ONLINE APPENDIX

University Innovation and the Professor's Privilege

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Appendix I: A Simple Formalization

Numerous countries maintain systems where the university, not the researcher, receives the majority of commercialization income. To sharpen the ideas behind these policies (which includes Norway after the professor's privilege reform and the U.S. after the Bayh-Dole Act), we introduce a simple formalization in the spirit of Holmstrom (1982). Namely, consider a policymaker that seeks to encourage the flow of commercially-valuable innovations from universities. This policy must balance the incentives of individual researchers with that of the university itself, which may make complementary investments that support successful technology commercialization. The policymaker's lever is rules on the allocation of rights assigned to each party.

To fix ideas, let a researcher have a unit of time of which a share s is devoted to producing a commercially-valuable innovation and the remainder $1 - s$ is used for other tasks (like basic research, teaching, or leisure). The university can also make investments (e.g., through a TTO) that facilitate the discovery and commercialization of technologies. By making an investment x, the university improves the commercial success of a researcher's insight.

Let the expected value of innovations that result be $v(s, x)$, which is increasing and concave in both arguments and where the inputs are complements ($v_{12} \geq 0$). The policy parameter is the

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portion α that accrues to the individual researcher, leaving a portion $1-\alpha$ for the university. As Aghion and Tirole (1994) and Scotchmer (2004) have emphasized in innovation contexts, giving all the rights to one party can make the first-best difficult to achieve given the desire to incentivize investment by both parties, and as Holmstrom (1982) emphasized broadly, there can be deep challenges in achieving first-best outcomes via the rent-sharing parameter α.

In particular, given a researcher investing s in commercialization activities, the university solves the problem

$$\hat{x} = argmax_x[(1-\alpha)v(s,x) - rx] \tag{A1}$$

where the cost per unit of investment is r. The university's investment level is thus sensitive to their expected share of income, $1-\alpha$.

Meanwhile, let the individual researcher have quasi-linear preferences in income so that, for a given x, the researcher solves the problem

$$\hat{s} = argmax_s[\alpha v(s,x) + G - \theta s] \tag{A2}$$

The researcher earns $\alpha v(s,x) + G$, where G represents the individual's academic salary or other non-commercialization income.[1] The disutility of commercialization effort (i.e. the loss of time for basic research, leisure, or other activities) is given by θs.[2]

With this simple approach, we can now examine the Nash equilibrium that emerges where the researcher and university make their choices, $\hat{s}$ and $\hat{x}$, as above, given the policy environment α. A key observation is that, with complementarities between university and researcher investments, innovative output may not be maximized at $\alpha = 1$, i.e. with a "professor's privilege".[3] Moreover, taking some rent share from one party may not only create more innovation but also encourage the party with the declining rent share to exert *more* effort.

[1] For simplicity and to focus on the issue of complementarity, we take quasi-linear preferences, which turn off income effects and also remove considerations of risk aversion.
[2] For simplicity, we will consider the model taking θ as fixed, although more generally this could be considered as a taste parameter drawn from a distribution $F(\theta)$. Thus, in general, some fraction of researchers may participate in commercialization activities while others may not.
[3] For example, this result appears directly for a Cobb-Douglas production function or more generally where each input is necessary to positive production ($v(s,0) = v(0,x) = 0$). In such cases, either $\alpha = 1$ or $\alpha = 0$ would not produce positive commercialization output, as one party would not invest.

To understand the role of such complementarities, consider a standard labor supply diagram for the researcher (see Figure A3) and consider how the researcher's budget constraint rotates in the presence of changes in the researcher's rent share. In a normal labor supply problem, increasing the tax rate on earned income will rotate the budget constraint counter-clockwise around the point C. This rotation generally creates two effects: the substitution effect will dissuade effort at the task, while the income effect pushes the other way, leading to the standard theoretical ambiguity linking tax rates and labor effort. Here, however, we have turned off income effects given the quasi-linear preferences of (A2), so the substitution effect will determine the worker's response. Nonetheless, the presence of complementarities in investment makes the direction of the rotation itself ambiguous. The slope of the budget set at an interior solution is $\alpha v_1(\hat{s},\hat{x})$ (see point B in Figure A3). Since the equilibrium investment of the university is a function of α, i.e., $\hat{x}(\alpha)$, there is both a direct effect of reducing the researcher share, rotating the budget line counterclockwise (like a standard tax), and an indirect effect, via changes in the university investment, that can rotate the budget line clockwise (via complementary investment). Formally,

Lemma. $Researcher\ investment\ is\ increasing\ in\ \alpha\ if\ and\ only\ if\ v_1(\hat{s},\hat{x}) + \alpha v_{12}(\hat{s},\hat{x})\hat{x}'(\alpha) > 0.\ Moreoever, for\ the\ professor's\ privilege, \hat{x}'(\alpha) \leq 0\ at\ \alpha = 1.$

Proof. By the first order condition for the university researcher, $\hat{s}$ is chosen such that $\alpha v_1(\hat{s},x) = \theta$. Totally differentiating this condition with respect to α we have

$$\hat{s}'(\alpha) = \frac{v_1(\hat{s},\hat{x}) + \alpha v_{12}(\hat{s},\hat{x})\hat{x}'(\alpha)}{\alpha v_{11}}$$

Noting that $v_{11} < 0$, it follows that $\hat{s}'(\alpha) > 0$ iff $v_1(\hat{s},\hat{x}) + \alpha v_{12}(\hat{s},\hat{x})\hat{x}'(\alpha) > 0$. Hence the first part of the Lemma. From the maximization problem for the university (see (1)), it follows by inspection that $\hat{x} = 0$ at $\alpha = 1$. Thus, $\hat{x}$ must be weakly larger for $\alpha < 1$. Therefore $\hat{x}'(\alpha) \leq 0\ at\ \alpha = 1$.

The first term in the Lemma, v_1, represents the "tax effect" from α, while the second term, $\alpha v_{12}\hat{x}'(\alpha)$, captures the "complementarity effect" from α, operating through the university's investment decision. By inspection, in the absence of complementarities ($v_{12} = 0$), researcher investment increases in the researcher's rent share.[4] However, in the presence of complementarities ($v_{12} > 0$), and where the university's investment is increasing in the

[4] Recall again that we are turning off income effects, for focus. If preferences were not linear in income, then taxing a researcher more could alternatively encourage more effort via a sufficiently strong income effect.

university's rent share ($\hat{x}'(\alpha) < 0$), researcher effort may actually decline in the researcher's rent share. Indeed, starting with a "professor's privilege" where the researcher has all rights to an innovation ($\alpha = 1$), the university does not invest: increasing the rent share to the university can then encourage greater university investment, and this in turn may encourage more (complementary) investment by the researcher -- even as the researcher's share of the pie is declining.

An Example that Can Motivate the Reform

A simple example can further illustrate the potentially non-monotonic relationship between a party's rent share and their equilibrium effort level. In particular, consider a CES production function

$$v(s,x) = [A_s s^\rho + A_x x^\rho]^{\varphi/\rho} \tag{A3}$$

with returns-to-scale parameter φ and elasticity of substitution $\sigma = \frac{1}{1-\rho}$. Equilibrium investment levels and innovative income are shown in Figure A4 as a function of the policy α for illustrative parameters.[5] We see that both researcher and university investments increase as one initially moves away from the professor's privilege. Indeed, this example is constructed to show a case where net innovation income from university-based researchers peaks at $\alpha \approx 1/3$. Thus, emphasizing complementarities in investment may provide a natural logic for reforming the "professor's privilege" in the vein of several European countries – and the similar balance between researcher and university rent shares often found in the United States today.

Of course, given that the empirical findings show a decline in the quantity and quality of both start-up activity and patenting, the candidate theoretical example in Figure A4 appears rejected by the data. Alternative examples in the income rights framework that match the findings are similarly easy to construct. For example, while the example in Figure A4 assumed that the productivity of the researcher and the university are equivalent ($A_s = A_x$), an alternative where the researcher's role is substantially more important ($A_s \gg A_x$) and the inputs are gross

[5] Namely, for this illustration we set $A_s = A_x = 1$ so that the inventor and university are equally productive in their investments; $\varphi = 0.5$ so that there is decreasing returns to scale; $\theta = 1$ and $r = 0.1$ so that the costs of investment are higher for the individual than the university; and $\rho = 1/3$ so that the inputs are complements but neither input is necessary for positive output.

substitutes can push the commercialization peak to the corner solution where the professor is given full rights, as in the pre-reform regime.

Application to Tax Rates

This income rights framework can also generate an implication for the effect of taxation. Namely, the decline in α can be thought of in part as increasing the tax rate on researcher's commercialization income. The policy change (lowering α) acts both as a tax on researcher income and an incentive for complementary investments by the university which may, ceteris paribus, raise the return to the researcher's investment. The additional effect on university investment distinguishes the experiment from a narrower tax experiment on the university researcher's commercialization income. However, under the conditions of the model, the shift in α provides a lower bound on the effect of an equivalent tax.

