the United States to internalize some of the positive externalities that these inventions confer on foreign consumers. But this potential benefit only applies to foreign patents; it cannot justify patents that merely raise prices of these knowledge goods for U.S. consumers.

In this article, we focus on a different potential benefit: increased incentives for individual innovators. The ex ante incentive to invent due to the prospect of a financial reward is the standard justification for patents (Lemley, 2004). And the Bayh–Dole statute, 35 U.S.C. § 202(c)(7)(B), requires university and nonprofit inventors to receive a share of patent royalties, though it leaves the size of the share to the discretion of the institution. (In contrast, the Stevenson–Wydler Act, 15 U.S.C. § 3710c(a)(1)(A)(i), specifies that inventors at government laboratories receive the first $2000 of royalties each year plus 15 % of any additional royalties.) This financial incentive might thus be expected to increase the quality or quantity of university research.

Legal scholars have typically assumed that this incentive effect must be negligible given the other incentives university researchers have to innovate, such as the desire for tenure and recognition (Eisenberg, 1996; Rai, 1999; Lemley, 2008; Love, 2014). The net effect could even be negative if financial incentives cause academics to shift their work away from more socially valuable but unpatentable research. But we do not think that the potential incentive benefit of patents for university researchers can be dismissed as a matter of theory—mixing grants and patents may shift research *toward* more socially valuable work by tying part of the reward from grant-funded work to market value (Hemel and Ouellette, 2019).

Distinguishing between these competing hypotheses is difficult without more information about the complex blend of incentives that drives academics to conduct research, and how financial incentives affect those motivations. We turn to these questions in the next section.

3. What motivates university researchers?

Before evaluating the potential effect of patent incentives on academic researchers, it is important to understand the environment in which their research takes place. We thus begin with an overview of the economics of academic research. We then turn the financial and non-financial benefits that patents might have for university researchers and examines both qualitative and quantitative efforts to explore how patents affect researchers' motivations.

3.1. The economics of academic research

Science is expensive. When a researcher begins a new science or engineering faculty position, she typically receives a start-up package of roughly $300,000 to $1 million in unrestricted funds to cover the initial costs of setting up and running her laboratory (Hoag, 2015). After this start-up period, the researcher must find grant support to pay all of her research costs and, at most universities, all or part of her salary (Guberman et al., 2006). As Stephan (2012) explains, "[m]ost academic scientists in the United States are hired on nine-to ten-month contracts. It is the grant that pays for their summer, not the institution."

Research costs include not only the cost of equipment, but also the cost of staffing the laboratory with graduate students, postdoctoral researchers (who typically spend one to five years in a lab while looking for a more permanent position), and technicians (more permanent employees who often do not have a PhD.) (Stephan, 2012). The average size of a university laboratory varies by field, by university, and over time; for example, Conti and Liu (2015) found that from 1966 to 2000, the average number of personnel in an MIT biology laboratory in addition to the principle investigator increased from six to twelve. Unlike in the social sciences, laboratory personnel are an integral and necessary part of a science or engineering faculty member's research team. It is unusual, for example, for a science graduate student to publish a paper that does not include her faculty mentor as an author, or for a faculty member to solo-author a research publication (Jones et al., 2008).

On top of these equipment and personnel expenditures, a faculty researcher must pay an overhead rate to the university, which averages 52 % for NIH grants—meaning that for every $100,000 spent on research, the faculty member must also pay $52,000 to cover the university's "indirect costs" of maintaining facilities and complying with regulations (and, in practice, paying for other researchers' start-up packages) (Kaiser, 2017). Overhead rates had been even higher before an incident with Stanford in the 1990s caught the eye of government auditors (Stephan, 2012). When salary, benefits, tuition, and overhead are all included, each graduate student costs the principal investigator roughly $50,000 to $100,000 per year, depending on the university.

To support these expenses, faculty must apply for grants. Unlike for private firms, there is not currently a market for loans to academic scientists to cover the costs of promising research with the hope of repaying those loans through profits or patent royalties. Of course, grants are not the only potential funding model: it would be possible to design a system in which grants reimburse only a fraction of the costs of academic research, and the ongoing decline in federal science funding may spur the development of alternatives (Mervis, 2017). But for now, university researchers must find money before they spend it.

According to the National Science Foundation (2016), in 2013, of the $65 billion universities spent on research, 57 % came from the federal government, 24 % from the universities (though some of this funding came from overhead charged on federal grants), 8 % from nonprofits (such as the Howard Hughes Medical Institute), 6 % from nonfederal governments, and 5 % from private firms. Six agencies distribute over 92 % of federal funding for academic research; in declining order of support, they are the Department of Health and Human Services (which houses the NIH and provides over 50 % of federal funding), the National Science Foundation (NSF), the Department of Defense, the Department of Energy, NASA, and the Department of Agriculture. The NIH offers a number of grant options, the most common of which is a four- or five-year award for a single project, which had an average size of over $400,000 and an application success rate of less than 20 % in 2016.

Each new grant facilitates additional research. One resulting benefit is to make it easier to apply for even more grants: preliminary research results are often necessary to obtain a federal grant, and one grant can be used to obtain preliminary findings to support a second grant (Guberman et al., 2006; Stephan, 2012). (A key reason universities provide start-up funding is to allow faculty to obtain preliminary results to submit with their initial grant applications.) Federal grant recipients are also required to report their results to the funding agency, and it is far easier to renew a grant if the researcher has demonstrated substantial progress (Stephan, 2012; Powell, 2017).

But the primary outcome of conducting grant-funded research is the production of new—and ideally publishable—scientific results. Peer-reviewed publications are the currency of science academia. They are essential for obtaining a faculty position (van Dijk et al., 2014). Publications are also essential for *keeping* a faculty position, as they are the primary consideration in tenure decisions (Guberman et al., 2006). And they are important for helping one's postdocs obtain faculty positions of their own; without a good track record of placing postdocs, hiring new postdocs will be difficult.

In addition to these instrumental benefits, the opportunity to discover new knowledge and disseminate it through publications is part of what draws many researchers to academia. The intellectual challenge of producing new scientific findings is often presented as scientific researchers' main motivation: to many, it is the point of the entire expensive enterprise. As Stephan (2012) summarized: "Ask almost any scientist what led him or her to become a scientist and the answer will be an interest in solving puzzles." The idealized vision of a scientific community focused on generating new knowledge through norms such as disinterestedness and communalism is perhaps best encapsulated by the pioneering sociology work of Merton (1973).

Other scholars have critiqued this romanticized view, arguing that scientists should instead be viewed as rational strategists who seek to maximize credibility, as measured both through concrete metrics like publications and grants as well as through more intangible markers of prestige. For example, Lam (2011) uses the framework of "gold" (financial rewards), "ribbon" (reputational rewards), and "puzzle" (intrinsic satisfaction) to describe the multidimensional nature of the scientific reward system. A new research finding—as conveyed through a publication—can further all of these goals: it is the solution to an intellectual puzzle that can lead to reputational rewards, which in turn can provide pecuniary gains. By increasing a faculty researcher's reputation among peers, publications make it more likely that the researcher will receive tenure and keep her faculty salary, and they also make it more likely that the researcher will receive additional grants to fund the portion of her salary that is not covered by her university. But isolating how faculty researchers weigh these different benefits is more challenging.

We will not attempt to canvas the full literature on the motivations of academic scientists; rather, we are interested in what this literature has to say about a particular question: What happens when the prospect of a financial return from patents is added to this blend of incentives?

3.2. The effect of patents: theory and evidence

As Ouellette and Weires (2020) review, the patent incentive could have a variety of positive or negative effects on academic research, although none of these theories have strong empirical support in existing qualitative or quantitative studies. It is also worth emphasizing that patenting is a minority activity: most academics never patent, and most university–industry knowledge transfer occurs through non-patent channels (Agrawal and Henderson, 2002).

The prospect of obtaining patents could have at least three independent benefits for researchers: (1) the *financial* effect from both patent royalties and patent-based faculty-run spin-offs; (2) the *reputational* effect of receiving credit for a particular novel idea (with patents even being considered in some tenure decisions, as Stevens et al. (2011) note); and (3) the *social impact* effect on adoption of the inventor's technology, which may have intrinsic benefits for inventors who care about promoting the public good with new technologies or about validation of their research, even aside from financial or reputational returns. This article focuses on the financial effect of patent royalties, but other potential benefits seem worth further investigation.

Interview and survey work with university researchers has found that financial incentives play at most a small role among reported motivations for patenting (Owen-Smith and Powell, 2001; Renault, 2006; Lam, 2011). Of course, there may be a perceived stigma against expressing an interest in financial gain in an academic environment, so it is unclear how informative these results are. It would be difficult to claim that faculty are uninterested in money; for example, as noted above, they typically use part of their research funding to pay salary to themselves rather than leaving all the funds for science. But as Ouellette and Weires (2020) summarize, "this does not mean that the financial incentive from *patents* matters—for most professors, the ability to maintain a steady stream of grants to pay summer salary each year is likely a more immediate financial concern than speculative patent royalties." Many faculty are not even aware of their university's royalty-sharing policy (Love, 2014).

Of course, an assessment of the net ex ante effect of patent incentives on university researchers must also consider the potential for negative effects. Legal scholars have expressed concern about the impact that property rights might have on scientific norms and academics' willingness to openly share their results with other researchers (Rai, 1999; Bagley, 2006). There is some evidence that patenting may delay disclosure (Grushcow, 2004), but patents do not seem to be substituting for publications. To the contrary, patents and publications seem to be complementary, with some evidence suggesting that patenting researchers produce more and higher-quality work (Azoulay et al., 2007, 2009; Goldfarb et al., 2009; Fabrizio and Di Minin, 2008). There is also little evidence that the rise of university patenting has been accompanied by a shift away from more basic research (Mowery et al., 2001; Thursby and Thursby, 2011; Schacht, 2012; Roach, 2017).

3.3. Prior work on university royalty-sharing

In this article, we attempt to disentangle patents' financial incentive for academic researchers from other effects, allowing us to better understand Bayh–Dole's researcher-level impact. We do so by examining variations in the amount of patent royalties that universities share with inventors. As noted above, in addition to specifying that universities may patent inventions created under federal grants, Bayh–Dole requires universities to share the resulting patent royalties with the inventors. Fortuitously, different universities offer their researchers different shares of patent royalty revenue, and some universities change these policies over time. That disparity offers the opportunity to determine empirically whether offering inventors a greater share of patent revenue has any observable outcome.

We are not the first to notice and exploit the opportunity provided by disparate university patent-royalty-sharing policies. Saul Lach and Mark Schankerman (L&S) collected royalty-share data from 102 U.S. university websites in 2001, which they combined with 1991–1999 survey data from the Association of University Technology Managers (AUTM) to conclude that a higher inventor's royalty share caused higher licensing income at the university, controlling for other factors (Lach and Schankerman, 2004, 2008). To estimate how royalty shares affect licensing income, they conducted a cross-sectional analysis comparing licensing income across universities with different royalty share rates, controlling for other observable university characteristics such as faculty size and quality. This identification strategy relies on the assumption that university royalty shares are, conditional on the other characteristics for which they control, unrelated to factors that shape licensing income. They argue in favor of this assumption based on a finding that university royalty shares appear largely unrelated to other university characteristics in the data they study.

Efforts to follow this approach in the European context have had mixed results. Baldini (2010) found that royalties shared with inventors or their departments had a significant positive effect on the number of patents filed by Italian universities. In contrast, Pere Arqué-Castells et al. (2016) found that royalty shares had no significant effect on patenting or licensing income in Portugal and Spain.

The strongest evidence that academics respond to patent incentives comes from Hvide and Jones (2018), who found that Norway's 2003 switch from inventor ownership (the "professor's privilege") to university ownership (with one-third of net income shared with inventors) was followed by a fifty percent decline in both entrepreneurship (as measured by start-up formation and performance) and patent counts. But this result does not imply that U.S. academics are sensitive to the specific patent royalty share, as summarized by Ouellette and Weires (2020): "It is unclear how this policy change (a change in title) compares with varying the share of inventor royalty income within a system in which the university holds title. Additionally, the faculty labor market in Norway has important differences from the United States that might cause Norwegian academics to be more sensitive to additional income sources: salaries are collective negotiations between trade unions and the state, and overall compensation is comparatively low, with a maximum annual salary for full professors around US$122,000 in 2008, and a median around US$73,000."

