University Innovation and the Professor's Privilege[1]

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Abstract

Policymakers often seek to encourage innovation by university workforces. This paper studies a natural experiment: the end of the "professor's privilege" in Norway, where university researchers had previously enjoyed full rights to their innovations. Upon the reform, Norway moved toward the U.S. model where majority rights are held by the university. Using comprehensive data on all Norwegian workers, firms, and patents, we find an approximate 50% decline in entrepreneurship and patenting rates by university researchers after the reform. Quality measures for university start-ups and patents also decline. These findings inform literatures on technology policy, innovation incentives, and taxes and entrepreneurship.

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I. Introduction

University-based researchers can be sources of valuable commercial innovations. Standing at the frontier of knowledge, these researchers can start successful technology-oriented companies (such as Genentech and Google) and create intellectual property that is licensed for large sums (such as the pain medication Lyrica).[2] Government policies often seek to encourage the creation and transfer of commercial technologies from university workforces, and university-based technology transfer, patenting, and entrepreneurship have become the subjects of large literatures, as reviewed below.

In the past 15 years, many European countries have enacted laws intended to increase university commercialization activity. Inspired partly by the U.S. Bayh-Dole Act and a belief that U.S.-based universities are more successful at commercial innovation (Mowery and Sampat 2005, Lissoni et al. 2008), these policy reforms substantially altered the allocation of rights to university-based innovations. In Germany, Austria, Denmark, Finland, and Norway, new laws ended the so-called "professor's privilege", by which university researchers had previously enjoyed full rights to new business ventures and intellectual property they created. Recognizing the potential complementary between institution-level investments and researcher-level investments, the new laws sought to enhance university incentives to support commercialization activity. In doing so, these reforms also sharply increased the effective tax rate on university-based innovators. Broadly, these national systems moved from an environment where university researchers had full property rights to a system that looks much like the U.S. system today, where the innovator typically holds a minority of the rights (often one-third) and the university holds the remainder (Jensen and Thursby 2001).

This paper studies the effects of ending the "professor's privilege". We use the Norwegian context, where two-thirds of the property rights from a university researcher's commercial ideas

[2] For example, University of California San Francisco Professor Herbert Boyer founded Genentech to bring genetic engineering into the marketplace, and Stanford graduate students Sergey Brin and Larry Page founded Google and revolutionized Internet search. In the patenting sphere, Northwestern University Professor Richard Silverman created the compound for a pain medication, Lyrica, which was Pfizer's top-selling drug in 2014, with global sales of $5 billion. U.S. universities and research institutions were granted over 5,000 patents and executed over 5,000 licenses in fiscal year 2012, according to a recent survey (AUTM 2013).

were transferred to the university itself. We investigate two key commercialization activities: new venture creation and patenting. In addition to providing the policy experiment, the Norwegian context also provides an uncommon data opportunity. Namely, Norwegian census data provides detailed information about all workers and firms, while also linking specific individuals to specific firms. We are thus able to identify all new firms in Norway and all new firms started by university employees. The data further provides far-reaching information about all Norwegian adults, including educational attainment, degree type, age, income, wealth, and family status, allowing us to compare the behavior of those directly affected by the policy shock (i.e., university employees) with various control samples (e.g., all Norwegian individuals, and various subsets with increasingly similar demographic characteristics to the university employees). We separately collect all patents issued in Norway and compare patenting by university-based researchers with other Norwegian inventors.

Our primary empirical finding is that the shift in rights from researcher to university led to an approximate 50% drop in the rate of start-ups by university researchers. This drop appears (1) in a simple pre-post analysis of university start-up rates, (2) when compared to background rates of start-ups in Norway, and (3) when analyzed at the level of the individual Norwegian citizen, controlling for fixed and time-varying individual-level characteristics. We further find that university researchers substantially curtailed their patenting after the reform, with patent rates falling by similar magnitudes as seen with start-ups. In addition to these effects on the *quantity* of innovative output, we find evidence for decreased *quality* of both start-ups and patents, where university start-ups exhibit less growth and university patents receive fewer citations after the reform, compared to controls. Overall, the reform appeared to have the opposite effect as intended. Inventors and entrepreneurs in this context appear highly sensitive to their effective tax rate, and rebalancing the rent-sharing away from these individuals substantially reduced innovative output.