To see this application formally, define a tax rate on earned income, $1-\tau$, so that a researcher's after tax income is

$$y = \tau(\alpha v(s,x) + G) \tag{A4}$$

Write the equilibrium commercialization effort of the individual researcher as $\hat{s}(\alpha,\tau)$. Now compare two policy regimes, a tax regime where $(\alpha,\tau) = (1,c)$ and a rent-sharing regime where $(\alpha,\tau) = (c,1)$, so that the tax rate and rent-sharing rate are of equivalent size.

Lemma. $\hat{s}(1,\tau) \leq \hat{s}(\alpha,1)$ for $\alpha = \tau$.

Proof. By the first order condition for the university researcher, $\hat{s}$ is chosen such that $\tau\alpha v_1(\hat{s},x) = \theta$. The first order condition for the "tax" case where $(\alpha,\tau) = (1,c)$ is then $cv_1\big(\hat{s}(1,c),x(1,c)\big) = \theta$. The first order condition for the "property rights allocation" case where $(\alpha,\tau) = (c,1)$ is then $cv_1\big(\hat{s}(c,1),x(c,1)\big) = \theta$. It therefore follows that

$$v_1\big(\hat{s}(1,c),x(1,c)\big) = v_1\big(\hat{s}(c,1),x(c,1)\big). \tag{A5}$$

Now note that $x(c,1) \geq x(1,c) = 0$, since the university does not invest when it has no rights (see (A1)). Therefore, with $v_{12} \geq 0$ (i.e. maintaining the assumption that investments are complements), (A5) can only hold if $\hat{s}(1,c) \leq \hat{s}(c,1)$. Hence the Lemma.

Based on this reasoning, university researchers appear very sensitive to the effective tax rates on their expected income. Noting that α in the policy experiment is increased by two-thirds and that the ensuing decline in start-up and patenting rates is approximately one-half to two-thirds, the implied elasticity to an equivalent tax rate τ has a lower bound of 0.75.

Appendix II: Analysis of Publications

The end of the professor's privilege may separately affect university researchers' publication behavior. To the extent that marketplace innovation becomes less appealing, the individual university researcher may shift effort toward other activities, including basic research, teaching, or leisure. The university commercialization literature has been concerned particularly with the balance between commercialization effort and research effort, noting potential welfare tradeoffs should patenting or start-up behavior come at the expense of basic research (e.g., National Academy of Sciences 2010).

To inform this issue, we collected all Web of Science (WOS) publications with at least one Norwegian address and then matched this data, based on author name, to the NIFU database of university researchers. This approach allows us to integrate publication data and patent data for the university researchers. Further, the NIFU database incorporates demographic information about university researchers, including doctoral field, PhD cohort, age, and gender among other observables.[6]

In assessing potential tradeoffs between commercialization and research activities, a central question is whether these activities are substitutes or complements. On the one hand, viewed from the perspective of a budget constraint (in time and/or money) effort at one task may seem to detract inevitably from the other. However, to the extent that the researcher substitutes commercialization activity against leisure or other non-research activities, commercialization activity need not come at the expense of basic research. On the other hand, viewed from the perspective of the knowledge production function, innovative and basic research activities may be complements. For example, effort in creating patentable inventions may spark an individual's research insights, which in turn increases an individual's publication output (e.g., Stokes 1997, Azoulay et al. 2009, Ahmadpoor and Jones 2017).

[6] The WOS provides an author's last name and first initial only. Given the potential increased matching noise with the limited information on first name, the analysis below focuses on the sample of individuals with low frequency names in Norway. These are individuals for whom the full name (from the NIFU data) appears three or less times in Norway as a whole. In practice, this drops 20% of the matched sample. Using the full sample shows similar results.

To shed light on these issues, we first analyze whether university researchers who patent ("university inventors") tend to publish more or less than university researchers who do not patent. We find strong evidence that university inventors tend to publish substantially more papers and also more highly-cited papers. Table A2 column 1 shows that university inventors average an additional 0.67 journal publications per year. Given an average publication rate of 1.08 publications per year for university researchers, the publication rate of the inventors appears about 60% greater. Column 2 shows that the publication advantage of university inventors is robust to controlling for year, PhD cohort, university, and doctoral field fixed effects, as well as gender. The robustness to doctoral field fixed effects shows that the heightened publication activity of university inventors is not due to the differences between, say, material science and economics, but rather appears within the same field. Columns 3 and 4 reconsider publication volume counting "fractional publications", where an author receives 1/N credit for a paper, where N is the number of authors. The increased publication rate of university inventors is robust to this alternative accounting. Columns 5 and 6 consider mean citations received per publication and show that the average citation impact of university inventors' papers is substantially higher than the citation impact for other university researchers. Collectively, these findings suggest that university inventors are especially productive researchers, producing both more papers and more highly-cited papers than their non-patenting counterparts. This finding appears both across and within fields.

The greater publication output of university inventors may suggest that patenting and publication activities are complements in production (e.g., Fabrizio and Di Minin 2008, Azoulay et al. 2009, Buenstorf 2009). However, the positive correlations in Table A2 may also be driven by an individual-level effect, where some researchers are simply more productive at both tasks. Then patenting and publications may still be substitutes within a given individual. The question of whether patents and publications are complements or substitutes at the individual level is thus unclear – and remains an important question for assessing potential tradeoffs with basic research that may emerge from university commercialization policies.

The professor's privilege reform provides an opportunity to further investigate this issue by looking at how the publications within individuals respond when the incentives to patent change.[7] We again take a differences-in-difference approach, but face a limitation. Namely, publications outside universities are rare in Norway, which makes control groups outside the university context (and hence unaffected by the reform) difficult to find.[8] Nonetheless, we may proceed on a different tack, noting that patenting is sequestered within a relatively small number of disciplines within universities so that a change in patent incentives may naturally affect some university researchers far more than others. A regression approach can then study publications by asking whether a treated group, for whom patenting matters relatively strongly, changes their publication output compared to other university researchers, who would presumably be less affected by the reform.

We consider two types of analyses along these lines. First, organizing the 35 different PhD disciplines in the Norwegian data, we find 15 disciplines for which university researchers never patent between 1995 and 2010. By contrast, in the top 5 PhD disciplines by patent propensity, university researchers produce patents in 1.2% of researcher-years. Table A3 considers regressions that compare individual researchers in the top 5 patenting PhD disciplines (the treated group) with those in PhD disciplines where patenting has not occurred (the control group). The regressions include individual fixed effects which allow us to focus on within individual changes. In column 1, we first consider the tendency to patent. In line with the analysis in Section IV.B, patenting rates declines after the reform for individuals in the patent-heavy disciplines. The following columns investigate publication measures. The findings indicate that individual university researchers in patent-heavy fields do not measurably change their publication rates after the reform compared to university researchers in patent-free fields. The potential exception is that average citation impact appears to decline within individual researchers in patent-heavy fields, after the reform. The statistical significance of this finding is, however, not robust to other reasonable specifications along these lines, including those below.

[7] Note that this analysis examines the interplay of patenting and publications; entrepreneurship may show a different relationship with research output. Recall that we cannot link publications to the university entrepreneurs, because the entrepreneurship analysis uses anonymized personal identifiers in Norwegian registry datasets (i.e., we do not know the entrepreneurs' names).

[8] In particular, examining WOS publications with Norwegian authors that do not match to university researcher names, we see that these authors only publish once in ten years, on average, which is also about one-tenth the publication rate for university researchers. It is thus difficult to find a relevant non-university control group for publications in Norway.

A possible difficulty with the analysis in Table A3 is that, even in patent-heavy fields, most researchers do not patent. Therefore, any publication effects on "patent-sensitive" researchers may go undetected by mixing them together with those who have no intention to patent. An alternative approach then is to focus explicitly on university researchers with a demonstrated interest in patenting; i.e., individuals who patented before the reform. We can then ask whether these specific university inventors, upon the reform, changed their publication behavior. Table A4 considers this analysis. In columns 1-4, the control group is all other university researchers. In columns 5-8, the control group is constructed from the two nearest neighbors for each pre-reform university inventor, where the nearest neighbors share the same PhD discipline as the university inventor and have the closest average number of publications per year in the pre-period. Columns 1 and 5 consider patenting to confirm that the patenting behavior of these individual inventors drops substantially after the reform. The remaining columns, which consider publication measures as indicated in the table, show no statistically significant changes. If anything, the coefficients tend to be negative, suggesting that publications of university inventors may have relatively declined.

Together, these analyses do not indicate that an increase in publications acted as a kind of "silver lining", offsetting the decline in university-based innovation detailed in main text. On net, the publications do not appear clearly as either complements or substitutes for more applied innovative activities. A tradeoff between inventive activity and publication activity does not visibly emerge at the individual level.

Appendix III: University Inventor Survey

We conducted a survey of university inventors in our data, with two purposes. First, the survey allowed us to investigate licensing behavior and thereby inform this additional feature of commercialization. Second, the survey allowed us to gather qualitative insights from the university inventors themselves about the professor's privilege reform and thereby further inform potential mechanisms.