4. Does royalty sharing with inventors affect U.S. university patenting and licensing?

We follow L&S's approach of examining variations in the amount of patent royalties that U.S. universities share with inventors. In addition to attempting to replicate their work, we conduct additional analyses using an expanded range of years (1991–2013), a larger range of universities, additional outcome variables, and an additional identification strategy with university and year fixed effects that relies on a more plausible set of assumptions. We describe our data sources in Section 4.1, our cross-sectional results in Section 4.2, and our panel data results in Section 4.3. Section 4.4 then presents an additional analysis of lateral moves between universities by the most active patenters among university faculty. None of these analyses support the claim that increasing the share of patent royalties for an inventor in a university's official policy causes inventors to increase their patent-related activity, calling into question the incentive effects of Bayh–Dole. Finally, Section 4.5 offers some caveats to extrapolating beyond these results.

4.1. Data

We merged data from a number of sources, including the same sources of data as L&S (survey data collected by AUTM and by the National Research Council (NRC)), as well as our own hand-collected data on university patent royalty-sharing policies. Our data and replication files are available on the Harvard Dataverse at https://doi.org/10.7910/DVN/TTGFW2. At the end of this section, we consider the various choices for converting nonlinear royalty-sharing policies into a single effective royalty share, and how this effective royalty share is related to observable university characteristics.

4.1.1. AUTM licensing surveys 1991–2013

AUTM is a nonprofit organization representing IP managers at the TTOs of over three hundred universities, research institutions, and teaching hospitals. AUTM conducts an annual survey about patenting and licensing activity, and responses are compiled in the

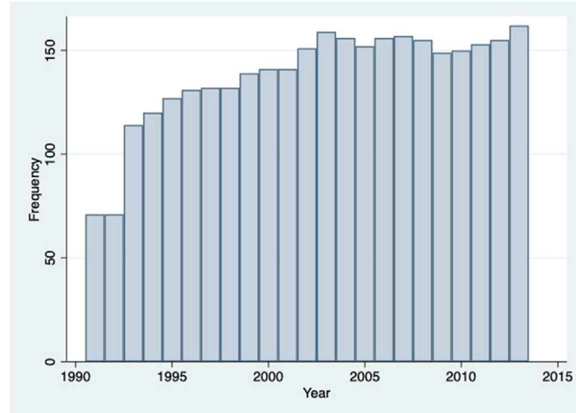

Fig. 1. Number of U.S. universities in AUTM's STATT database per year.

Statistics Access for Tech Transfer (STATT) database (AUTM, 2014, 2015). Fig. 1 shows the number of U.S. universities in the database by year from 1991 to 2013.[6]

We compiled the following outcome variables for each university based on the AUTM survey data:

- *Invention disclosures* (mean = 92, std. dev. = 130) indicate the number of disclosures made to the TTO about potential new inventions each year, "no matter how comprehensive." These disclosures typically initiate the TTO's process for determining whether a patent application should be filed, although many disclosures do not lead to patent applications.
- *New patent applications* (mean = 51, std. dev. = 87) indicate "the first filing of the patentable subject matter," including provisional applications, but not including continuations, divisions, or reissues.
- *New patents issued* (mean = 21, std. dev. = 33) indicates the number of new issued U.S. patents in a given year.
- *Net licensing income* (mean = $8 M, std. dev. = $31 M) = *gross licensing income* (mean = $8 M, std. dev. = $31 M) − *legal fees* (mean = $1 M, std. dev. = $3 M) + *reimbursed legal fees* (mean = $0.6 M, std. dev. = $1.5 M). Gross licensing income includes "license issue fees, payments under options, annual minimums, running royalties, termination payments, the amount of equity received when cashed-in, and software and biological material end-user license fees equal to $1000 or more"; legal fees include "the amount spent by an institution in external legal fees for patents" but not litigation expenses; and reimbursed legal fees include "the amount reimbursed by licensees." Approximately 20 % of universities report negative net licensing income across the years observed.

Net patent licensing income is the outcome studied by L&S. They used invention disclosures to estimate the expected income per disclosure, but did not use disclosures, patent applications, or issued patents as outcome variables. These outcomes are imperfectly (or even negatively) correlated with social value: not all patents and contributions are equal. But they are the outcomes one would expect to be most directly affected by the financial patent incentive for university researchers.

[6] More precisely, Fig. 1 shows the number of distinct reporting entities. Some university systems (such as the University of California System) complete one aggregate report each year, while others (such as the University of Illinois at Chicago and the University of Illinois at Urbana-Champaign) report separately. Others changed over time; for example, the University of Texas System began submitting an aggregated report in 2009.

We also gathered the following variables that were used by L&S as controls in at least some regressions, although they note that some of these—particularly TTO size—may be endogenous.

- *TTO size* (mean = 4.2, std. dev. = 6.4) is the number of full-time equivalent (FTE) employees in the TTO "whose duties are specifically involved with the licensing and patenting process." This information was not reported in 1991, so we used the 1992 data for 1991, following L&S.
- *TTO age* (mean = 17, std. dev. = 13) is measured from the year the TTO was established, as reported to AUTM.
- *Med school dummy* (mean = 0.6, std. dev. = 0.5) indicates whether the university has a medical school.
- *R&D funding* (mean = $236 M, std. dev. = $362 M) "include expenditures (not new awards) made by the institution in the survey year in support of its research activities that are funded by all sources including the federal government, local government, industry, foundations, voluntary health organizations . . ., and other nonprofit organizations. Indirect costs should be included." Although excess patent licensing income must be directed to science research and education, net licensing income (an upper bound on the amount of patent income going to R&D) is almost always much less than R&D funding: the mean of net licensing income / R&D funding is 0.02 (std. dev. = 0.09).[7]

4.1.2. NRC graduate program surveys 1992–93 and 2005–06

To provide additional control variables for faculty size, research orientation, and research quality, we followed L&S in using data from the 1992–93 academic year provided by schools that participated in the NRC's survey of graduate programs (National Research Council, 1995).[8] To add more recent information, we also gathered data from the NRC's 2005–06 survey (National Research Council, 2011). We calculated the following data from these reports:

- *Faculty size* is the total number of faculty in the science and engineering programs reported in the survey.
- *Publications per faculty / citations per faculty* are the number of program publications / citations per faculty in the period 1988–92 (for the 1992–93 report) or 2000–06 (for the 2005–06 report).
- *Quality* (for 1992–93 survey only) is the trimmed mean of the scholarly quality of the program faculty based on survey responses from faculty at other institutions, with "0" denoting "Not sufficient for doctoral education" and "5" denoting "Distinguished." The quality results for individual programs were aggregated to the university level using faculty weights.
- *Science fields*: The 23 science and engineering doctoral programs in the 1992–93 survey and the 38 programs in the 2005–06 survey were aggregated into six broader fields, as shown in Table 1. For the 1992–93 survey, we followed L&S. For the 2005–06 survey, we attempted to match this categorization.

4.1.3. University royalty-sharing policies

University policies for sharing patent royalties with inventors were primarily gathered from the websites of each university TTO. L&S state that their royalty-share information for 102 U.S. universities "was downloaded from the websites of each university technology licensing office during the summer of 2001." Because L&S did not initially respond to requests to share their data or their list of universities (which is not reported in their publications), we searched for policy information for the 152 U.S. universities whose first AUTM reporting year was in the 1990s and that were in the NRC 1992–93 report.

L&S did generously share some of their data in September 2018. As explained below, to facilitate comparison of complex royalty-sharing policies, they converted each policy to a single expected inventors' share. Appendix Table A1 compares their expected inventors' share with the key royalty-sharing policy information we independently gathered for 101 U.S. universities: 34 private universities and 67 public universities. (The total is 101 rather than 102 because one school on Lach and Schankerman's list of public U.S. universities is the University of Victoria, which is located in Canada.) Discrepancies between their data and ours are discussed further below.

For each of the 152 universities in our dataset, we attempted to locate policies at least as far back as the first year the university reported to AUTM. For universities that only presented the most recent policy on their websites, we used the Internet Archive to access older versions. We also contacted TTOs individually by email to check the online information and to clarify points of confusion. The royalty-sharing policies we found are documented at http://universitypatentdata.com. For 141 out of 152 schools, we were able to obtain policy information at least back to 2001, the year when L&S collected policies. For 32 of those 141 schools, we were unable to confirm that the 2001 policy was in effect for as long as the university had been reporting to AUTM. It appears that L&S treated the 2001 policy as applying throughout the 1990s except for the 11 universities that informed them of an earlier policy, in which case they averaged the old and new shares. Our dataset contains 27 universities that changed their policy before 2001.

Our complete dataset reflects 237 separate policies: out of 152 universities, 83 (55 %) had the same policy for all the years in our dataset, 55 (36 %) changed their policy once, 12 (8 %) changed their policy twice, and 2 schools (1 %) changed their policy three times. A few university systems changed the way they aggregate data for AUTM reporting during the 2000s; for example, the University of Texas system reported as separate universities from 1991 to 2008, and then as a single system starting in 2009. When we perform analyses in this article that include later years, we aggregate data for these schools in the earlier years as well. With aggregation, our data reflects 217 separate policies for 141 universities, as shown in Fig. 2.

The typical policy provides the inventor with a share of *net* patent royalties as personal income, after subtracting legal fees and sometimes a fixed overhead fee for the TTO. The inventor's royalty share is often nonlinear, decreasing as net royalties increase (that is, as the patent earns more money). Some policies also give inventors control of an additional share of royalties as research support for their laboratories.[9] For example, from 1981 to 2005, Brown University gave inventors 50 % of the first $100,000 of net licensing income

[7] There are only three universities that have any year in which net licensing income / R&D funding is greater than one: Emory in 2005 (1.7), NYU in 2007 (2.7), and Northwestern in 2008 (2.2). In all three cases, the anomalously high licensing income for that year was due to the sale of the entire future royalty stream from one successful drug. In none of the three cases was there a corresponding spike in the total R&D funding, raising questions about how directly these returns were invested in science research and education. For the 1991–99 period studied by L&S, the maximum net licensing income / R&D funding is 0.43, for Florida State in 1999 (also for a pharmaceutical).

[8] We used Appendix K on engineering programs, Appendix L on life science programs, and Appendix N on biological sciences. Data were hand-coded from the print survey results with the help of optical character recognition.

[9] Following L&S, our data includes royalties as part of this laboratory share only if "the university's IP policy states that the share accruing to the lab was under the control of the inventor." We thus did not include royalties given to the inventors' department. In practice, the department's share is sometimes directed to the inventor's lab at the discretion of the department chair, with practices varying even within a given university across departments and time.

Table 1
Categorization of Science and Engineering Fields from NRC Surveys.