The analysis can provide insights for several literatures. Primarily, and most directly, this study informs the literature on university commercialization policy. The end of the professor's privilege constitutes a major shift in technology policy that was enacted in Norway and mirrored in several other European countries and, by design, created a post-reform regime similar to the rights allocation prevailing in U.S. universities today. The study thus informs the policy's effects in Norway, with potential applications to similar reforms and ex-post policy regimes more generally. Secondarily, we address the challenge of balancing rent-sharing in pursuit of innovative outcomes, a central theoretical concern in the economics of innovation (Aghion and Tirole 1994, Green and Scotchmer 1995) but one that has not, to our knowledge, been examined empirically using shocks to the rent-sharing regime. Finally, the end of the professor's privilege provides an opportunity to inform the link between tax rates and entrepreneurial activity. The literature on taxes and entrepreneurship has almost exclusively examined sole-proprietors and self-employed workers (e.g. Gentry and Hubbard 2000), who are typically quite different from the growth-creating innovators that motivate many studies of entrepreneurship (Glaeser 2007, Levine and Rubinstein 2015). The experiment in this paper considers a class of innovators who work at the frontier of science and technology, face in part a large increase in their effective tax rate, and subsequently substantially curtail their entrepreneurial activity.

This paper is organized as follows. Section II details the institutional setting, reviews relevant literature, and provides a simple formalization to fix ideas. Section III introduces the data and identification strategy. Section IV presents the empirical results. Section V discusses these findings, including their relevance to broader settings, and Section VI concludes.

II. University-Based Innovation

To frame our research questions and the potential effects of the policy reform, we review here relevant antecedent literature and then consider the institutional setting of the "professor's privilege" in numerous European countries, including the details of the Norwegian policy reform. We further provide a simple formalization to help clarify incentive tradeoffs that arise when balancing rent-sharing between the individual researcher and the research institution.

A. Foundational Literature

The long-standing upward trend in patenting and new venture activity among U.S. universities has triggered an enormous literature investigating university innovation and entrepreneurship. Scholars have seen universities as increasingly important wellsprings of innovative ideas, and researchers have investigated the legal systems, incentive conditions, organizational attributes, technology areas, and local business environment among other features that may help explain the relative success of various universities in commercializing innovations both along patenting and new venture channels (see, e.g., Lockett et al. 2005, Rothaermel et al. 2007, Grimaldi et al. 2011, National Academy of Sciences 2010). A major thrust of this research (and associated policy debate) takes the goal of university-based innovation as given and seeks to understand the features that influence its success.[3]

The 1980 Bayh-Dole Act is a signal event for researchers and policymakers in this space. The law eliminated U.S. government claims to university-based innovation, giving U.S. universities the rights to innovative ideas that were federally funded. Studies have since examined the potential effects of Bayh-Dole on patent rates (e.g., Mowery et al. 2001), patent quality (e.g., Henderson et al. 1998), and entrepreneurship (e.g., Shane 2004) among other issues. Interestingly, while U.S. university patenting rates were approximately five times larger in 1999 than in 1980, there is no evidence that Bayh-Dole caused a structural break in the pre-existing trend (Mowery and Sampat 2005). Nonetheless, policymakers in other countries have associated Bayh-Dole with high rates of university-based innovation and sought to emulate Bayh-Dole (Mowery and Sampat 2005, Lissoni et al. 2008).

Beyond its potential to inform technology policy, the shock of ending the professor's privilege can provide empirical insight on core theoretical ideas in the economics of innovation that consider property rights allocation issues (Aghion and Tirole 1994, Green and Scotchmer 1995, Scotchmer 2004, Hellman 2007). Aghion and Tirole (1994) provide canonical analysis of innovation contexts where different agents bear private costs but share in future payoffs and emphasize the challenge in effectively balancing incentives across investing parties. A natural mapping to the university-based innovation context is the rent-sharing between the inventor and the research institution, where both may make separate investments in pursuit of a commercial outcome. Investments by the individual researcher, as the source of the ideas, naturally appear critical. The university may also play important roles by supporting research infrastructure, searching for commercializable ideas within university laboratories, facilitating patent

[3] Separately, many scholars have addressed whether universities should engage in commercial innovation activity given potential tradeoffs with other activities, especially basic research (Jaffe et al. 2007, Thursby and Thursby 2003, Sampat 2006). These tradeoffs are essential to understand for a complete assessment of commercialization policy; they are also difficult to assess given the manifold spillover margins, including the difficulty of estimating the social returns from basic research or returns to other activities, like investment in teaching new generations of scientists. Along one dimension, individual-level publishing and patenting appear positively correlated (Azoulay et al. 2007, Buenstorf 2009) which suggests that basic research and invention may be complements rather than substitutes. This finding is consistent with conceptualizations of scientific progress based on Pasteur's Quadrant (Stokes 1997), so that the tradeoffs between research and invention may not be so acute.