The survey, which was web-based, was conducted from November 2016 through January 2017. The 20 survey questions are reproduced below. To conduct our survey, we performed online searches of current university homepages to locate the email addresses for 282 university inventors. Of these 282 university inventors, 63 individuals completed the survey, giving a response rate of 22.3%.

Table A5 reports summary statistics on all relevant survey questions. The 20 survey questions themselves are included at the end of this Appendix. Below we discuss the main findings.

Licensing Activity

Licensing activity can build on the creation of the underlying intellectual property to generate potentially important channels to marketplace commercialization. In the survey, 36% of inventors with an application date prior to the reform report licensing at least once (Q7), while the post-reform fraction is 26% (Q12). Using a one-tailed t-test, we can reject at the 10% confidence level that the fraction of inventors that license is larger post-reform. We also asked the respondents about their licensing income in Norwegian kroner. The mean licensing income was higher for pre-reform patents (Q8) than for post-reform patents (Q13). With the caveat that licensing income is skewed and hence sensitive to outliers, a one-sided t-test rejects at the 10% level that mean licensing income is higher after the reform. These results are consistent with the finding in Section IV, where measures for the quality of the underlying patents dropped after the reform.

Prior to the reform, the university inventors report that the university played some role in licensing for 30% of the cases (Q9), while the corresponding number after the reform is 33% (Q15), which is only slightly larger and not significantly different. It is somewhat surprising that the universities do not contribute more regularly after the reform, given that they invest substantial resources in TTOs. On the other hand, this result is again consistent with the lower quality of patents, where the university has less to work with and does not succeed in licensing lower quality patents. This finding may also be a statistical artifact. Notably, all the post-reform inventors (40 of 40 individuals) responded on whether the university played a role but only 57% of the pre-reform inventors (27 of 47 individuals) responded to this question (see Table A5). It is unclear whether non-response is due to imperfect recall or due to it being "obvious" that the university played little or no role pre-reform. If one interprets non-response as indicating the latter, then the fraction where the university played a role pre-reform would be 17%. In this view, one could interpret the licensing survey findings as indicating that the reform did lead to an increase in university support for licensing, but licensing activity didn't increase on net as the quantity and quality of the underlying intellectual property declines.

Mechanisms and Views of Reform

The survey also asked the researchers for their views on the reform. Two survey questions asked how the reform affected the individual's "interest in patenting, entrepreneurship, or other commercialization activities." To allow a quantitative categorization, the first question asked whether the reform had a positive, negative, or neutral influence (Q16). To allow more qualitative assessment and gather potential ideas about mechanisms, the next question asked for an open-ended comment on "what role the reform played" (Q17). The survey further asked for the respondent's views on how the reform affected their colleagues' interest in commercialization (Q18).

Of the 56 university inventors who responded to the first question (Q16), 61% reported that the reform had no effect on their interest in commercialization activity while 27% reported a negative effect and 13% reported a positive effect. Where a positive or negative view was given, the respondents' answers were therefore in the direction or viewing the reform negatively. Considering that 15 of the 22 non-neutral views were negative, a simple binomial test rejects that the reform had a positive effect with p=.067. Similarly, 56 university inventors responded when asked how they think their colleagues' viewed the reform. Here, most respondents (57%) said they did not know. However, where a positive or negative view was given, negative views were again more common. With 10 of these 14 views being negative, a binomial test rejects the reform had a positive effect with p=.090.

Written comments were provided by 20 respondents as to how the reform affect their interest in commercialization activity. As seen below, the majority of comments (10 of 20) were negative, while some comments (6 of 20) were positive and a few (4 of 20) appeared neutral. The positive comments typically pointed to useful features of the TTOs, while the negative comments typically mentioned the dilution of the individual's income rights.

Regarding the 6 positive comments, the full texts were as follows:[9]

1) "The technology transfer office did a realistic evaluation of an idea for patent that I had. The conclusion was that the idea/concept was not patentable. That saved me for a lot of unnecessary work"
2) "Better support, better integration with institutional policy, interests etc and less potential conflict of interest situations"
3) "I got support in the judicial work around patenting"
4) "The TTO established itself as an active partner which supports in commercialization. Without such support very few researchers have resources or capacity to commercialize by themselves"
5) "Without the TTO, no patent or further developments"
6) "Became more orderly and less random"

Regarding the 10 negative comments, the full texts were as follows:

7) "Less attractive to work with entrepreneurship when you as an inventor only get a marginal portion of the ownership. The services that TTO provides does not justify their high portion of ownership"
8) "The university had nothing that added value compared to personal network. The reform became in practice a complicating factor and removed much of the incentives to commercialize as a university researcher"
9) "The university contributed little, but was entitled to a substantial income share"

[9] When given in Norwegian (the majority of cases), the comments below have been translated into English.

10) "We experience that the university does not contribute substantially and the motivation drops when one loses two-thirds of ownership shares on startup."
11) "I would never start up a company in the current system. In the current system, the TTO has a large ownership fraction and a dominating position from the start, and the entrepreneur has for example 33%. With venture financing, venture gets about 50% at every stage. It is common with 2-3 stages. Thus the entrepreneur will have 16.6% after the first stage, 8% after two stages, and 4% after three stages. The entrepreneur early onwards loses control over the startup and must rely on other actors, who from experience do not need to have much competence on neither technology or management of startups. Furthermore a low ownership share also means limited upside. The most important feature, however, is that the entrepreneur loses control over the startup. This creates a lot of uncertainty and I would not start up a company under this model. Before the reform I started up a company and had good control over the first six years. This was critical for the substantial success it made. NTNU has a budget of about 2 billion kroner and does not need to flay entrepreneurs for several millions through the TTO. NTNU should rather be rewarded by the government ministries for having spun out a company."
12) "I, and others I know in the same situation, do what they can to avoid the university system because we think they do not have enough to offer"
13) "TTOs at the universities does not function well. Too much bureaucracy"
14) "The TTO has so far not contributed to developing patents, I work with many ideas but there is no support to perform such work in the future. The innovations get stuck in a vacuum, without being able to develop"
15) "None. I was not active as inventor back then. I was negative to the reform"
16) "The new rules have made it significantly less attractive to develop patents as a university employee. The new rules typically provide a significant initial dilution, which may be a problem in financing, and a company founded on IP in the form of patents also need to carry the burden of a significant bureaucracy in the form of the TTOs. It is claimed that the TTOs provide a useful service, but this is not my experience." [Authors' note: This person goes on to describe two very high-growth companies that have emerged from this person's research and inventions; to preserve anonymity, we do not present this information.]

Overall, many comments emphasize the problems of dilution for the university researchers' commercialization incentives (comments 7, 8, 9, 10, 11, and 16). Further, there are both positive comments (numbers 1, 4, and 5, and possibly 2 and 3) and negative comments (numbers 13, 14, and 16 and possibly 8 and 11) about the TTOs. Notably, several comments explicitly balance the value of the TTO's or university's contribution weighed against loss of inventor rights and all these are negative about the reform (comments 7, 8, 9, 10, 11, and 16).

Putting these qualitative results together with the econometric results in the paper, one may then imagine that TTOs can play useful roles but that that the dilution experienced by the university researcher is the major effect, leading to less effort and success at commercialization. While the survey results are only a sample of the university inventors, the reactions to the reform and licensing results appear consistent with an overall decline in the quality and quantity of new ventures and patenting documented in the paper. The emphasis on income incentives, which appears in a number of comments above (and very strongly in some) provides further qualitative support for rent-sharing perspectives discussed in the text and presented formally in Appendix I.

Addendum: Survey Questions

Each university inventor received an email with a link to an online survey, which was hosted by NSD (Norwegian Centre for Research Data). By clicking on the link, each respondent was taken to the NSD survey webpage and then guided through the following questions. Depending on the answer to any given question, the survey was coded to move to the next question as indicated in square brackets below.