Field	1992–93 NRC Survey	2005–06 NRC Survey
biomedical and genetics	biochemical/molecular biology; biomedical engineering; cell and developmental biology; molecular and general genetics	biochemistry, biophysics, and structural biology; biomedical engineering and bioengineering; cell and developmental biology; genetics and genomics; immunology and infectious disease
other biological sciences	ecology/evolution and behavior; neurosciences; pharmacology; physiology	animal sciences; biology/integrated biology; ecology and evolutionary biology; entomology; food science; forestry and forest sciences; kinesiology; microbiology; neuroscience and neurobiology; nursing; nutrition; pharmacology, toxicology and environmental health; physiology; plant sciences; public health
computer science	computer sciences	computer sciences
chemical science	chemical engineering; chemistry	chemical engineering; chemistry
engineering	aerospace; civil engineering; electrical engineering; industrial engineering; material science; mechanical engineering	aerospace; civil and environmental engineering; computer engineering; electrical and computer engineering; engineering science and materials; materials science and engineering; mechanical engineering; operations research
physical science	astrophysics/astronomy; geosciences; mathematics; oceanography; physics; statistics/biomedical statistics	applied mathematics; astrophysics and astronomy; earth sciences; mathematics; oceanography; physics; statistics

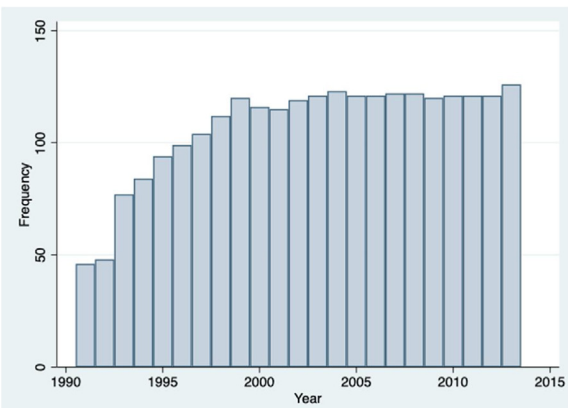

Fig. 2. Universities with royalty share policies, AUTM reporting, and NRC data.

as personal income, 25 % of any net income between $100,000 and $1 million, and 20 % of net income in excess of $1 million. Starting in May 2005, Brown added a 15 % overhead fee before other shares are calculated, changed the inventor's personal share to a flat 1/3 of net income (minus the overhead fee), and also provided a 1/6 share for the inventor's laboratory.

For 12 universities (16 policies), at least one of the policies computes the inventor's share out of *gross* royalties, and another 11 universities (14 policies) used some hybrid, such as of giving the inventor the first $5000 of gross income and then 40 % of net income. We omitted these policies from our analysis because it is unclear how these variations might affect the inventor's expected income. For example, inventors might focus on the number and assume that a 40 % share of net income is larger than a 30 % share of gross income, or they might recognize that most patents generate little net income, so that gross-income policies have a higher expected value. With these gross-income policies dropped, our dataset contains 207 net income policies for 140 schools. L&S's publications do not state how they treated policies based on gross royalties, but 10 of the schools in their dataset have gross-income policies, which they appear to have treated identically to net-income policies. Because of the substantial legal costs of acquiring and licensing patent rights, it seems inappropriate to directly compare these policies with net-income policies.

Fig. 3(A) shows the average royalty share in each of the seven net income bands used by L&S for all 207 of these policies, separating out the inventor's personal income share and the share for the inventor's laboratory (which is only provided by 49 of the policies). Fig. 3(B) shows the average royalty share in each income band for only the 79 policies in which the reward increases nonlinearly with net income, 22 of which provide a laboratory share. While the laboratory share sometimes increases in higher net income bands, for every policy in our dataset, the inventor's personal share remains constant or declines as the patent generates additional net income.

Fig. 4(A) shows that the average inventor's royalty share (not including any lab share) in each net income band has remained relatively constant over time. When the nonlinear policies are separated from the linear ones in Fig. 4(B), we see that the mean share in linear policies has slightly declined over time, whereas the mean share in nonlinear policies has increased in every income band, but these changes are not statistically significant. (The mean share in linear policies declined 3 % from 1991 to 2017, while the standard deviation was over 7 % for this whole period.)

These averages mask the substantial changes in the policies of some individual schools. For example, in 1994 Caltech switched from sharing 15 %–25 % of net licensing income, in 2004 the University of Washington switched from sharing 100 % of initial revenues to a flat rate of 33 %, and in 2005 the University of Iowa switched from a flat rate of 25 % to sharing 100 % of initial patent revenues.

4.1.4. Calculating an expected royalty share

To compare the incentive effect of nonlinear royalty-sharing policies with linear ones, it is necessary to consider how desirable these might appear from the perspective of academic scientists. For policies with linear royalty share schedules, this is straightforward: all else equal, an inventor should prefer receiving 50 % of net licensing income to 30 %. But comparing a linear policy with a nonlinear policy is more challenging. For example, is a policy that provides inventors with 50 % of the first $100,000 of net licensing income and 10 % after that more or less attractive ex ante than a flat rate of 30 % of all net income? Of course, the answer to this will be heterogeneous across university, field, and individual professor, with faculty who expect high income having a different change in incentives from faculty who expect low income. But quantitative cross-school comparisons are easiest if each nonlinear policy can be reduced to a single expected royalty share. As noted below, we conduct some analyses using only schools that provide a flat rate for all licensing income, which would not be affected by this complication.

Most inventions bring in less than $50,000 of licensing income, as can be roughly illustrated by dividing the university-wide net licensing income reported to AUTM by a university in a given year by (a) the number of invention disclosures received, (b) the number of patent applications filed, or (c) the number of new issued patents each year. Fig. 5 shows the kernel density estimate of these distributions for two time periods: 1991–99 (the period considered by L&S) and 2000–13 (the remainder of our dataset). Note that income

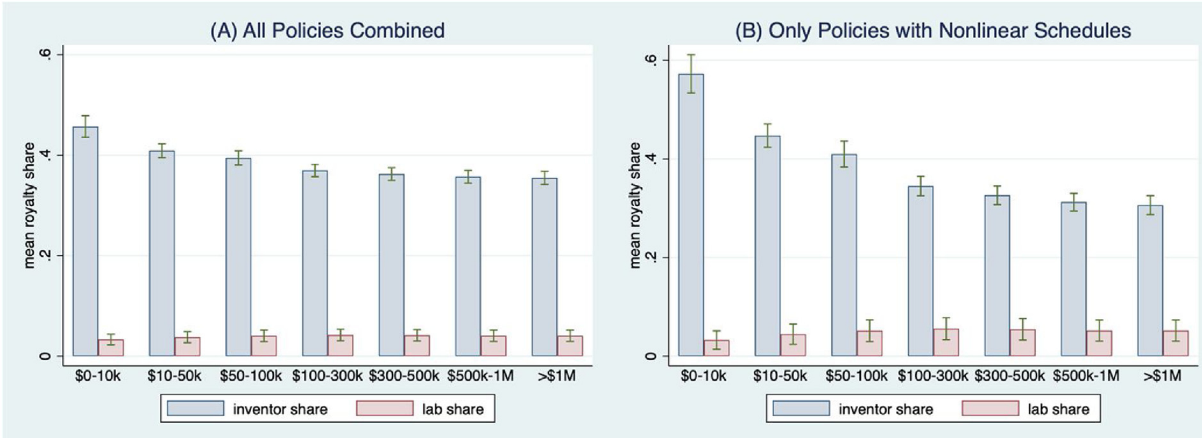

Fig. 3. Mean patent royalty share for inventor (as personal income) and for inventor's laboratory based on net royalties received, averaged across all policies.

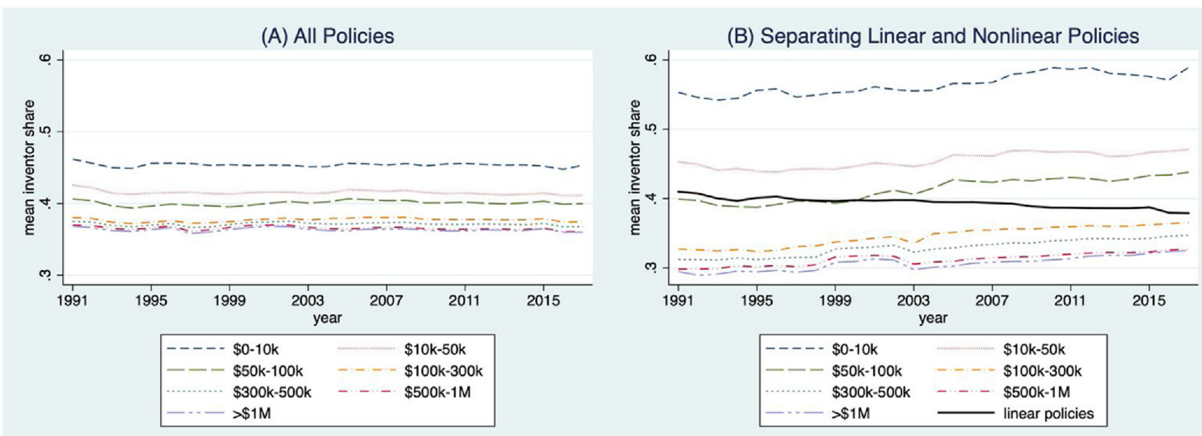

Fig. 4. Mean patent royalty share for inventor from 1993 to 2017.

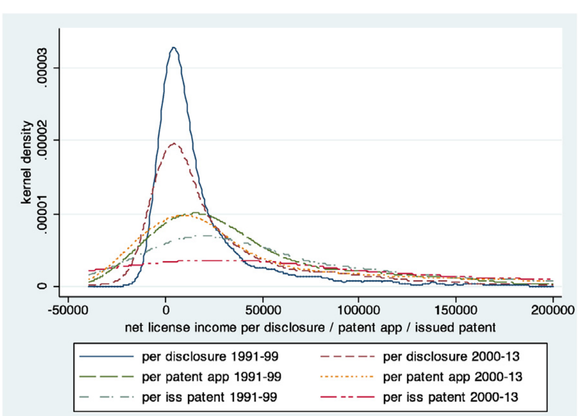

Fig. 5. Distributions of net licensing income per disclosure or patent application.

in any given year will generally stem from patent applications filed in earlier years—the AUTM dataset does not enable attribution of income to a particular patent—but the distributions in Fig. 5 still roughly approximate the patent income universities bring in per disclosure / application / issued patent.

If inventors recognize that most inventions bring in relatively low levels of net income, the expected royalty share for nonlinear schedules should be skewed toward the share provided in the lower income bands. L&S computed their expected royalty share

Table 2
Cumulative Distribution from Fig. 5 Under Given Caps.

Distribution	$10k	$50k	$100k	$300k	$500k
income per disclosure 1991–99 (*Cf.* L&S)	51 %	85 %	92 %	98 %	99.5 %
income per disclosure 2000–13	41 %	74 %	85 %	96 %	98 %
income per patent app 1991–99	28 %	61 %	77 %	93 %	96 %
income per patent app 2000–13	31 %	59 %	72 %	90 %	94 %
income per patent 1991-99	23 %	49 %	67 %	87 %	91 %
income per patent 2000-13	17 %	32 %	46 %	69 %	78 %

for the nonlinear royalty schedules by weighting the share in each income band by the probability of observing licensing income in that interval based on the kernel density of the licensing income per disclosure in the period 1991–99, as in the solid line in Fig. 5.[10] (A kernel density estimate is basically derived by fitting a smooth curve to a histogram.) They found that "[n]early all of the weight is on the first two income intervals—50.2 % in the 0–$10,000 interval and 46.1 % in the $10,000–$50,000 bracket," for a combined 96.3 % of the distribution under $50,000. Thus, they conclude that "for practical purposes a good approximation is simply to average the first two sharing rates." Table 2 shows that our distributions are

[10] Our distribution for the solid line in Fig. 5 is based on 770 income-per-disclosure data points from the 1991–99 AUTM survey results, while L&S's is based on 723, perhaps because they eliminated schools for which they did not have policy information.

not quite so heavily weighted toward the first two income bands, but that these bands are weighted more heavily than later ones.

It is not obvious, however, that L&S's assumptions reflect how academic scientists would compare different policies. Their methodology does not account for heterogeneity across fields, and it treats all universities equally, so that a researcher at Stanford (where the mean net licensing income per disclosure is about $160,000) expects the same licensing income as a researcher at Florida Atlantic University (where the mean net licensing income per disclosure is just under $0, meaning that they spend more on patent-related legal fees than they make in licensing income). (Out of 3081 university–year observations of net licensing income in the full AUTM dataset, 555, or 18 %, are less than zero.) Moreover, they assume that inventors have some knowledge of the average income per disclosure across universities, and that they base their expectations on this, rather than the income per application, or per issued patent, or per similar invention.[11] Researchers should not expect *any* share unless they expect their invention to be patentable, so it is unclear that invention disclosures are the right denominator.

Inventors might also focus more on the average royalty rate *per dollar earned* rather than the average royalty per invention, so that even though the vast majority of inventions fall in the lower net income bands, the few blockbusters that bring in the most income may be driving assessments of the relevant royalty rate. Relatedly, inventors may be overly optimistic about the likelihood that their work will fall within the high end of the income tail (Åstebro et al., 2007), or they may be risk averse, preferring the surer bet of a high share of initial net royalties.