applications, managing licensing, and otherwise investing to promote successful commercial outcomes (e.g., Rothaermel et al. 2007). Amidst these potential benefits, university-level investments are the subject of much debate. Some scholars argue that university technology transfer offices (TTOs) have poor capabilities or inappropriate incentives and suggest reallocating rights toward the faculty in pursuit of greater technology transfer (Litan et al. 2007, Kenney and Patton 2009). In practice, the appropriate rights allocation in the university context remains unknown. More generally, while theories emphasizing rights allocations in the economics of innovation are highly influential, empirical studies testing these theories remain relatively few (Lerner & Merges 1998; Lach and Schankerman 2008, Lerner & Malmendier 2010), especially those employing natural experiments. The "professor's privilege" reform provides a natural experiment to examine the importance of rights allocations in practice, leveraging a large change in the rent-sharing regime.

A closely related question concerns innovators' responsiveness to income incentives. Shifting property rights away from an innovator acts, in part, as an increase in the effective tax rate on their effort, and the extent to which innovators are sensitive to income considerations may thus modulate the effect of rent-sharing policies. The public finance literature links higher tax rates to diminished entrepreneurial activity (Hubbard and Gentry 2000, Bruce and Gurley 2005), although the data traditionally focus on the self-employed and/or sole proprietors (e.g. tradesman, dry cleaners), who appear to match poorly with the kinds of entrepreneurship often thought to play a central role in creating new ideas and driving economic growth (Levine and Rubinstein 2015; Glaeser 2007). By contrast, while university-based researchers are arguably a key source of innovative ideas for the economy, the responsiveness of such innovators to income expectations is not well known. Evidence suggests that university-based researchers on average value income relatively less than industrial researchers (Stern 2004), and entrepreneurs in general appear to have strong tastes for autonomy and other motivational characteristics distinct from income (e.g. Evans and Leighton 1989, Hamilton 2000, Shane et al. 2003). Moreover, studies of university entrepreneurs further suggest the importance of motivations beyond income and distinct traits from other university researchers (Roach and Sauermann 2012, 2014). Overall, the extent to which university-based innovators react to effective tax rates appears unknown.

In sum, the policy experiment of ending the professor's privilege may shed light on several related literatures. First, as a study of national commercialization policy, we can inform the policy's effects in Norway, with potential applications to similar reforms elsewhere in Europe and similar ex-post policy regimes more generally. Second, this policy experiment speaks to canonical issues of innovation incentives in the context of rights allocations, drawing on Norway's large shock to inventor and university rights. Third, the experiment may inform how changes in the effective tax rate influence innovative activity for an important class of innovators. A simple formalization in Section II.C further clarifies these issues.

B. The Professor's Privilege Reform

The acceleration of patenting and licensing from U.S. universities eventually caught the attention of European policymakers, who concluded that European universities lagged their U.S. counterparts in commercialization outcomes (Geuna and Rossi 2011). In the early 2000s, numerous European countries passed laws that attempted to encourage universities' interest and success in commercialization. This policy goal was implemented in several countries (Germany, Austria, Denmark, Finland and Norway) by ending the "professor's privilege". Under the professor's privilege (i.e., prior to the reform), a university researcher retained blanket rights to his or her invention. The new policies shifted substantial rights to the university. Notably, although policy makers in Europe were inspired by the post-Bayh-Dole Act environment in the U.S., the policy changes around the professor's privilege were quite different from the Bayh-Dole Act. Instead of transferring rights away from the government, this transfer came from the researchers themselves. The end result was that these European countries obtained a legislative environment similar to that in the U.S. since Bayh-Dole.

In Norway, the professor's privilege (*laererunntaket* in Norwegian) was abolished by unanimous Parliament decision in June 2002, and made effective for all public higher education institutions from January 1, 2003.[4] The new law gave the university the formal ownership rights to the commercialization of research (including startups and patents). Norwegian universities shared one third of the net income with the researcher after the law change, so in effect the policy

[4] The non-public higher education sector is very small in Norway and was not covered by the reform. The law change is named Proposition No. 67 of the Odelsting (2001–2002). A full transcript of the Parliamentary session leading to Proposition 67 is available at https://www.stortinget.no/globalassets/pdf/referater/odelstinget/2002-2003/o021107.pdf.

change reduced the inventor's pre-tax expected income by two thirds.[5] Given income taxes in Norway, this change represents an approximately 33 percentage point increase in the effective tax rate the researcher faces when forming new ventures or creating patentable inventions.[6] In the case of patents, university bylaws obligate the university to claim its property rights within six months after the researcher discloses the invention. Should the university decide not to use its option, the rights are returned to the inventor.