1. Which language do you prefer/hvilket språk foretrekker du? (tick one box)
    a. Norwegian/norsk
    b. English/engelsk
2. Through data from Norsk Patentkontor, we have identified you as an inventor of at least one patent. Is this information correct? (tick one box)
    a. Yes [to Q3]
    b. No [to end]
3. For how many patents were you an inventor? (two digit number box)

4. Were you employed full-time at a Norwegian university at any time between 1995 and 2010? (tick one box)
    a. Yes [to Q5]
    b. No [to end]
5. Which years? (two four digit boxes)
   Start year (four digit box)
   End year (four digit box)

Pre 2003 patents

6. Were you an inventor on any patent with application date before 2003? (tick one box)
    a. Yes [to Q7]
    b. No [to Q11]
7. For all your patents with application date before 2003, how many licenses were issued (excluding any licenses issued to companies you own)? (tick one box)
    a. 0 [to Q9]
    b. 1 or more [to Q8]
8. For any patent with application date before 2003, how much income in kroner was generated from licensing in total (excluding any licenses issues to companies you own)? (eight digit box)
9. For any patent with application date before 2003, what role did the university play in finding licensees and/or negotiating licensing agreements? (tick one box)
    a. None [to Q11]
    b. Slight [to Q10]
    c. Substantial [to Q10]
10. For any patent with application date before 2003, please comment on what role the university played in your licensing activities.
    (text box)

<u>Post 2003 patents</u>

11. Were you an inventor on any patent with application date in 2003 or after? (tick one box)
    a. Yes [to Q12]
    b. No [to Q16]
12. For any patent with application date in 2003 or after, how many licenses were issued (excluding any licenses issued to companies you own)? (tick one box)
    a. 0 [to Q14]
    b. 1 or more [to Q13]
13. For any patent with application date in 2003 or after, how much income in kroner was generated from licensing in total?
    (eight digit box)
14. For any patent with application date in 2003 or after, what role did the university play in finding licensees and/or negotiating licensing agreements? (tick one box)
    a. None [to Q16]
    b. Slight [to Q15]
    c. Substantial [to Q15]
15. For any patent with application date in 2003 or after, please comment on what role the university played in your licensing activities.
    (text box)

In 2003, the Norwegian Parliament abolished the so-called "Lærerunntaket" (Professor's privilege) which meant that researcher-inventors after the reform received a lower fraction of commercialization income than before, and the university more. At the same time, the reform created Technology Transfer Offices at each university, to assist in commercialization. The following four questions are about the effect of this reform.

16. Did the reform have any influence on your interest in patenting, entrepreneurship, or other commercialization activities? (tick one box)
    a. Negative effect [to Q17]
    b. No effect [to Q18]

c. Positive effect [to Q17]

17. Please comment on what role the reform played in your interest in patenting, entrepreneurship, or other commercialization activities
    (text box)
18. Did the reform have any impact on your colleagues interest in patenting, entrepreneurship, or other commercialization activities? (tick one box)
    a. Negative effect [to Q19]
    b. No effect [to Q20]
    c. Positive effect [to Q19]
    d. I do not know [to Q20]
19. Please comment on what role the reform played in your colleagues' interest in patenting, entrepreneurship, or other commercialization activities
    (text box)
20. May we follow up by email or phone to ask further questions about your experience? (tick one box)
    a. Yes
    b. No

Thanks for your participation!

Appendix IV: Patent Measures

The core patent data is provided by the Norwegian Patent Office (NPO). The data includes all patents issued by the NPO where at least one inventor has a Norwegian address. The data include patents issued in Norway that were initially patented in other jurisdictions.[10] The NPO data covers all granted patents with applications in the period 1995-2010.[11] The NPO data provides each inventor's full name and address as well as the patent number and technology classification. Names are given in the Norwegian alphabet, which is important for matching correctly to the NIFU university employee database. The data further include the legal status for each patent, including whether that patent remains in force as of 2014 and, if not, the date at which the patent right lapsed. We use this information to construct the duration each patent lasted as one of our patent quality measures.

For other patent quality measures, including citations received and whether the patent received protection in other jurisdictions, we use the PATSTAT database as of spring 2015. The Norwegian patents are linked by their application identification number to the relevant patent family in PATSTAT. We use the DOCDB definition of patent family, as defined by the European Patent Office.[12] Matching each NPO patent to its patent family provides indicators for NPO patents that are also patented in any of the European Patent Office, United States Patent and Trademark Office, and/or Japanese Patent Office. For citation counts, we use citations in PATSTAT to the given patent family.

A potential challenge in the patent data is that recent patent applications have had less time to accumulate citations or be renewed. The delay between application and grant, which averages 2.7 years in the NPO over our sample period, further curtails the time period after which granted patents can be seen. For example, patent applications in the year 2010, with grants typically coming three years later, face short time windows ex-post of issuance. Given this issue, quality

[10] We thank Bjarne Kvam and the Norwegian Patent Bureau for providing this data. The NPO data includes all patents that were granted by the EPO and then registered in Norway, which became possible in Norway starting in January 2008, as well as patents applied for in any other jurisdictions, so long as the patent sought protection in Norway. Starting in 2008, 13.6% of NPO patents were granted by the EPO and then registered in Norway.
[11] These application years are those that match the data availability of the NIFU database of university employees (see text), which is what allows us to determine whether a given inventor is employed at university.
[12] The DOCDB patent family measure is constructed by EPO patent examiners; it is a standard, expert-validated patent family measure based on the principle that a patent family represents multi-jurisdictional patents that contain the same technical content.

measures based on multi-jurisdictional patenting may be favored in our analysis, as these patent families see similar filing dates and do not require substantial post-issuance windows to construct the measure.

Table 10 in the main text investigates various patent quality measures, using application year fixed effects to account for differential opportunities to accumulate citations or renew patents as time progresses. Table A6 considers further specifications to capture these dynamics in alternative ways. In addition to different construction of the quality measures, the regression specifications also consider alternatives with grant year fixed effects (to capture dynamics related to grant year, which may better capture the time window for citations and patent renewals) as well as technology class fixed effects, to account for potential differential dynamics across technology areas.

In Table A6 columns (1)-(2) we consider citations received within 5 years of application. The idea here is to create a common time window over which citations can be counted regardless of when in the sample period the patent application came. Column (1) uses application year fixed effects while column (2) further includes grant year and technology class fixed effects. We see that the coefficient is negative and quite large but not statistically significant.

Columns (3)-(4) return to the first measure in Table 10, which is a simple indicator for whether the patent is cited at least once. This indicator provides a common range of the dependent variable regardless of the application year, with time fixed effects adjusting for the larger opportunity for a citation among older patents. Column (3) adds grant year and technology class fixed effects and shows similar results in magnitude and statistical significance as Table 10 column 1. Column (4) considers the same specification but restricts the sample to patents that are granted by 2010, which provides at least a five-year window since application to observe citations after each patent. This specification shows larger effects.

Columns (5)-(8) consider alternative indicators, here considering the propensity for unusually highly-cited patents. The dependent variable is an indicator for an upper tail patent according to a given percentile citation threshold for that grant year. By construction, these measures show the same mean regardless of year of patent issuance and thus provide another approach to dealing with citation dynamics. Columns (5)-(6) use the 75^{th} percentile citation threshold and

Columns (7)-(8) use the 95th percentile citation threshold. These results also show large, negative declines in the quality measure, with statistical significance at standard levels except for column (8), which is not quite significant (p=.120).

Columns (9)-(10) further consider patent renewal measures. In column (9), the dependent variable is an indicator for the patent still being in force in the year 2015. Column (10) considers an indicator for whether the NPO patent is still in force 5 years after the patent is issued, restricting the sample to patents issued by 2010. Both measures show a large, negative difference-in-difference estimate although the results are not statistically significant.

Overall, integrating across the quality measures based on citation counts or patent renewals, we see that all tend to show large and negative coefficients. Statistical significance depends on the specification, with results typically either statistically significant at conventional measures or close to such significance thresholds. To the extent that these measures face challenges given limited time windows for later application years, one may emphasize instead the metrics based on multi-jurisdictional patenting (see main text, Section IV.B). These metrics also show large, negative effects, and typically with greater precision.

Appendix V: Further Background on the Norwegian Innovation System and TTOs

This appendix provides further institutional detail and analysis of the Norwegian innovation system, with an emphasis on leading businesses and technology areas.[13] We further provide additional detail and analysis of the Technology Transfer Offices (TTOs)

The Norwegian Innovation System

We describe here the orientation of business, patenting, startups, and research in Norway. A distinguishing feature of the Norwegian economy is a large energy sector, with about one-third of the market capitalization at Oslo Stock Exchange based on energy companies. The largest such company is Statoil with a market value of approximately $50 billion. From the 1970s onwards, numerous inventions in Norway's oil & gas sector have advanced North Sea production, and Statoil was one of the early developers and users of the horizontal drilling technology, which later revolutionized shale gas and oil production in the U.S. and elsewhere. Other leading Norwegian firms include Norsk Hydro, a global aluminum supplier with a market cap of approximately $10 billion and Yara, a chemicals firm that is the world's largest supplier of mineral fertilizer and has a market cap of around $10 billion. Other large technology companies on the Oslo Stock Exchange include Telenor (telecommunications) and the Kongsberg group (weapons technology, as well as marine navigation and systems).

Table A7 provides information on the industrial composition and firm size distribution in Norway, using 2-digit NACE codes. Distinctive sectors of the economy include oil and gas extraction and related services (NACE code 11) as well as health and social work (NACE code 85). Many sectors are dominated by large firms, defined as firms with at least 500 employees based on their consolidated accounting statements in Norway. Manufacturing sectors in which Norway is relatively prevalent includes chemicals, which is dominated by large firms, and fabricated metals and machinery, which are more balanced toward small firms. Computer and related activities occupy 2% of the workforce, with employment balanced toward smaller firms. See Table A7 for further detail.

[13] Each year, Statistics Norway publishes a broad overview of the Norwegian innovation system, see https://www.forskningsradet.no/prognett-indikatorrapporten/Indikatorrapporten_2016/1254018195927.