An inventor's expected share may also vary based on the way the policy is presented. For example, consider the overhead fee collected by some TTOs before the inventor's share is calculated. Out of the 207 net income policies in our dataset, 45 (22 %) had such a fee, with an average fee of 15 % (std. dev. = 4 %). Based on L&S's statement that they " made an adjustment for the [TTO]'s overhead rate, when it was reported," we recalculated the inventor's share to account for these fees, such that a policy with a 20 % overhead rate and then a 50 % inventor's share is treated equivalently to a policy with no overhead and a 40 % inventor's share. But it seems possible that some inventors would focus more on the percentage listed as their share than on what that share is calculated from, making the former seem larger, especially because the administrative fee is often in a separate section of the policy. And as Table A1 illustrates, a comparison with L&S's dataset suggests that they did not in fact adjust shares to account for the TTO's overhead rate at about 12 universities, including Stanford and MIT.

Finally, it is not obvious how royalties dedicated to an inventor's research laboratory rather than his or her personal income should factor into the expected royalty share. While both personal and research income are certainly valuable, it seems likely to us that most academic scientists would weight personal income more heavily than research income.[12] L&S stated that they lumped both kinds of income together: "when the university's 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." Examination of their dataset, however, reveals about 11 universities for which they did not add the lab share even though the policy indicated that it was under the inventor's control, including Columbia, Harvard, and Johns Hopkins, as shown in Table A1.

Because we are not confident in any single methodology, we have calculated expected royalty shares for nonlinear policies using several different methodologies in our analyses below, including a weighting scheme approximating that of L&S (50.2 % in the 0–$10,000 band, 46.1 % in the $10,000–$50,000 band, and 3.7 % in the $50,000–$100,000 band) and weighting these first three or four net licensing income bands equally (to show that changing the distribution among lower income bands still does not lead to statistically significant effects). We have also done some analyses using only the schools with linear policies, for which the weighting of bands is irrelevant. We conduct some analyses without adjusting for the overhead fee charged by the TTO before net income is distributed. And we have considered both the combined share (summing the inventor's personal share and lab share) and the inventor's personal share alone.

Fig. 6 shows the distribution of some of these expected shares using the 2001 policies (averaged with any different earlier policies in the 1990s), which can be compared with Fig. 1 of Lach and Schankerman (2004).

4.1.5. Determinants of royalty shares

L&S treat royalty-share policies as essentially randomly assigned: they say that policies "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." They do find that expected royalty share is negatively correlated with TTO age, and their p-value for the F-test for joint significance declines from 0.10 to 0.01 as they add additional observables to their regressions.[13] Table 3 compares linear regression results for our data (in the first four columns) and L&S's data (in the last two columns). A number of our technology field variables are significant, and the F-test indicates that these observables are jointly highly significant.

If the royalty share is in fact correlated with observable characteristics of each university, this raises the concern that it will also be correlated with unobservable factors. For this reason, our preferred specification is a panel data model that controls for fixed effects across both universities and time, as we present in Section 4.3. But given the prominence of L&S's work, we begin in Section 4.2 with their cross-sectional approach.

Of course, even with our panel data model, one endogeneity concern is that universities might adopt changes to royalty policies in response to tough times, such as by increasing the inventor's share in response to declines in inventor disclosures or in licensing income. Similarly, they might respond to increases in disclosures or licensing income by decreasing the inventor's share. (Analogously, one might observe that an increase in the size of local police force corresponds to an increase in the crime rate—a seemingly paradoxical result unless one realizes that causation runs in reverse: as crime rates increase, cities hire police.) While we cannot rule out this concern, we do not see any striking dips or increases in our

[11] Estimating expected inventor share through use of a kernel density estimate is also potentially inappropriate. Outlier universities—such as those with a small number of very high-income patents—can substantially skew the distribution. A reasonable argument could be made that the average university researcher who thinks about expected license income would expect her income to be normally distributed around the mean license income of university researchers across all universities, or perhaps more accurately, across researchers at similar universities in similar fields. But while the precise numbers would differ, this would lead to the same general result of weighting lower income bands more heavily.

[12] If this were not true, we would expect to observe many science professors funding their laboratories out of pocket. While we are unaware of any science professors who do so, we are anecdotally aware of professors who sometimes choose not to take their summer salary out of their grants. Note, however, that behavioral considerations such as loss aversion might complicate this conclusion—people may prefer having money donated to a cause that they pre-specify over being given money and then being asked to donate it.

[13] Note that the extra controls that cause this p-value to decrease all the way to 0.01 are the ones that are potentially the result of the shares in the first place, so the high correlation is not necessarily indicative of shares being set nonrandomly. But the specification in column 3 does not include those variables and has an F-test p-value of 0.05, making it difficult to make the case that shares are set basically randomly. And as noted in the text, the F-test p-value for our data is far smaller.

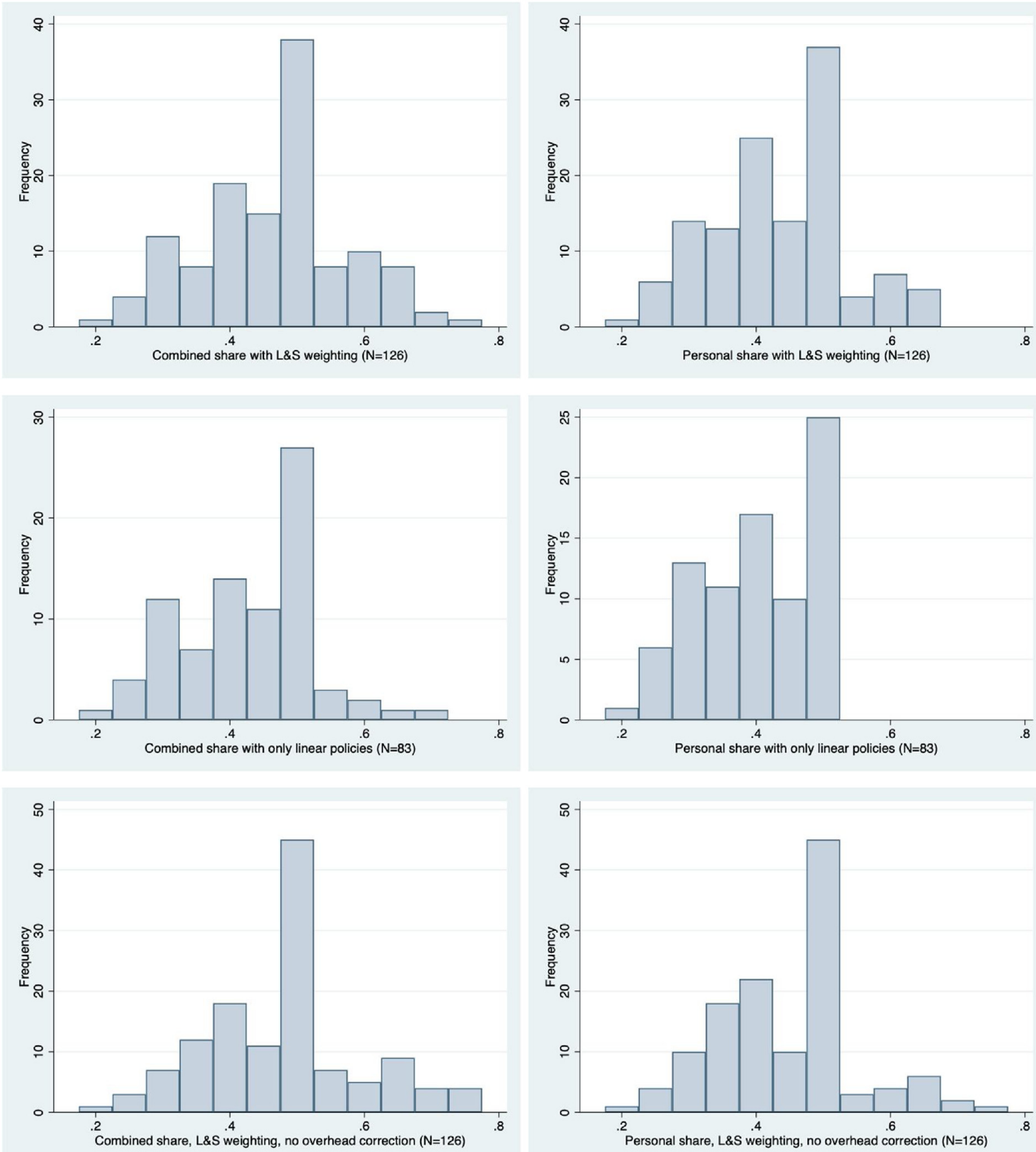

Fig. 6. Distributions of 2001 expected royalty shares.

outcome variables of interest just prior to changes in university policies.

4.2. Cross-sectional results

To assess the impact of the inventor's expected royalty share, we begin with the same cross-sectional analysis as L&S. Table 4 shows the results of regressing the natural logarithm of the net licensing income on the expected combined royalty share (including both personal and lab income) and controls from the NRC and AUTM surveys. (L&S regressed on the natural logarithm of net income rather than net income itself because of the nonlinear relationship they observed between inventor royalty share at net license income; we did not observe a similar relationship.)

Following L&S, data reported to AUTM is averaged over the period 1991–99 (excluding the latter portion of our dataset), and the expected royalty share is based on 2001 policies, averaged with earlier policies where available. The first two columns show the results from our dataset with different controls, and with the expected royalty share calculated as described by L&S. The third and fourth columns repeat the prior two specifications, but with the expected royalty share based on personal income alone (without the lab share), and without correcting for the TTO overhead. The fifth and sixth columns show L&S's results. L&S found a statistically significant coefficient on the expected share of just over 2, meaning that a 10-percentage-point increase in the expected share causes over a 20 % increase in net licensing

Table 3
Determinants of 2001 combined inventor and lab royalty shares (x100).

	Combined Share Weighted as in L&S		Without Lab Share & Overhead Correction		Comparison: L&S (2004) Table 3	
	1	2	3	4	5	6
NRC survey (1992–93)						
Faculty size	−0.15	−0.30	0.013	−0.05	−0.52	−1.27
('00 s)	(0.099)	(0.42)	(0.091)	(0.43)	(0.40)	(0.86)
Quality	−2.66	−1.63	−2.60	−2.09	−2.56	−1.28
	(2.29)	(1.72)	(2.17)	(1.58)	(3.67)	(2.45)
Private	−0.14	−0.62	−1.09	−1.48	−1.16	−3.18
	(1.99)	(2.26)	(2.12)	(2.17)	(2.91)	(2.97)
Publications	−0.03		−0.44		0.93	
/faculty	(0.94)		(0.91)		(0.97)	
Citations	0.03		0.019		−0.14	
/faculty	(0.05)		(0.054)		(0.08)	
Biomedical	2.58	4.39	2.66	2.85	0.28	0.21
	(6.26)	(5.87)	(6.18)	(5.55)	(9.77)	(11.6)
Other	14.27*	15.70*	7.90	7.67	−6.42	−4.83
biological	(7.73)	(7.96)	(6.80)	(6.59)	(9.41)	(11.2)
Computer	54.0**	51.1**	59.1**	58.3**	54.1	50.1
science	(23.3)	(22.3)	(24.4)	(23.9)	(38.1)	(42.1)
Chemical	−30.3**	−27.25**	−34.8***	−32.3***	−17.9	−16.1
science	(12.6)	(13.01)	(12.3)	(12.1)	(9.66)	(12.0)
Engineering	2.49	2.50	1.44	2.40	−13.8	−10.7
	(8.27)	(8.19)	(7.07)	(6.89)	(13.2)	(15.5)
AUTM survey (1991–99 avg)						
R&D		0.017*		−0.010		0.008
(millions)		(0.009)		(0.010)		(0.016)
TTO size		−0.43		0.50		0.91
		(0.59)		(0.56)		(0.64)
TTO age		−0.17		−0.12		−0.38***
		(0.10)		(0.14)		(0.10)
Constant	50.31***	48.52***	52.84***	50.57***		57.4***
	(7.23)	(6.30)	(7.00)	(5.90)		(13.2)
R^2	0.15	0.19	0.17	0.19	0.12	0.19
F-test: *p*-value	0.0000	0.0000	0.0000	0.0000	0.05	0.01
N	126	123	126	123	102	99

Notes: Robust standard errors in parenthesis; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Following L&S, expected royalty share includes both personal income and research income under the inventor's control, based on 2001 policies, which were averaged with any earlier policy from the 1990s. Nonlinear policies were weighted with 50.2 % in the first 0–$10,000 net licensing income band and 46.1 % in the second $10,000–$50,000 band, and the remaining 3.7 % in the third $50,000–$100,000 band. Technology field variables measure the percentage of faculty in each field; the omitted field is physical sciences.

income. We do not find a statistically significant result in any of our specifications.[14]

After L&S shared their dataset, we were able to determine that the source of their positive and statistically significant coefficient is differences in share information for some universities, and that the results seem sensitive to subtracting or adding a few universities. For example, for Carnegie Mellon University, L&S have an expected share of 97 % even though the university's IP policy has given the inventor 50 % of net patent income (with no lab share) since 1985. Changing this one value makes their correlation no longer statistically significant. Additionally, as noted above, there are inconsistencies in how L&S treat lab shares and TTO overhead fees. For a more detailed discussion of these discrepancies, see the Appendix.

Table 5 presents additional robustness checks on our result from Table 4. In addition to calculating the expected share for nonlinear policies using L&S's weighting of net income bands (which approximately averages the first two bands), we attempted averaging the first three bands; averaging the first four bands; only using data from schools with linear policies; and trying each of these approaches with only the inventor's personal share rather than the combined share that includes research funding for the inventor's lab. In no case did we observe coefficients similar to those found by L&S.

For Table 6, we conduct the same cross-sectional analysis for the early 1991–99 data using our three other outcome variables: (1) invention disclosures received, (2) patent applications filed, and (3) patents issued. If the incentive story were true, we would expect to see a positive effect on these outcomes: inventors who expect a higher royalty share would be incentivized to file more invention disclosures with their university TTO and to encourage the TTO to file more patent applications, leading to more issued patents. We find no evidence for such an effect. The coefficient on the expected royalty share variable is negative in all three regressions. Of course, given the size of the standard error, we cannot rule out a large positive effect, but the data do not show a statistically significant positive effect.

Table 7 presents the same cross-sectional analysis as above, but over the period 2000–13 rather than 1991–99. The expected share and AUTM data were averaged over this time period, and we used controls from the 2005–06 NRC survey rather than the 1992–93 survey.

4.3. Panel data results

As noted above, there are shortcomings in the identification approach used in the last section. The results could be biased. The royalty-share policy might be uncorrelated with observable characteristics but correlated with unobservable ones that relate to

[14] In an effort to reproduce L&S's result in column 5 (with a coefficient on the expected royalty share of 0.23, significant at the 5% level), we randomly drew 98 observations from our sample and ran the regression in column 1, repeating the exercise 10,000 times. Only 58 out of 10,000 resamples had a regression coefficient that was within 10% of L&S's, and none of them were statistically significant. We also attempted resampling to find the sets of universities with descriptive statistics that most closely matched L&S's, and then running the regression on those sets, but this was even less successful. We thank Sarah Kotb for this analysis.

Table 4
Linear Regression of Log Average Net Licensing income 1991–99.

	Combined Share Weighted as in L&S		Without Lab Share & Overhead Correction		Comparison: L&S (2004) Table 4	
	1	2	3	4	5	6
Expected royalty share	−0.19 (1.29)	−0.27 (1.22)	0.52 (1.33)	0.67 (1.21)	2.3** (1.1)	2.1** (1.0)
NRC survey (1992–93)						
Log faculty size	0.78*** (0.24)	0.30 (0.24)	0.80*** (0.24)	0.32 (0.24)	0.92*** (0.19)	0.25 (0.30)
Quality	0.83** (0.32)	0.47 (0.31)	0.83** (0.32)	0.46 (0.31)	0.64** (0.28)	−0.15 (0.31)
Private	0.69* (0.37)	0.80** (0.35)	0.71* (0.37)	0.82** (0.35)	0.22 (0.43)	0.52* (0.31)
Biomedical	0.43 (1.13)	0.04 (1.04)	0.40 (1.13)	0.002 (1.04)	−1.02 (1.23)	−0.76 (1.36)
Other biological	−0.25 (1.23)	0.03 (1.13)	−0.36 (1.16)	−0.14 (1.07)	−0.70 (0.98)	−1.07 (1.24)
Computer science	−0.96 (3.24)	−2.15 (2.83)	−1.29 (3.21)	−2.59 (2.78)	0.20 (2.46)	0.03 (2.68)
Chemical science	0.58 (2.96)	2.09 (2.84)	0.71 (2.96)	2.27 (2.89)	−0.95 (1.07)	−1.17 (1.72)
Engineering	2.43* (1.29)	1.72 (1.11)	2.39* (1.26)	1.64 (1.09)	0.49 (1.07)	−0.35 (1.42)
AUTM survey (1991–99 avg)						
Log R&D		0.71*** (0.26)		0.72*** (0.26)		1.15*** (0.38)
TTO size		0.070** (0.029)		0.069** (0.028)		0.013 (0.021)
TTO age		0.0012 (0.0096)		0.0025 (0.0099)		0.027*** (0.008)
Constant	5.81*** (1.43)	−3.55 (3.82)	5.42*** (1.45)	−4.21 (3.87)		
R^2	0.54	0.61	0.54	0.61	0.48	0.66
N	106	105	106	105	98	97

Notes: Robust standard errors in parenthesis; $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Following L&S, expected royalty share is based on 2001 policies, which were averaged with any earlier policy from the 1990s. Nonlinear policies were weighted with 50.2 % in the first 0–$10,000 net licensing income band and 46.1 % in the second $10,000–$50,000 band, and the remaining 3.7 % in the third $50,000–$100,000 band. Technology field variables measure the percentage of faculty in each field; the omitted field is physical sciences. Note that L&S used the royalty share x100, so the coefficients.

Table 5
Robustness Checks: Changes to Expected Share Coefficient from Table 4 Based on Different Methods of Calculating Expected Share.

Expected Royalty Share	Coefficient from Col. 1 Specification (Robust Std. Err.)		Coefficient from Col. 2 Specification (Robust Std. Err.)	
combined share, L&S weighting (Table 4, columns 1–2)	−0.19	(1.29)	−0.27	(1.22)
personal share, L&S weighting	−0.25	(1.40)	0.10	(1.32)
combined share, L&S weighting, without overhead correction	0.49	(1.30)	0.32	(1.19)
personal share, L&S weighting, without overhead correction (Table 4, columns 3–4)	0.52	(1.33)	0.67	(1.21)
combined share, 1st 3 income bands equally weighted	−0.58	(1.33)	−0.62	(1.30)
personal share, 1st 3 income bands equally weighted	−0.91	(1.50)	−0.40	(1.44)
combined share, 1st 4 income bands equally weighted	−0.98	(1.32)	−1.03	(1.31)
personal share, 1st 4 income bands equally weighted	−1.76	(1.60)	−1.18	(1.57)
combined share, only linear (constant-share) policies	−0.84	(1.54)	−0.83	(1.44)
personal share, only linear (constant-share) policies	−0.72	(1.87)	0.30	(1.66)
combined share, only linear policies, without overhead correction	−0.20	(1.58)	−0.45	(1.50)
personal share, only linear policies, without overhead correction	0.25	(1.85)	0.93	(1.69)

licensing income. And in our data, as Table 3 showed, we find that even the observable characteristics are strongly associated with the royalty-share policy; given that, there is little reason to expect there not to be unobserved correlated differences as well. Lach and Schankerman (2008) attempted to address this problem by using pre-sample information on the university's patenting activity. They note that "[i]t would be more convincing if [they] could control for fixed university effects," but they explain that for their data, "there is not sufficient variation over time in the royalty sharing arrangements to permit this."

Fortunately, as noted above, our dataset stretches over a longer period and includes substantial variation in royalty-sharing policies across time, allowing us to control for fixed effects across both universities and time. A panel data model with fixed effects focuses on within-university variation—that is, what happens within a given university when it changes its policy over time—which reduces the problem of omitted variable bias.

Unfortunately, this approach will not work for the licensing income outcome variable because income received in a given year will generally stem from patents filed many years earlier.[15] The

[15] The current patent term is twenty years from the effective filing date, with potential adjustments. For patents filed before June 8, 1995 (which will include many

Table 6
Linear Regression of Average Invention Disclosures, Patent Applications, and Issued Patents 1991–99.

	Disclosures	Patent Apps	Issued Patents
Expected combined royalty share	−36.3	−17.4	−9.41
	(37.9)	(13.5)	(7.46)
NRC survey (1992–93)			
Log faculty size	−4.43	−1.79	−0.89
	(6.32)	(2.19)	(1.31)
Quality	14.8	6.05	2.98
	(11.9)	(3.84)	(2.10)
Private	−0.43	3.34	2.53*
	(5.10)	(2.22)	(1.51)
Biomedical	−0.84	−3.16	−1.89
	(17.1)	(5.88)	(4.19)
Other biological	−13.9	−1.71	−3.19
	(17.1)	(6.94)	(5.06)
Computer science	−37.7	−10.2	−6.45
	(44.8)	(20.7)	(13.8)
Chemical science	−7.79	−8.87	−3.89
	(26.5)	(9.70)	(7.33)
Engineering	28.2*	6.70	5.18
	(16.6)	(6.03)	(4.43)
AUTM survey (1991–99 avg)			
Log R&D	14.23***	5.74***	2.76**
	(4.92)	(2.07)	(1.19)
TTO size	13.91***	5.04***	4.25***
	(0.64)	(0.22)	(0.19)
TTO age	0.49**	0.154	0.226*
	(0.23)	(0.110)	(0.127)
Constant	−239.9***	−95.3***	−47.2**
	(84.0)	(33.8)	(19.1)
R^2	0.865	0.846	0.870
N	123	122	123

Notes: Robust standard errors in parenthesis; $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Expected royalty share was calculated as in Table 4, columns 1 and 2.

Table 7
Linear Regression of Average Outcome Variables 2000–2013.

	Disclosures	Patent Apps	Issued Patents	Log Net Inc.
Expected combined royalty share	−21.6	−10.2	−16.8	−0.75
	(45.9)	(47.7)	(13.7)	(1.55)
NRC survey (2005-06)				
Log faculty size	3.50	−6.91	−0.71	0.43
	(18.6)	(17.8)	(5.94)	(0.43)
Citations/faculty	17.08**	16.47*	5.38*	0.39
	(8.12)	(8.85)	(3.09)	(0.35)
Private	18.5	22.9	6.38	0.73
	(14.4)	(13.8)	(4.63)	(0.50)
Biomedical	−166.3*	−213.6**	−62.4**	−0.91
	(97.4)	(82.3)	(28.5)	(1.64)
Other biological	−86.6	−138.0**	−32.6	−0.06
	(67.4)	(58.8)	(20.8)	(1.68)
Computer science	−134.3	−280.8*	−51.9	3.28
	(162.2)	(144.6)	(50.0)	(4.77)
Chemical science	217.2**	132.7	42.3	4.98
	(87.0)	(81.1)	(26.4)	(4.08)
Engineering	11.6	−28.5	1.05	−1.82
	(67.7)	(64.7)	(21.9)	(2.10)
AUTM survey (2000-13 avg)				
Log R&D	32.7*	32.7*	8.58	1.02***
	(19.3)	(18.6)	(6.11)	(0.33)
TTO size	16.95***	9.62***	3.90***	0.016
	(1.08)	(1.05)	(0.31)	(0.027)
TTO age	0.014	0.212	0.16	0.015
	(0.416)	(0.406)	(0.19)	(0.010)
Constant	−614.2***	−523.0**	−146.2**	−8.92*
	(225.7)	(228.7)	(71.8)	(5.16)
R^2	0.915	0.808	0.847	0.567
N	107	107	107	98

Notes: Robust standard errors in parenthesis; $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Expected shares for nonlinear policies were calculated using the same weights as in Table 4, but averaged over policies from 2000–13. Technology field variables measure the percentage of faculty in each field; the omitted field is physical sciences.