In the last two decades, Norway has not produced prominent, consumer-facing tech startup successes like those in Sweden (Skype, Spotify). The most successful such information technology startup in Norway is arguably Opera Software, which has a current market capitalization of approximately $600 million and has developed a multiplatform browser with hundreds of millions of users globally. Norway's venture capital investment as a percentage of GDP is above the EU average (Statistics Norway, 2015). For both university researchers and non-university PhDs, the top startup sectors are: NACE 72 (computer and related activities), NACE 73 (research and development), NACE 74 (other business activities), and NACE 85 (health and social work). In terms of notable companies that have grown substantially, prominent technology startups by university researchers have been related to offshore oil and gas services (such as logistics software and drilling analysis firms) as well as biopharma and medical device companies.

For Norway as a whole, the highest frequency technology classes are related to marine technology, communications, machine engineering, agriculture, and medicine.[14] For university patenting in Norway, the highest frequency technology classes are related to biomedicine, mining, physics instrumentation, organic chemistry, agriculture, and naval transport.[15] Looking at the Web of Science, biomedicine accounts for 49% of journal articles in Norway, which is a similarly large share of biomedical research as seen in the United States. Outside of biomedicine, the largest Web of Science research fields are Physics, Physical Chemistry; Geoscience, Geochemistry, and Geophysics; Marine and Freshwater Biology; Oceanography; Environmental Sciences; Food Science; Meterology and Atmospheric Science; Chemical Engineering; and Physics, Particles and Fields.

[14] The top 5 IPC patent classes are B63 (Ships or Other Waterborne Vessels; Related Equipment), F16 (Engineering Elements Or Units; General Measures For Producing And Maintaining Effective Functioning Of Machines Or Installations; Thermal Insulation In General); H04 (Electric Communication Technique); A01 (Agriculture; Forestry; Animal Husbandry; Hunting; Trapping; Fishing); and A61 (Medical or Veterinary Science).

[15] Among university researchers, the top 10 IPC patent classes are A61 (Medical or Veterinary Science), E21 (Earth drilling; mining), G01 (Physics: Measuring, Testing), A01 (Agriculture; Forestry; Animal Husbandry; Hunting; Trapping; Fishing), A23 (Foodstuffs, tobacco), G05 (Physics: instruments), B01 (Physical or chemical processes or apparatus), B63 (Ships or Other Waterborne Vessels; Related Equipment), C07 (Organic Chemistry), and F03 (Machines Or Engines For Liquids; Wind, Spring Weight And Miscellaneous Motors; Producing Mechanical Power; Or A Reactive Propulsive Thrust).

The Norwegian government's innovation support system is focused around Innovation Norway, which runs a number of networking, seed funding, and subsidized loan programs, with offices in all the Norwegian counties. The major innovation hubs and largest research universities are in Oslo (Univesity of Oslo), Bergen (University of Bergen), Trondheim (Norwegian University of Science and Technology), and Stavanger (University of Stavanger). Gulbrandsen and Smeby (2003) and Gulbrandsen (2003) provide examinations of industry-university linkages and Statistics Norway (2015) gives an overview of industry-public sector linkages.

Technology Transfer Offices

Upon the reform of the professor's privilege, each Norwegian university established a technology transfer office (TTO). With the exception of University of Stavanger (which was founded in 2004 through a merger of pre-existing institutions but had a TTO-like unit, Prekubator, in operation since 2002) all TTOs were founded in 2003. Most TTOs were based on precursor technology offices that were financed by the Norwegian Research Council since 1996. In this sense, the TTOs were not wholly de novo entities at the time of the reform, but rather with the reform they became substantially larger entities. As of 2005, the TTO offices typically had about ten employees, led by a director, and were partially financed by the university itself, partially by the Norwegian Research Council (FORNY program), and partially by the Ministry of Education (see Rasmussen et al. 2006 for further description).[16]

In interpreting the empirical findings, one may ask whether the TTOs did not function well. The licensing survey (Section IV.B and Appendix III) and the inventor viewpoint survey (Section V and Appendix III) further suggest that the TTOs did not provide substantially impactful services on net, given the decline in inventor rights. Nonetheless, upon the advent of the formal TTOs, perhaps these entities didn't start with effective teams or cultures or perhaps there will be learning by doing. To the extent that TTOs are heterogeneous across time or across universities, there may be substantial room to improve TTO functioning in the future. Related, TTO

[16] In terms of daily commercialization activities, such as assessing ideas, contacting potential investors, and so on, the TTO offices will be running the show. In the case of startups, the TTO will approve its establishment, and may be engaged in formulating an R&D plan, IP strategy, and financing plan. There is to our knowledge no formal requirement that a TTO employee sit on the board of the startup.

heterogeneity can also bear on representativeness of the findings outside Norway, should TTOs in other jurisdictions be more effective in some general fashion.

While TTO quality (and variation therein) is difficult to assess conclusively, we can consider two features of our data to help inform this issue. The first observation involves time dynamics. Were TTOs initially bad but then improved with time, we may expect to see, other things equal, larger initial drops in startup and entrepreneurship activity followed by convergence back toward controls as the TTOs improve. However, looking at the start up results (Fig. 1) or patenting results (Fig. 2), it is clear visually that the gap between universities commercialization activities and the background rates are widening rather than narrowing.[17] Related, Figures A1 and A2 present regression findings by year after the reform. The point estimates, echoing the raw data in Figures 1 and 2, also suggest that the gap is widening rather than narrowing with time.

A perhaps more sensitive test for TTO heterogeneity is to examine whether specific universities reacted differently to the law change. That is, we can look for heterogeneous treatment effects across Norwegian universities as evidence that TTOs have performed differently in different settings. To implement this estimation strategy, we separate out the three largest Norwegian universities – Oslo, Bergen, and Trondheim, each of which see substantial new venture and patenting activity on their own. We then run again difference-in-difference regressions from the main text but now with indicators for each of these three universities and interactions of treated x post with these indicators. We can then look at the t-statistics for these triple interactions to see if any of these three universities had statistically different treatment effects from the overall treatment effect in Norway. Separately, we can use an F-test to test for collective differences of these university-specific treatment effects from the overall treatment effect.

Table A8 shows the results for both new ventures and patenting. Columns (1)-(2) extend core specifications from Table 3 (startups), while columns (3)-(4) extend core specifications from Table 8 (patents). For startups, examining the triple-interaction coefficients, we see no evidence

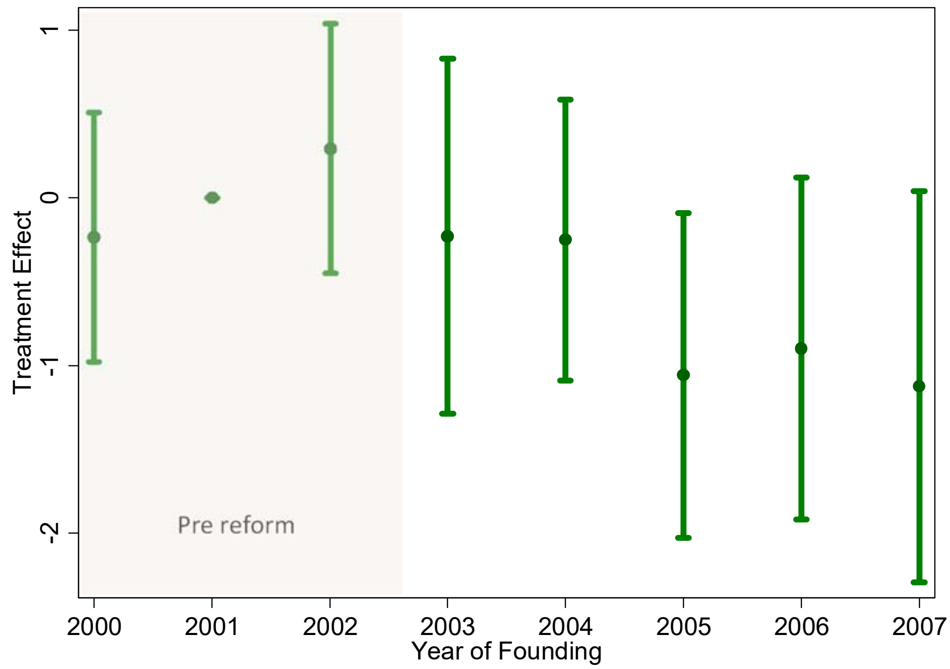
[17] The reverse dynamic is consistent with, for example, weakening in researchers' commercialization investment (e.g., due to the income rights interpretation – see Section V) coupled with TTOs having some initial advantage due to latent intellectual property (a one-shot "searching the closets" effect) or a momentum effect where individual researchers are initially completing commercialization investments they had already begun in the pre-reform period.

that any of Oslo, Bergen, and Trondheim experience a differentially positive or negative effect compared to the background treatment effect. Nor do we see any evidence for a collective difference for these universities when examining the F-statistic p-value (see last role of table). For patents, we see some evidence in the point estimates of column (3) that the effects were somewhat more negative in Oslo and Bergen, with marginal statistical significance for Oslo. When looking at the refined set of inventors with rarer names, for whom the individual identifiers are cleanest, the evidence for any differential effects weaken. In either specification, there is no collective significance to the treatment effects for these three universities.