Table 8
University and Year Fixed Effects Models.

A. Raw outcome variables as in Table 6			
	Disclosures (no lag)	Patent Apps (no lag)	Issued Patents (3-yr lag)
Expected combined royalty share	−131**	−113**	−13.6
	(51.4)	(49.3)	(11.1)
R^2	0.85	0.71	0.88
N	2172	2140	1715
B. Outcome variables scaled by faculty in NRC 2005–06 (All Schools)			
	Disclosures per Fac (no lag)	Patent Apps per Fac (no lag)	Iss Patents per Fac (3-yr lag)
Expected combined royalty share	−0.04	−0.05	0.02
	(0.07)	(0.08)	(0.03)
R^2	0.82	0.70	0.78
N	2009	1981	1612
C. Outcome variables scaled by faculty in NRC 2005–06 (Schools Above Median Faculty)			
	Disclosures per Fac (no lag)	Patent Apps per Fac (no lag)	Iss Patents per Fac (3-yr lag)
Expected combined royalty share	−0.12**	−0.12*	−0.01
	(0.05)	(0.06)	(0.01)
R^2	0.79	0.68	0.75
N	1007	998	836

Notes: Standard errors clustered by university; $^{**}p < 0.05$, $^{*}p < 0.1$. Expected shares for nonlinear policies were calculated using the same weights as in Table 4.

other outcome variables should be more immediately responsive to changes in the inventor's royalty share, although there will be a lag before royalty policies can affect issued patents because patents take an average of almost three years to issue. And depending on the incentive mechanism, one might expect an additional lag for the time spent conducting new research between a change in policy and the ability to disclose a patentable invention.

Table 8(A) presents the results of regressing invention disclosures, patent applications, and issued patents on the expected combined royalty share with university and year fixed effects, using a three-year lag for issued patents.[16] Although the incentive story would predict that higher shares would lead to more disclosures, applications, and issued patents, we in fact find the opposite for all three outcomes, though it is only significant for the first two. For example, a ten-percentage-point increase in expected share leads to an average of about twelve *fewer* invention disclosures. This negative coefficient is not implausible: a higher inventor's share implies a smaller share for other parts of the university, and if patent-related activity is primarily driven by top-down encouragement rather than faculty coming forth unprompted, one might expect smaller shares for the university administration to lead to less patent-related activity.

But note that this result seems to be driven by large universities with many disclosures. Table 8(B) shows that when the outcome variables are scaled by the number of faculty at each university,

patents generating licensing income in this dataset), the term is 17 years from the date of grant. In either case, the patent term is almost as long as the 23-year period of our dataset.

[16] Adding an additional two-year lag to all three regressions to account for research time between the announcement of a new policy and having a patentable invention does not change these results. Note that faculty size, quality, and research orientation cannot be included as controls in Table 8 because we do not have year-by-year data for them (only the two NRC snapshots), but the fixed effects approach accounts for variation across universities. It does not account for *time-varying* differences, so we can include the (potentially endogenous) controls from the AUTM dataset for R&D expenditures, TTO size, and TTO age, which produce similar coefficients for the expected share.

the expected share coefficients become close to zero and non-significant. When these regressions are then repeated for only schools above the median number of faculty, the share coefficient declines across all outcomes and becomes significant for the disclosures outcome, as seen in Table 8(C). This may indicate that patent disclosures are driven more by TTO recruitment efforts than by faculty volunteers, but as noted above, we cannot rule out that universities may have increased faculty royalty shares in response to exogenous events—such as a decline in our outcome variables or a general downturn in the local economy—when they believe that failing to increase royalty share incentives would mean an even sharper decline in faculty patenting.

Which specification one finds most convincing will depend on the population of interest. For understanding the impact on individual faculty, independent of their university, Table 8(B) is likely most appropriate. But across all specifications, both in Table 8 and in the earlier cross-sectional analyses, we have never observed higher expected royalty shares—through any means of calculation—to have a statistically significant positive effect on any of the outcomes of interest.

4.4. Moves between universities by active patenters

We conducted one additional set of analyses, focused on lateral moves between universities by the most active patenters, that was inspired by the statement in Lach and Schankerman (2008) that "[r]oyalty incentives work both by raising faculty effort and sorting scientists across universities." Universities might be inclined to raise the inventor's share of patent revenue not only to spur faculty participation in the patenting process but also to attract patenting faculty to their institutions.

Using a list of all inventors who had ten or more U.S. patents assigned to a university in the ten years prior to 2016, we determined that 777 were U.S. faculty (at least at some point in their careers), and of those, 244 (31 %) had moved between institutions.[17] Only seven of these faculty members moved from academia to industry,[18] and all but two of those moved back to academia. Another nine moved from U.S. universities to foreign universities, and none of them returned to the United States. When we look at the number of lateral moves between U.S. universities where we had a royalty policy at the time of the move, and where we were able to convert the policy to an expected share (i.e., excluding the policies based in part or whole on gross licensing income), there were 133 lateral moves.

If any faculty are influenced by the inventor share in official university patent policies, it is likely to be the faculty who patent most frequently. On average, one might thus expect active patenters to move to universities that offer a higher share of patent royalties. As Fig. 7 illustrates, we do not find this result. Out of 133 moves, only 43 were to schools with a higher expected share; 68 were to schools with a lower share, and in the remaining 22, there was no change. Nor is it true that the moves to higher-share schools involved larger changes. Rather, the average change in the combined expected share (calculated as in Table 4) is −3.2 %. The standard deviation is 13 %, so we cannot exclude a large positive effect, but we do not observe the strong positive effect that the incentive story would suggest. This result holds if the sample is restricted to even more

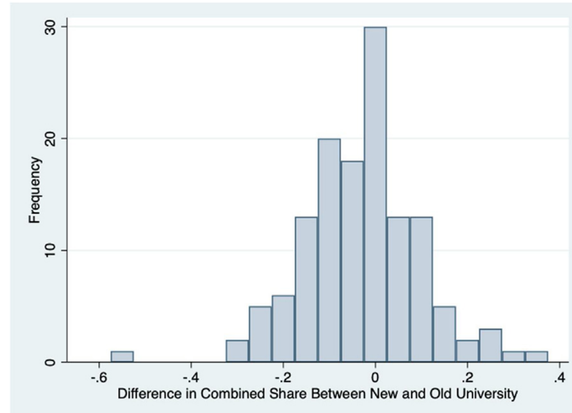

Fig. 7. Change in Combined Expected Share for Moves Between Universities by the Most Active Patenters.

active patenters: for the 21 faculty with thirty or more patents in ten years, the average change is −4.1 % (std. dev. = 12 %).

To be clear about the limitations of this analysis, we did not examine each faculty member's productivity at their old or new university. It is possible, for example, that an academic scientist could move from a school with a high share where she filed many patents to a lower-share school where she stops patenting. But we do not find evidence that official policies are driving these professors' decisions to move between universities.

This conclusion is supported by our results above: We would expect any sorting effect to show up in our cross-sectional and fixed effects regressions because it would be one of the explanations for additional patent-related activity in additional to greater researcher effort. The fact that we were unable to observe a statistically significant effect from increasing researcher royalty shares provides an additional reason to doubt that royalty shares have a significant effect in attracting (or repelling) faculty.

4.5. Caveats

In sum, our data do not support the claim that increasing the inventor's share in a university patent policy causes greater faculty participation in the technology transfer process. None of our analyses show a statistically significant positive relationship between the inventor's share—calculated various ways—and invention disclosures, patent applications, issued patents, or net licensing income. Nor do we find that the most active faculty patenters tend to move to universities offering higher shares. Our results call into question L&S's findings, and we do not believe policymakers should rely on their results in crafting university patent policy until the key questions we raise here are resolved.

But our conclusions should be interpreted in an appropriately limited way, and we offer four such caveats here. First, we do not claim that there is no relationship between financial incentives from patents and faculty behavior—only that we do not observe one using the data we believe would be most likely to show it. Relatedly, our data do not address any non-financial incentives that academic researchers might receive from patents.

Second, our conclusions are based on each university's *official* patent royalty-sharing policy. But it is possible that posted royalty rates do not reflect the share received by some university researchers. Based on conversations with about a half-dozen technology transfer officials at a range of universities with significant licensing experience, our understanding is that faculty occasionally negotiate different rates in individualized deals. But these officials stated that non-standard agreements were the exception rather than the rule, and that deviations from the official policy

[17] The list of inventors with ten or more patents was compiled by Daniel E. Ho based on USPTO data for a separate project with Lisa Larrimore Ouellette. Moves between institutions were determined from each faculty's curriculum vitae or biography. Where a biography was unavailable, we tracked affiliation on scholarly papers.

[18] They moved from Stanford University Medical Center, the University of Arkansas, the University of Iowa, the University of Michigan, the University of Pennsylvania, the University of Wisconsin–Madison, and Ohio State University.

typically involved aspects of the license other than the inventor's share—particularly because TTOs worry about setting a precedent for future deals. For example, the head of one large TTO that typically files over 200 patent applications each year told us that in the past year, the single policy waiver related to royalty shares was simply to make clear that a soon-to-be-implemented new policy would cover the invention. When there is negotiation over the inventor's share, the TTO representatives suggested that it tends to be over how the share is split among joint inventors rather than the overall rate. In any case, this caveat does not affect our conclusion that increasing the inventor's share in a university's official policy does not seem to increase any of the outcomes that seem most likely to be affected—which may be relevant to universities contemplating future policy changes. Nonetheless, one should be cautious about extrapolating from our data to royalty-sharing rates in practice.

Third, as Markman et al. (2008) have documented, faculty members sometimes bypass university TTOs and patent inventions themselves. The practice is not necessarily lawful—the fruits of publicly funded research are supposed to belong to the university under Bayh–Dole, and even for non-Bayh–Dole patents, academic inventors typically assign IP rights to the university.[19] If bypassing is a frequent practice, however, it could mean that data reported by AUTM does not tell the whole story about individual researchers' patenting practices. But this phenomenon is unlikely to affect our results. First, if the outcome of interest is technology transfer *through the university*, then inventions that bypass this route should not be counted as part of the outcome variables. More importantly, if the outcome of interest is all technology transfer activity by faculty, these undercounted inventions are likely to *understate* our conclusion. If anything, one would expect faculty to be more likely to bypass their TTO—resulting in less patent-related activity in the AUTM statistics—when the inventor's share is *lower*. If we had found a positive correlation between inventor's share and these technology transfer metrics, the bypassing effect would call that correlation into doubt. But as explained above, we did not observe this correlation.

Fourth, our analysis is limited to existing university patent royalty-sharing policies, all of which offer *some* non-zero share, as required by Bayh–Dole. The minimum net-income inventor's share in our dataset was Caltech's 15 % share before 1994; the next smallest share was 25 %, offered by eight schools. We cannot conclude that nothing would happen if the inventor share were reduced to zero. Nonetheless, we can say that we do not see an effect on patenting activity from offering substantially higher shares—there are many schools in our dataset offering shares of 50 % or more. Our results thus suggest that reducing inventor's shares at many schools would not have a measurable effect on faculty patenting activity. As noted previously, the Stevenson–Wydler Act mandates that inventors at federal laboratories receive the first $2000 of royalties each year plus 15 % of any additional royalties; such a policy may be appropriate for other federally funded researchers as well.

5. Implications and conclusion

University researchers play an important role in U.S. innovation and Bayh–Dole policy. And yet we still know little about whether the financial promise of patent revenue affects university researchers' incentives to innovate and commercialize their research. In this paper, we have cast doubt on earlier conclusions that providing greater financial incentives to university researchers to patent (by increasing their relative royalty share from patent licensing) increases patent license income for universities. We have similarly been unable to conclude that higher inventor's royalty shares have any effect on the number of invention disclosures or patent applications at a university. We have also been unable to show that it influences sorting between universities among the most active patenters—those faculty who would presumably be the most sensitive to differences in royalty-sharing policies.

The lack of any strong impact of higher patent royalty shares on the behavior one would expect to be most affected suggests that an important pivot might be warranted with respect to university royalty-sharing policy. From a social welfare perspective, university patent royalties may not be optimally allocated between researchers and universities. We have not found evidence that decreasing the percentage of patent income provided to inventors as personal income would have a deleterious effect on researchers' behavior. Reducing their royalty share also would not affect any non-financial benefits that patents already give to researchers, such as reputational rewards. And reducing inventors' personal shares of patent income would have the benefit of increasing universities' shares, leading to increased investment in science research and education. Even if some of this extra money for universities is used for improving the quality of a TTO, this may be a more effective way to increase faculty incentives to patent than giving the money to faculty directly.[20] At the very least, we would caution universities against relying on the conclusions of L&S in support of increases to their inventors' shares.

These conclusions may also have implications for non-university patent policy. It is often assumed that universities are a special case. But corporate researchers at for-profit firms are in many ways similar to academic researchers. Indeed, science and engineering graduate students often debate whether to pursue careers in industry or academia, with their choice often forced by fluctuations in the academic job market, and some researchers move between the two settings over their careers. Corporate researchers often get a fixed salary, without any special bonus based on patents. As Lobel (2017) explains, "[a]n anomaly of the American legal system is the complete absence of any requirement for businesses to compensate their employed inventors," unlike many other countries. Lobel and other scholars argue that corporate inventors should be paid more like university inventors—that is, that they should receive bonuses based on the financial success of their inventions. But given our inability to find a strong effect in the university context, it seems worth investigating whether this intervention would in fact impact the behavior of corporate researchers.

More broadly, our results also show that predicting the incentive effect of patents is more difficult than it may at first appear, and that patent policy should be driven by rigorous attention to empirical outcomes rather than by predictions about incentives, however plausible those predictions might seem (Ouellette, 2015). Although some universities may have changed their policies to offer inventors a higher patent royalty share based on the reasonable hypothesis that this would increase patenting activity by faculty, our results suggest that this hypothesis may not match up with real-world outcomes. As discussed above, there are numerous reasons that we cannot rule out a positive incentive effect from patents. But we think the lack of compelling evidence of such a benefit should put pressure on university technology transfer offices and

[19] It might seem surprising that university TTOs would allow professors to bypass their legal obligations, but Rai and Sampat (2012) have shown that these offices often fail to comply with their own obligations, and many universities might rationally choose not to sue their own faculty.

[20] Faculty surveys suggest that perceptions of TTOs as high quality and efficient are a key factor in faculty motivations to patent (Owen-Smith and Powell, 2001). Similarly, a technology transfer official from a large state school informed us that their internal surveys about the faculty experience with technology transfer showed that the biggest complaints are delays and the appearance of unresponsiveness.

Bayh–Dole defenders to develop the case for patents that are not justified by their commercialization benefit.

Appendix A

We are grateful to Mark Schankerman for generously providing some of the data analyzed in Lach and Schankerman (2008), which enabled our comparison with their results. As discussed above, to facilitate comparison of complex royalty-sharing policies, they converted each policy to a single expected inventors' share. Table A1 compares their expected inventors' share with the corresponding royalty-sharing policy information we independently gathered for these 101 U.S. universities: 34 private universities and 67 public universities. (As noted above, the total is 101 rather than the 102 reported by Lach and Schankerman because one school on their list of public U.S. universities is the University of Victoria, which is located in Canada.)

Shading in the "Expected Share" column indicates that our expected inventors' share is at least five percentage points different from theirs. Shading in the "Laboratory Share" or "Overhead" columns indicate that this information does not seem to have been accounted for by Lach and Schankerman (contrary to their reported coding methodology). Rows without inventor shares indicate that we were unable to obtain policy information back to at least 2001 for these schools. The policies we found—including for more recent policies used for our panel data results—are documented at http://universitypatentdata.com.

Table A1
Royalty-Sharing Policy Information for 101 U.S. Universities.

Private Institutions (N = 34)	Expected Share		Personal Income Share							Laboratory Share							Overhead
	L&S	Our Data	$0-10k	$10-50k	$50-100k	$100-300k	$300-500k	$500k-1M	>$1M	$0-10k	$10-50k	$50-100k	$100-300k	$300-500k	$500k-1M	>$1M	
Albert Einstein/Yeshiva	0.33	0.67	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	
Baylor College of Medicine	0.49	0.43	0.50	0.50	0.50	0.50	0.50	0.50	0.50								0.15
Brandeis Univ.	0.40	0.50	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.10	0.10	0.10	0.10	0.10	0.10	0.10	
Brigham Young Univ.	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45								
Brown Univ.	0.49	0.50	0.50	0.50	0.50	0.25	0.25	0.25	0.20								
Caltech*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25								
Carnegie Mellon Univ.	0.97	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Case Western Reserve Univ.	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Columbia Univ.	0.49	0.60	0.50	0.50	0.50	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.20
Cornell Univ.*	0.49	0.50	0.50	0.50	0.50	0.25	0.25	0.25	0.25								
Dartmouth College	0.50	0.58	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.08	0.08	0.08	0.08	0.08	0.08	0.08	
Emory Univ.	0.40	0.60	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.20	0.20	0.20	0.20	0.20	0.20	0.20	
Georgetown Univ.*	0.50	0.43	0.50	0.50	0.50	0.50	0.50	0.50	0.50								0.15
Harvard Univ.	0.34	0.50	0.35	0.35	0.25	0.25	0.25	0.25	0.25	0.15	0.15	0.20	0.20	0.20	0.20	0.20	
Illinois Inst. of Tech.	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Johns Hopkins Univ.	0.34	0.65	0.35	0.35	0.35	0.30	0.30	0.30	0.15	0.30	0.30	0.30	0.30	0.25	0.25	0.25	
MIT	0.33	0.28	0.33	0.33	0.33	0.33	0.33	0.33	0.33								0.15

Table A1 (*Continued*)

Private Institutions (N = 34)	Expected Share		Personal Income Share							Laboratory Share							Overhead
	L&S	Our Data	$0-10k	$10-50k	$50-100k	$100-300k	$300-500k	$500k-1M	>$1M	$0-10k	$10-50k	$50-100k	$100-300k	$300-500k	$500k-1M	>$1M	
Northeastern Univ.**	0.30	0.60	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	
Northwestern Univ.*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25								
Princeton Univ.	0.49	0.50	0.50	0.50	0.50	0.40	0.40	0.30	0.30								
Stanford Univ.	0.33	0.28	0.33	0.33	0.33	0.33	0.33	0.33	0.33								0.15
Syracuse Univ.	0.50	0.43	0.50	0.50	0.50	0.50	0.50	0.50	0.50								0.15
Thomas Jefferson Univ.	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40								
Univ. of Chicago**,***	0.25	0.35	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.10	0.10	0.10	0.10	0.10	0.10	0.10	
Univ. of Dayton	0.50	0.40	0.50	0.50	0.50	0.50	0.50	0.50	0.50								0.20
Univ. of Denver	0.64	0.55	0.70	0.40	0.33	0.33	0.33	0.33	0.33								
Univ. of Miami	0.33																
Univ. of Pennsylvania*	0.49	0.45	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.15	0.15	0.15	0.15	0.15	0.15	0.15	
Univ. of Rochester*	0.49	0.50	0.50	0.50	0.40	0.39	0.35	0.35	0.35								
Univ. of Tulsa	0.45	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40								
Vanderbilt Univ.	0.49	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40								
Wake Forest Univ.**	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35								
Washington Univ. in St. Louis*	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45								
Yale Univ.*	0.49	0.45	0.50	0.50	0.50	0.35	0.30	0.30	0.30								0.10

Public Institutions (N = 67)	Expected Share		Personal Income Share							Laboratory Share							Overhead
	L&S	Our Data	$0-10k	$10-50k	$50-100k	$100-300k	$300-500k	$500k-1M	>$1M	$0-10k	$10-50k	$50-100k	$100-300k	$300-500k	$500k-1M	>$1M	
Auburn Univ.*	0.49	0.49	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.09	0.09	0.09	0.09	0.09	0.09	0.09	
Ball State Univ.	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Clemson Univ.	0.39	0.40	0.40	0.40	0.20	0.20	0.20	0.20	0.20	0.00	0.00	0.20	0.20	0.20	0.20	0.20	
Colorado State Univ.*	0.44	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35								
Florida Atlantic Univ.	0.69	0.66	0.75	0.50	0.35	0.35	0.35	0.35	0.35	0.03	0.05	0.07	0.07	0.07	0.07	0.07	
Florida State Univ.**	0.76	0.63	0.85	0.40	0.40	0.40	0.40	0.40	0.40								
Indiana Univ.*	0.49	0.50	0.50	0.50	0.50	0.40	0.35	0.30	0.25								
Iowa State Univ.	0.33	0.28	0.33	0.33	0.33	0.33	0.33	0.33	0.33								0.15
Kansas State Univ.	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25								
Louisiana State Univ.	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40								
Medical College of Ohio	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Michigan State Univ.**	0.38	0.37	0.40	0.33	0.33	0.30	0.30	0.20	0.15								
Mississippi State Univ.	0.49	0.63	0.75	0.50	0.50	0.50	0.50	0.50	0.50								
Montana State Univ.	0.49	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
New Jersey Inst. of Tech.	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35								
North Dakota State Univ.	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30								
Ohio State Univ.**	0.49	0.50	0.50	0.50	0.42	0.33	0.33	0.33	0.33								
Ohio Univ.	0.49	0.50	0.50	0.50	0.50	0.30	0.30	0.30	0.30								
Oregon State Univ.	0.39	0.40	0.40	0.40	0.35	0.30	0.30	0.30	0.30								
Penn State Univ.	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40								
Rutgers the State Univ. of NJ	0.25	0.44	0.63	0.25	0.28	0.28	0.28	0.28	0.28								
SUNY**	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40								
Temple Univ.	0.49	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Texas A&M Univ. System	0.50	0.43	0.50	0.50	0.50	0.50	0.50	0.50	0.50								0.15
Univ. of Akron**	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65								
Univ. of Alabama in Birmingham	0.70	0.56	0.75	0.56	0.50	0.30	0.30	0.30	0.30								0.15
Univ. of Alabama in Huntsville	0.69	0.59	0.70	0.70	0.40	0.40	0.40	0.40	0.40								0.15

Table A1 (*Continued*)