Overall, we see no evidence of heterogeneous treatment effects for startups. For patents, we see at most weak evidence, limited to Oslo and itself not robust, for a differential effect. Furthermore, testing collectively for heterogeneous treatment effects among these large universities shows no statistical significance. This evidence, in tandem with the dynamic pattern, thus provides little evidence for interpretations based on differential TTO quality, to the extent one would expect the TTOs to either improve over time or differ substantially across institutions. That said, it is possible that TTOs in Norway improve beyond the horizon of our data or will do so in the future. Regarding heterogeneous treatment effects, one caveat is that universities are very much public sector in Norway, and the universities have similar governance structure and bylaws. Although there were some differences in how the reform was implemented, these differences may be relatively small (Gulbrandsen et al. 2006). Notably, Trondheim's institutional setup was somewhat different, and we see no differential treatment effect for Trondheim, but more generally the institutional setting in Norway may have limited potential for differences across TTOs.[18]

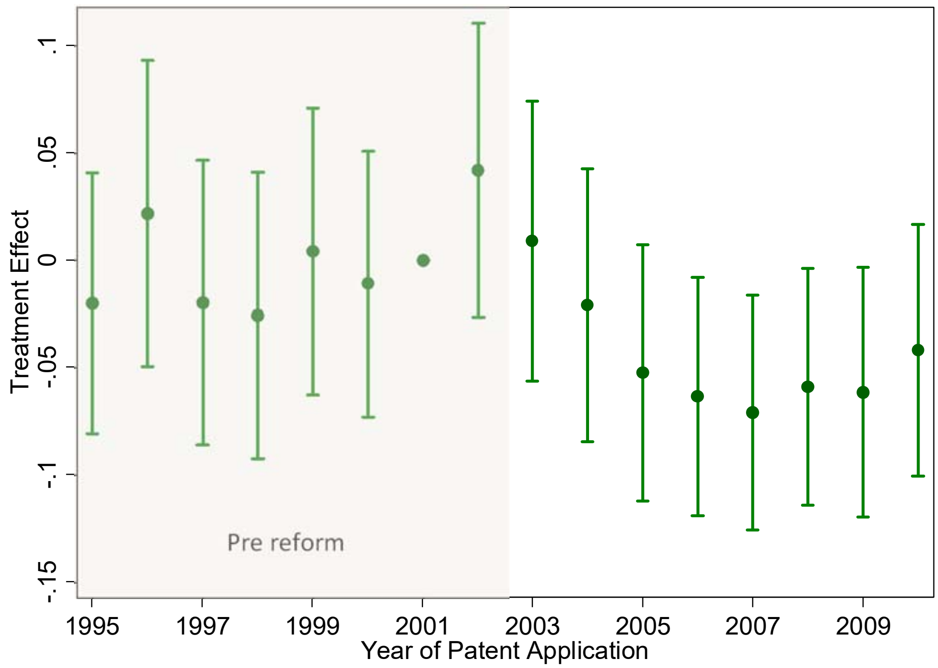
[18] The differences were to a large degree concerning the role division between the university and the TTO. For example, the University of Trondheim (NTNU) keeps the control and ownership rights of commercialization, while the other universities to a larger extent transfer the rights to the TTO (Rasmussen et al, 2006). The TTOs are at any extent controlled by the universities, so these differences are unlikely to play a large role for the incentives of the individual researcher.

Figure A1: Startup Treatment Effects by Year, Individual Level Analysis



Notes: The regression is at the individual level panel as in Table 5. We analyze a balanced panel of Norwegian PhDs over the 2000-20007 period, with interactions between treatment status and year for each founding year. Estimates are logit, with 95% confidence intervals shown. We visualize the 0 baseline using 2001 (two years prior to the reform) to better allow visualization of any potential racing to start firms in the year prior to reform.

Figure A2: Patent Treatment Effects by Year, Individual Level Analysis



Notes: The regression is at the individual level as in Table 8, now with interactions between treatment status and year for each application year. Estimates are the linear probability model, with 95% confidence intervals shown. We visualize the 0 baseline using 2001 (two years prior to the reform) to better allow visualization of any potential racing to start firms in the year prior to reform, for which there is some evidence in the patenting case.

Figure A3: Researcher Utility Maximization and Effort at Commercial Innovation

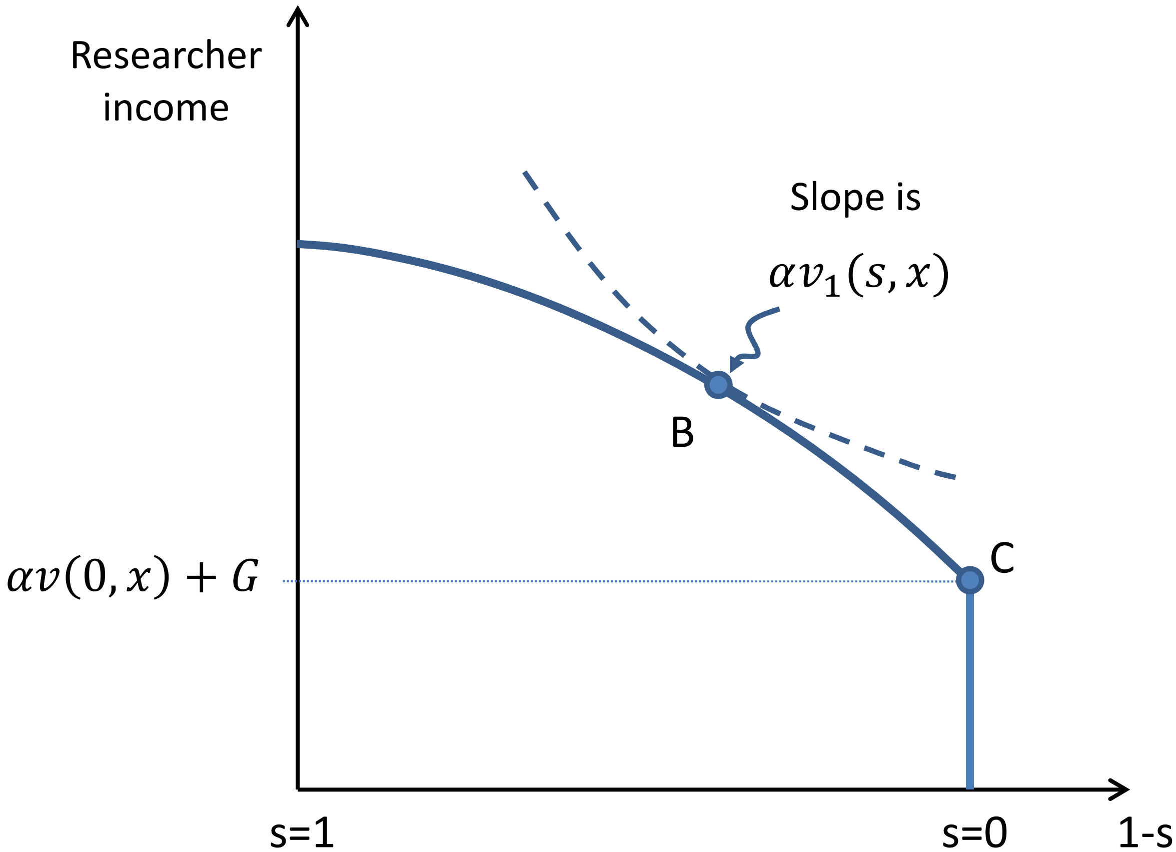
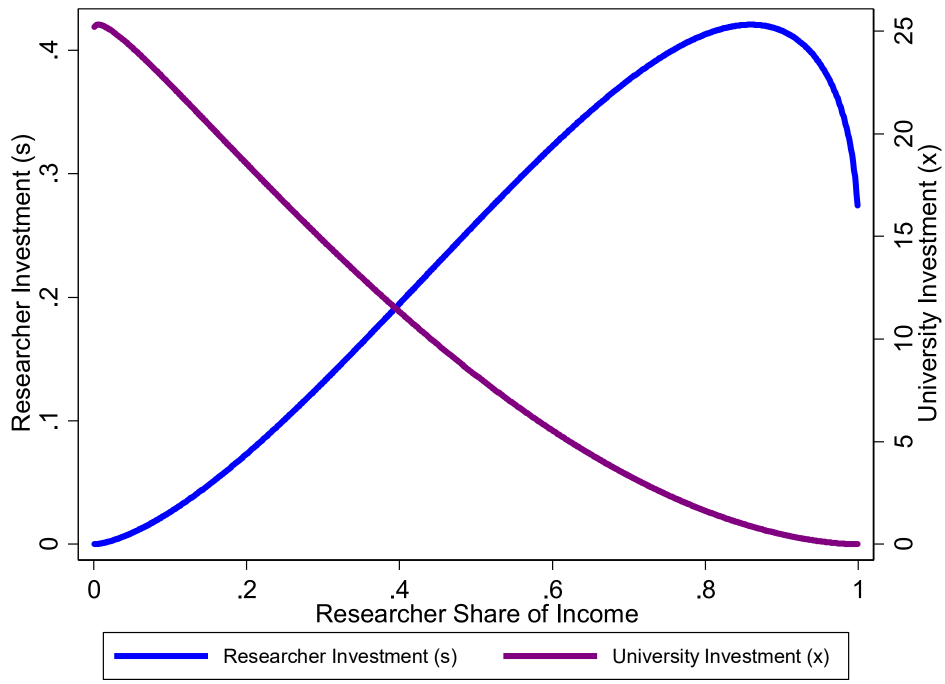
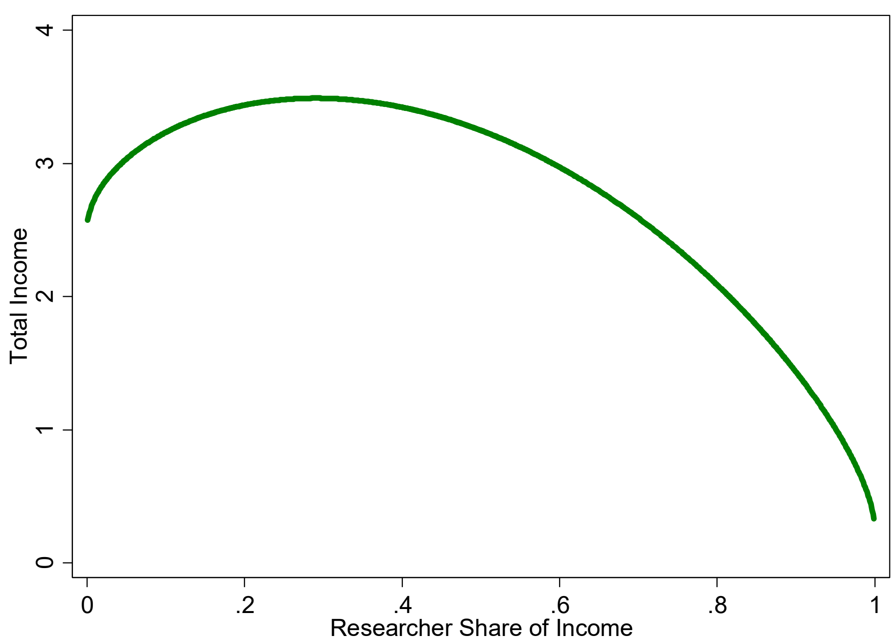


Figure A4: Investment and Innovation as Function of Researcher Rent Share (α)

CES Example





Notes: Example is CES (see equation (A3)). Parameters are $A_s = A_x = 1$, $\varphi = 0.5$, $\theta = 1$, $r = 0.1$, and $\rho = 1/3$.

Table A1: Exit Rates of Technical PhDs after the Reform

	(1) Exit	(2) Exit	(3) Exit
Treated x Post	-0.00989	-0.00815	-0.0303
	(0.00719)	(0.00834)	(0.0425)
Treated	0.00455	--	--
	(0.00656)		
Post	0.000700	--	--
	(0.00452)		
Observations	21,302	21,302	8,289
R-squared	0.000	0.272	0.257
Year FE	NO	YES	YES
Individual FE	NO	YES	YES
Age FE	NO	YES	YES
Sociodemographic controls	NO	YES	YES
Sample	University Phds	University Phds	Technical Phds

Notes: In columns (1)-(2), the sample consists of Phds employed at a university in 2000. The treated group are those with a science and engineering Phd and the control group are those with a non-technical Phd. The dependent variable, exit, equals 1 if the individual leaves the university sector in that year and zero if not. The mean of the dependent variable indicates a 5% probability of exit from (all) university employment each year. In column (3) the treated group are university science and engineering Phds who start a company in the pre-reform period, and the control group are university science and engineering Phds who do not start up a firm in the pre-reform period. Results are for the linear probability model, Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Table A2: The Publication Output of University Inventors

	(1) Publications	(2) Publications	(3) Fractional Publications	(4) Fractional Publications	(5) Mean Citations	(6) Mean Citations
University Inventor	0.668***	0.487***	0.177***	0.131***	3.317***	1.945**
	(0.188)	(0.185)	(0.051)	(0.051)	(0.976)	(0.979)
Doctoral Field FE	No	Yes	No	Yes	No	Yes
PhD Year FE	No	Yes	No	Yes	No	Yes
Year FE	No	Yes	No	Yes	No	Yes
University FE	No	Yes	No	Yes	No	Yes
Gender	No	Yes	No	Yes	No	Yes
R^2	0.00	0.08	0.07	0.00	0.05	0.04
Obs	49,640	49,640	49,640	49,640	49,640	49,640

Notes: Regressions are OLS. Observations are individual name by year. The sample mean of the dependent variables are 1.08 (publications), 0.30 (fractional publications), and 6.06 (mean citations). Doctoral field fixed effects account for differences between 35 different fields. The sample is limited to university researchers with rare names, though using entire sample produces similar results. Standard errors clustered by individual (* p<0.1; ** p<0.05; *** p<0.01).

Table A3: The Change in Publication Output within Individuals - Patent-Heavy vs. Patent-Free Research Disciplines

	(1) Patents	(2) Publications	(3) Fractional Publications	(4) Mean Citations
Patent-Heavy x Post	-0.006**	0.025	-0.034	-1.971***
	(0.003)	(0.107)	(0.024)	(0.657)
Individual FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R^2	0.25	0.00	0.64	0.00
Obs	17,329	17,329	17,329	17,329

Notes: Regressions are OLS. The patent-heavy and post terms are absorbed by the individual and year fixed effects, respectively. Patent-heavy fields are the top 5 (of 35) PhD disciplines by patent propensity on a per-person and per-year basis. Patent-free fields are the 15 (of 35) PhD disciplines with zero patents by university researchers from 1995-2010. Observations are individual name by year. The sample is limited to university researchers with rare names, though using the entire sample produces similar results. Standard errors clustered by individual (* p<0.1; ** p<0.05; *** p<0.01).

Table A4: The Change in Publication Output within Individuals - University Inventors vs. Non-Inventors

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Control Group: All Other University Researchers				Control Group: Nearest Neighbors			
	Patents	Publications	Fractional Publications	Mean Citations	Patents	Publications	Fractional Publications	Mean Citations
Inventor	-0.120***	-0.122	-0.073	-1.774	-0.123***	-0.177	-0.050	0.583
x Post	(0.018)	(0.194)	(0.057)	(1.414)	(0.018)	(0.275)	(0.073)	(1.982)
Indiv FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.26	0.75	0.64	0.32	0.23	0.77	0.61	0.35
Obs	49,640	49,640	49,640	49,640	3,694	3,694	3,694	3,694

Notes: Regressions are OLS. The inventor and post terms are absorbed by the individual and year fixed effects, respectively. Inventors are those university researchers who patented prior to the reform. In columns (1)-(4) the control group is all other university researchers. In columns (5)-(8) the control group are the two nearest neighbors to the inventor based on pre-reform publication rates, conditional on being in the same PhD field. Observations are individual name by year. The sample is limited to university researchers with rare names, though using the entire sample produces similar results. Standard errors clustered by individual (* p<0.1; ** p<0.05; *** p<0.01).

Table A5: Results from Survey of University Inventors

	(1) mean	(2) sd	(3) p50	(4) min	(5) max	(6) N
Q3. Number of patents between 1995 and 2010	4.46	6.10	3	1	40	63
Q5. Start year university	1,997	3.95	1,995	1,986	2,008	64
Q5. End year university	2,009	3.26	2,010	1,999	2,017	64
Q6. Inventor on any patent with application date before 2003. Fraction yes	0.80	0.41	1	0	1	59
Q7. At least one license on patents with application date before 2003	0.36	0.49	0	0	1	44
Q8. NOK in patenting income on patents with application date before 2003	423,438	1.25e+06	0	0	5.00e+06	16
Q9. University played at least some role on patents with application before 2003	0.30	0.47	0	0	1	27
Q11. Inventor on any patent with application date 2003 or after. Fraction yes	0.71	0.46	1	0	1	56
Q12. At least one license on patents with application date 2003 or after	0.23	0.42	0	0	1	40
Q13. NOK in patenting income on patents with application date 2003 or after	2,222	6,667	0	0	20,000	9
Q14. University played at least some role on patents with application 2003 or after	0.33	0.47	0	0	1	40
Q16. No effect on individual	0.61	0.49	1	0	1	56
Q16. Negative effect on individual	0.27	0.45	0	0	1	56
Q16. Positive effect on individual	0.13	0.33	0	0	1	56
Q18. Reform had no effect on colleagues	0.18	0.39	0	0	1	56
Q18. Reform had negative effect on colleagues	0.18	0.39	0	0	1	56
Q18. Reform had positive effect on colleagues	0.071	0.26	0	0	1	56
Q18. Reform had unknown effect on colleagues	0.57	0.50	1	0	1	56

Notes: The table reports summary statistics of a survey sent to university researchers that were inventors between 1995 and 2010. The survey was sent out by email and had a response rate of 22%. The survey did not require respondents to answer each question; the number of respondents for each question is given in column (6). For those that reported that they licensed a patent but did not report licensing income we imputed a zero income (6 respondents pre-reform and 4 respondents post-reform).