Public Institutions (N = 67)	Expected Share		Personal Income Share							Laboratory Share							Overhead
	L&S	Our Data	$0-10k	$10-50k	$50-100k	$100-300k	$300-500k	$500k-1M	>$1M	$0-10k	$10-50k	$50-100k	$100-300k	$300-500k	$500k-1M	>$1M	
Univ. of Arizona	0.45																
Univ. of Arkansas	0.49	0.50	0.50	0.50	0.50	0.43	0.35	0.35	0.35								
Univ. of Cal. System*	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35								
Univ. of Central Florida	0.49																
Univ. of Cincinnati	0.59	0.59	0.60	0.60	0.40	0.30	0.30	0.30	0.30								
Univ. of Colorado	0.25	0.48	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.04
Univ. of Connecticut	0.33	0.50	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.17	0.17	0.17	0.17	0.17	0.17	0.17	
Univ. of Delaware	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33								
Univ. of Florida	0.39	0.50	0.40	0.40	0.40	0.40	0.40	0.25	0.25	0.10	0.10	0.10	0.10	0.10	0.10	0.10	
Univ. of Georgia	0.86	0.68	1.00	0.25	0.25	0.25	0.25	0.25	0.25	0.00	0.10	0.10	0.10	0.10	0.10	0.10	
Univ. of Hawaii	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Univ. of Illinois Urbana Champaign	0.40	0.50	0.50	0.50	0.50	0.38	0.25	0.25	0.25								
Univ. of Iowa	0.33	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25								
Univ. of Kansas	0.49	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25								
Univ. of Kentucky	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40								
Univ. of Louisville	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Univ. of Maryland Baltimore	0.50	0.63	0.75	0.50	0.50	0.50	0.50	0.50	0.50								
Univ. of Maryland College Park	0.50	0.63	0.75	0.50	0.50	0.50	0.50	0.50	0.50								
Univ. of Massachusetts Amherst	0.29	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30								
Univ. of Michigan*	0.49	0.50	0.50	0.50	0.50	0.42	0.33	0.33	0.33								
Univ. of Minnesota	0.33	0.59	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
Univ. of Missouri System	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33								
Univ. of New Hampshire	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30								
Univ. of New Orleans	0.40																
Univ. of North Carolina Chapel Hill	0.50	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40								
Univ. of North Texas	0.49	0.50	0.50	0.50	0.25	0.25	0.25	0.25	0.25	0.00	0.00	0.25	0.25	0.25	0.25	0.25	
Univ. of Oklahoma**	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35								
Univ. of Oregon	0.39	0.40	0.40	0.40	0.35	0.30	0.30	0.30	0.30								
Univ. of Pittsburgh	0.46	0.45	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.15	0.15	0.15	0.15	0.15	0.15	0.15	
Univ. of South Carolina	0.40	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30								
Univ. of Tennessee	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Univ. of Texas at Austin	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Univ. of Texas Hlth Sci Ctr Houston	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Univ. of Texas Medical Branch at Galveston	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Univ. of Texas Southwestern Med. Ctr.	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50								
Univ. of Utah	0.38	0.37	0.40	0.35	0.30	0.30	0.30	0.30	0.30								
Univ. of Virginia*	0.49	0.58	0.50	0.50	0.50	0.30	0.25	0.25	0.15	0.08	0.08	0.08	0.20	0.15	0.15	0.15	
Univ. of Washington	0.89	0.55	1.00	0.45	0.30	0.30	0.30	0.30	0.30								0.24
Univ. of Wisconsin Madison**	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20								
Wayne State Univ.	0.69	0.63	0.75	0.50	0.50	0.40	0.40	0.40	0.35								

Notes: * University changed its royalty-sharing policy during the 1990s; policy information here is for 1999 except for the University of Wisconsin (information is correct for 1991–97; in 1998 the policy added a lab share of 70 % for the first $100,000 of income) and Northwestern (information is correct for 1991–98, but the 1999 policy increased the personal share to 30 %, added a 20 % lab share, and added a 20 % overhead fee). Policy changes are not always reflected in Lach and Schankerman's data; for example, their information for Washington University in St. Louis is correct for the policy starting July 1998, but the earlier policy provided a higher personal share of 50 %.
** Inventors' shares are computed at least in part out of gross rather than net license income, making it difficult to compare these policies with more typical net-income policies.
*** The University of Chicago had no standardized policy until 2002, so these shares did not apply in the 1990s.

References

Agrawal, A., Henderson, R., 2002. Putting patents in context: exploring knowledge transfer from MIT. Manage. Sci. 48 (1), 44–60.

Arqué-Castells, P., Cartaxo, R.M., García-Quevedo, J., Godinho, M.M., 2016. Royalty sharing, effort and invention in universities: evidence from Portugal and Spain. Res. Policy 45 (9), 1858–1872.

Åstebro, T., Jeffrey, S.A., Adomdza, G.K., 2007. Inventor perseverance after being told to quit: the role of cognitive biases. J. Behav. Decis. Mak. 20 (3), 253–272.

AUTM, 2014. AUTM STATT: Statistics Access for Technology Transfer Database. https://autm.net/surveys-and-tools/databases/statt.

AUTM, 2015. AUTM Licensing Survey: 2014 Instructions and Definitions. https://www.autm.net/AUTMMain/media/Resources/Documents/AUTM_FY2014_Licensing_Survey_Instructions_Definitions.pdf.

Azoulay, P., Ding, W., Stuart, T., 2007. The determinants of faculty patenting behavior: demographics or opportunities? J. Econ. Behav. Organ. 63 (4), 599–623.

Azoulay, P., Ding, W., Stuart, T., 2009. The impact of academic patenting on (public) research output. J. Ind. Econ. 57 (4), 637–676.

Ayres, I., Ouellette, L.L., 2016. A market test for Bayh–Dole patents. Cornell Law Rev. 102 (2), 271–334.

Bagley, M.A., 2006. Academic discourse and propriety rights: putting patents in their proper place. Boston College Law Rev. 47 (2), 217–274.

Baldini, N., 2010. Do royalties really foster university patenting activity? An answer from Italy. Technovation 30 (2), 109–116.

Clements, J.D., 2009. Improving Bayh–dole: a case for inventor ownership of federally sponsored research patents. IDEA 49 (4), 469–516.

Colaianni, A., Cook-Deegan, R., 2009. Columbia University's axel patents: technology transfer and implications for the Bayh-Dole act. Milbank Q. 87 (3), 683–715.

Conti, A., Liu, C.C., 2015. Bringing the lab back in: personnel composition and scientific output at the MIT Department of Biology. Res. Policy 44 (9), 1633–1644.

Czarnitzki, D., Doherr, T., Hussinger, K., Schliessler, P., Toole, A.A., 2016. Knowledge creates markets: the influence of entrepreneurial support and patent rights on academic entrepreneurship. Eur. Econ. Rev. 86, 131–146.

Economist, 2002. Innovation's golden goose. Economist (Technol. Q.) 365, 3.

Eisenberg, R.S., 1996. Public research and private development: patents and technology transfer in government-sponsored research. Virginia Law Rev. 82 (8), 1663–1727.

Eisenberg, R.S., Cook-Deegan, R., 2018. Universities: The fallen angels of Bayh–Dole? Daedalus 147 (4), 76–89.

Fabrizio, K.R., Di Minin, A., 2008. Commercializing the laboratory: faculty patenting and the open science environment. Res. Policy 37 (5), 914–931.

Goldfarb, B., Marschke, G., Smith, A., 2009. Scholarship and inventive activity in the university: complements or substitutes? Econ. Innov. New Technol. 18 (8), 743–756.

Gruschcow, J.M., 2004. Measuring secrecy: a cost of the patent system revealed. J. Legal Stud. 33 (1), 59–84.

Guberman, J., Shapiro, B., Torchia, M., 2006. Making the Right Moves: A Practical Guide to Scientific Management for Postdocs and New Faculty. Howard Hughes Medical Institute and Burroughs Wellcome Fund.

Hemel, D.J., Ouellette, L.L., 2013. Beyond the patents–prizes debate. Texas Law Rev. 92 (2), 303–382.

Hemel, D.J., Ouellette, L.L., 2017. Bayh–Dole beyond borders. J. Law Biosci. 4 (2), 282–310.

Hemel, D.J., Ouellette, L.L., 2019. Innovation policy pluralism. Yale Law J. 128 (3), 544–614.

Hoag, H., 2015. Lab budgets: a numbers game. Nature 524 (7563), 127–128.

Jaffe, A., Lerner, J., Stern, S., Thursby, M., 2007. Academic science and entrepreneurship: dual engines of growth? J. Econ. Behav. Org. 63 (4), 573–576.

Jones, B.F., Wuchty, S., Uzzi, B., 2008. Multi-university research teams: shifting impact, geography, and stratification in science. Science 322 (5905), 1259–1262.

Hvide, H.K., Jones, B.F., 2018. University innovation and the professor's privilege. Am. Econ. Rev. 108 (7), 1860–1898.

Kaiser, J., 2017. NIH plan to reduce overhead payments draws fire. Science https://www.sciencemag.org/news/2017/06/nih-plan-reduce-overhead-payments-draws-fire.

Lach, S., Schankerman, M., 2004. Royalty sharing and technology licensing in universities. J. Eur. Econ. Assoc. 2 (2–3), 252–264.

Lach, S., Schankerman, M., 2008. Incentives and invention in universities. Rand J. Econ. 39 (2), 403–433.

Lam, A., 2011. What motivates academic scientists to engage in research commercialization: 'Gold', 'ribbon' or 'puzzle'? Res. Policy 40 (10), 1354–1368.

Lemley, M.A., 2004. Ex ante versus ex post justifications for intellectual property. Univ. Chic. Law Rev. 71 (1), 129–149.

Lemley, M.A., 2008. Are universities patent trolls? Fordham Intell. Prop. Media Ent. Law J. 18 (3), 611–631.

Leute, K., 2005. Patenting and licensing of university-based genetic inventions: a view from experience at Stanford University's Office of Technology Licensing. Public Health Genom. 8 (4), 217–222.

Lobel, O., 2017. You Don't Own Me: How Mattel v. MGA Entertainment Exposed Barbie's Dark Side. W.W. Norton & Co.

Love, B.J., 2014. Do university patents pay off? Evidence from a survey of university inventors in computer science and electrical engineering. Yale J. Law Technol. 16, 285–343.

Markman, G.D., Gianiodis, P.T., Phan, P.H., 2008. Full-time faculty or part-time entrepreneurs. IEEE T. Eng. Manage. 55 (1), 29–36.

Merton, R.K., 1973. The Sociology of Science. University of Chicago Press.

Mervis, J., 2017. Data check: U.S. Government share of basic research funding falls below 50%. Science http://www.sciencemag.org/news/2017/03/data-check-us-government-share-basic-research-funding-falls-below-50.

Mowery, D.C., Nelson, R.R., Sampat, B.N., Ziedonis, A.A., 2001. The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh–dole Act of 1980. Res. Policy 30 (1), 99–119.

National Research Council, 1995. Research Doctorate Programs in the United States. Continuity and Change. National Academies Press.

National Research Council, 2011. A Data-Based Assessment of Research-Doctorate Programs in the United States (with CD). National Academies Press, http://dx.doi.org/10.17226/121994.

National Science Foundation, 2016. Science and Engineering Indicators 2016.

Ouellette, L.L., 2015. Patent experimentalism. Virginia Law Rev. 101 (1), 65–128.

Ouellette, L.L., Weires, R., 2020. University patenting: Is private law serving public values? Michigan State Law Rev. (forthcoming).

Owen-Smith, J., Powell, W.W., 2001. To patent or not: faculty decisions and institutional success at technology transfer. J. Technol. Transf. 26 (1-2), 99–114.

Powell, K., 2017. The best-kept secrets to winning grants. Nature 545 (7655), 399–402.

Pressman, L., et al., 2017. The Economic Contribution of University/Nonprofit Inventions in the United States: 1996–2015. AUTM and Biotechnology Innovation Organization.

Renault, C.S., 2006. Academic capitalism and university incentives for faculty entrepreneurship. J. Technol. Transfer 31 (2), 227–239.

Rai, A.K., 1999. Regulating scientific research: intellectual property rights and the norms of science. Northwestern Univ. Law Rev. 94 (1), 77–152.

Rai, A.K., Sampat, B.N., 2012. Accountability in patenting of federally funded research. Nat. Biotechnol. 30 (10), 953–956.

Roach, M., 2017. Encouraging entrepreneurship in university labs: research activities, research outputs, and early doctorate careers. PLoS One 12 (2), e0170444.

Roin, B.N., 2009. Unpatentable drugs and the standards of patentability. Texas Law Rev. 87 (3), 503–570.

Schacht, W.H., 2012. The Bayh–Dole Act: Selected Issues in Patent Policy and the Commercialization of Technology. Congressional Research Service Reports.

Siegel, D.S., Veugelers, R., Wright, M., 2007. Technology transfer offices and commercialization of university intellectual property: performance and policy implications. Oxford Rev. Econ. Policy 23 (4), 640–660.

Stephan, P.E., 2012. How Economics Shapes Science. Harvard University Press.

Stevens, A.J., Johnson, G.A., Sanberg, P.R., 2011. The role of patents and commercialization in the tenure and promotion process. Technol. Innov. 13 (3), 241–248.

Thursby, J.G., Thursby, M.C., 2011. Has the Bayh–Dole Act compromised basic research? Res. Policy 40 (8), 1077–1083.

van Dijk, D., Manor, O., Carey, L.B., 2014. Publication metrics and success on the academic job market. Curr. Biol. 24 (11), R516–R517.