Table A6: Additional Patent Quality Specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Cites Within 5 Years	Cites Within 5 Years	Cited at Least Once	Cited at Least Once	Upper 75th Cites	Upper 75th Cites	Upper 95th Cites	Upper 95th Cites	In Force Patent	Renew for 5+ Years
Treated x Post	-0.320	-0.169	-0.078*	-0.135**	-0.108**	-0.074*	-0.053**	-0.039	-0.062	-0.047
	(0.223)	(0.212)	(0.047)	(0.055)	(0.046)	(0.044)	(0.027)	(0.025)	(0.042)	(0.045)
Treated	0.469**	0.310**	0.082***	0.086***	0.137***	0.099***	0.066***	0.046**	0.024	0.031
	(0.154)	(0.141)	(0.030)	(0.031)	(0.032)	(0.031)	(0.021)	(0.020)	(0.031)	(0.028)
Application Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Grant Year FE	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes
Technology Class FE	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes
Sample	Full	Full	Full	Granted by 2010	Full	Full	Full	Full	Full	Granted by 2010
Estimator	Poisson	Poisson	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
R^2	.	.	0.06	0.04	0.02	0.07	0.01	0.07	0.26	0.20
Obs	7,162	7,162	7,339	6,075	7,341	7,339	7,341	7,339	7,339	6,038

Notes: The table reports additional patent quality measures for citation counts and patent renewals. See discussion in Appendix IV.

Table A7: Norwegian Firm Size Distributions by 2-Digit NACE Industry

Industry		Firm Size Distribution by number of employees			Share of Work-force	Industry		Firm Size Distribution by number of employees			Share of Work-force
Code	Name	Small	Med.	Large		Code	Name	Small	Med.	Large	
1	Agriculture, hunting and related service activities	0.59	0.33	0.08	0.00	40	Electricity, gas, steam and hot water supply	0.05	0.10	0.84	0.01
2	Forestry, logging and related service activities	0.53	0.13	0.34	0.00	41	Collection, purification and distribution of water	0.27	0.17	0.56	0.00
5	Fishing, operation of fish hatcheries and fish farms service activities incidental to fishing	0.57	0.29	0.15	0.01	45	Construction	0.53	0.32	0.15	0.08
11	Extraction of crude petroleum and natural gas service activities incidental to oil and gas extraction,	0.01	0.01	0.98	0.04	50	Sale, maintenance and repair of motor vehicles and motorcycles retail sale of automotive fuel	0.63	0.29	0.08	0.03
13	Mining of metal ores	0.02	0.00	0.98	0.00	51	Wholesale trade and commission trade, except of motor vehicles and motorcycles	0.47	0.22	0.31	0.06
14	Other mining and quarrying	0.42	0.19	0.39	0.00	52	Retail trade, except of motor vehicles and motorcycles repair of personal and household goods	0.47	0.19	0.33	0.11
15	Manufacture of food products and beverages	0.14	0.22	0.64	0.03	55	Hotels and restaurants	0.45	0.37	0.18	0.04
17	Manufacture of textiles	0.33	0.30	0.37	0.00	60	Land transport transport via pipelines	0.31	0.16	0.53	0.03
18	Manufacture of wearing apparel dressing and dyeing of fur	0.40	0.60	0.00	0.00	61	Water transport	0.10	0.08	0.82	0.02
19	Tanning and dressing of leather manufacture of luggage, handbags, saddlery, harness and footwear	0.82	0.18	0.00	0.00	62	Air transport	0.06	0.10	0.85	0.00
20	Manufacture of wood and of products of wood and cork, except furniture manufacture of articles of	0.36	0.31	0.33	0.01	63	Supporting and auxiliary transport activities activities of travel agencies	0.27	0.17	0.56	0.02
21	Manufacture of pulp, paper and paper products	0.03	0.03	0.93	0.01	64	Post and telecommunications	0.25	0.32	0.43	0.00
22	Publishing, printing and reproduction of recorded media	0.29	0.14	0.57	0.02	65	Financial intermediation, except insurance and pension funding	0.04	0.14	0.82	0.02
24	Manufacture of chemicals and chemical products	0.05	0.05	0.89	0.01	66	Insurance and pension funding, except compulsory social security	0.03	0.02	0.94	0.01
25	Manufacture of rubber and plastic products	0.34	0.39	0.26	0.00	67	Activities auxiliary to financial intermediation	0.39	0.16	0.45	0.00
26	Manufacture of other non-metallic mineral products	0.28	0.22	0.50	0.00	70	Real estate activities	0.61	0.18	0.21	0.02
27	Manufacture of basic metals	0.07	0.08	0.85	0.00	71	Renting of machinery and equipment without operator and of personal and household goods	0.50	0.14	0.35	0.00
28	Manufacture of fabricated	0.39	0.40	0.21	0.01	72	Computer and related	0.45	0.26	0.30	0.02

	metal products, except machinery and equipment						activities				
29	Manufacture of machinery and equipment n.e.c.	0.34	0.23	0.43	0.01	73	Research and development	0.05	0.09	0.86	0.01
30	Manufacture of office machinery and computers	0.26	0.12	0.62	0.00	74	Other business activities	0.45	0.17	0.38	0.09
31	Manufacture of electrical machinery and apparatus n.e.c.	0.32	0.21	0.47	0.00	75	Public administration and defence compulsory social security	0.04	0.15	0.81	0.00
32	Manufacture of radio, television and communication equipment and apparatus	0.14	0.36	0.50	0.00	80	Education	0.32	0.31	0.37	0.01
33	Manufacture of medical, precision and optical instruments, watches and clocks	0.34	0.24	0.42	0.00	85	Health and social work	0.07	0.05	0.88	0.16
34	Manufacture of motor vehicles, trailers and semi-trailers	0.20	0.33	0.47	0.00	90	Sewage and refuse disposal, sanitation and similar activities	0.37	0.36	0.27	0.00
35	Manufacture of other transport equipment	0.16	0.22	0.63	0.01	91	Activities of membership organizations n.e.c.	0.05	0.09	0.86	0.02
36	Manufacture of furniture manufacturing n.e.c.	0.30	0.23	0.47	0.01	92	Recreational, cultural and sporting activities	0.25	0.13	0.62	0.02
37	Recycling	0.42	0.58	0.00	0.00	93	Other service activities	0.64	0.28	0.08	0.01

Notes: For each NACE industry code, the firm size distribution indicates the employment-weighted share of firms in the NACE code that are small, medium, or large, where small is defined as firms with 15 or less employees, large is defined as firms with 500 or more employees, and medium is defined as firms in between these other two categories. For each NACE industry code, the last column (share of workforce) is the employment share of that 2-digit NACE code among all full time workers in Norway.

Table A8: TTO Heterogeneity

	(1)	(2)	(3)	(4)
	Startups, All Workers	Startups, Entrepreneurs Only	Patents, All Inventors	Patents, Rare Names
Treated x Post x Oslo	0.000746	0.0116	-0.055*	-0.050
	(0.00252)	(0.0805)	(0.031)	(0.043)
Treated x Post x Bergen	-0.000973	-0.0269	-0.036	0.007
	(0.00291)	(0.0864)	(0.038)	(0.056)
Treated x Post x Trondheim	-0.00274	0.0312	-0.005	0.003
	(0.00337)	(0.0717)	(0.028)	(0.040)
Treated x Post	-0.00402**	-0.141***	-0.027	-0.028
	(0.00180)	(0.0528)	(0.019)	(0.033)
Oslo	-9.23e-05	0.0212	0.021	-0.012
	(0.00275)	(0.101)	(0.031)	(0.042)
Bergen	0.000195	-0.0166	0.024	0.003
	(0.00238)	(0.126)	(0.037)	(0.058)
Trondheim	0.000450	-0.0144	0.022	0.019
	(0.00261)	(0.0782)	(0.026)	(0.035)
Treated	0.000299	0.00332	0.028	0.039
	(0.00223)	(0.0673)	(0.019)	(0.029)
Year FE	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes
R^2	0.164	0.029	0.002	0.002
Obs	19,937,044	535,039	108,752	75,008
F-Test, p-value	0.751	0.916	0.287	0.449

Notes: These panel regressions follow the individual-level specifications in Tables 3 and 8 of the main text. For the startup regressions, the dependent variable is an indicator for whether the individual started a company that year. For the patent regressions, the dependent variable is an indicator for whether the individual patented at least once that year. Estimates are the linear probability model. The F-test tests the joint significance of Treated x Post x Oslo, Treated x Post x Bergen, and Treated x Post x Trondheim. Standard errors clustered by individual. (* p<0.1; ** p<0.05; *** p<0.01)