The premise behind the policy change was that the university will be encouraged to make investments that support patenting and licensing by their researchers and labs, so that this property rights transfer would improve commercialization outcomes on net (Czarnitzki et al. 2008). However, as discussed in Section II.A, the empirical evidence that could motivate this view was lacking (Lissoni et al. 2008). Moreover, the policy arguments – and literature on the Bayh-Dole Act more generally – tend to focus on university-owned IP as the mode of technology transfer from universities. This focus leaves aside the potential for university academics to start companies, rather than license, which is a primary commercialization alternative (e.g. Gans and Stern 2003). As we will show, both patenting and this "other" commercialization mode – new ventures – appear to have been severely affected by the end of the "professor's privilege".[7]

C. Formalization

Numerous countries eliminated the "professor's privilege" with the goal of increasing university commercialization policy. To sharpen the ideas behind these policy reforms, we introduce a simple formalization. Namely, consider a policymaker that seeks to encourage the flow of

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[5] While Germany included a clause in the new law that the university must share 1/3 of net revenues with the researcher, in Norway this norm was not formally established in the law per se but rather was called for by the parliamentary committee chairman, who stated explicitly at the time the law was passed that a one-third split with the researcher was expected. This norm was then further formally established later in the decade in university bylaws.

[6] The marginal tax rate in Norway is approximately 50% on both labor and business income, so that pre-reform 100 kroner in commercialization profits would have net value of about 50 kroner for the researcher. Post-reform the net value would be one-third, i.e., 16.7 kroner, so that the post-reform effective tax rate would be 83%. The increase in effective tax rate is thus approximately 33 percentage points.

[7] Interestingly, Lissoni et al. (2008) have shown that, in contrast to the U.S. experience where 69% of university-based inventions are assigned to universities, the great majority of university-based inventions in France, Italy, and Sweden are actually assigned to private firms. While it is not known whether these firms are new ventures, the Lissoni et al. study raises further questions about the empirical motivation for the European policy reforms. Once these privately-owned patents are accounted for, university researchers in these three European countries (especially Sweden) show only modestly lower patenting rates than U.S. universities, which undercuts the empirical view that European universities were laggards in commercialization activities in the first place.

commercially-valuable innovations from the university sector. 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, via law, rules on the allocation of property 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 any discovered 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 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, and 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

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

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

$$\hat{s} = argmax_s[\alpha v(s, x) + G - \theta s] \quad (2)$$

The researcher earns $\alpha v(s, x) + G$, where G represents the individual's academic salary or other non-commercialization income.[8] The disutility of commercialization effort (i.e. the loss of time for basic research, leisure, or other activities) is given by θs.[9]

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".[10] 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.

To understand the role of such complementarities, consider a standard labor supply diagram for the researcher (see Figure 1) 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 A. 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 (2), 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 1). 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,

[8] 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.

[9] 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.

[10] 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.

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. See appendix.

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.[11] However, in the presence of complementarities ($v_{12} > 0$), and where the university's investment is increasing in the 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 only 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.

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

$$v(s,x) = [A_s s^\rho + A_x x^\rho]^{\varphi/\rho} \tag{3}$$

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 2 as a function of the policy α for illustrative parameters.[12] We see that both researcher and university investments increase here 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

[11] 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.

[12] 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.

"professor's privilege" in the vein of several European countries – and the similar balance between researcher and university rent shares in the United States today.

III. Data and Identification

In this section, we describe the data sets and the econometric methods we employ.

A. Data

The data on startup activity draws together several Norwegian register databases. The socio-demographic data, compiled by Statistics Norway, covers the Norwegian adult population, and consist of yearly records of workplace ID, in addition to education level, gender, income, wealth, marital status, and many other variables. We identify university employees through their workplace ID, and researchers as individuals with a PhD degree. These university-employed PhDs are the 'treatment group' in our analyses.

The startup data, collected from the government registry "Bronnoysundregisteret", covers the population of incorporated companies started in Norway between 2000 and 2007, and provides total equity, owner ID, and ownership shares at the incorporation date. The owner ID, which is available for any individual who owns at least 10% of the company, can be matched to the sociodemographic data, and in this manner we identify new firms started up by university researchers as well as the sociodemographic characteristics of entrepreneurs more generally. The data further contains anonymous ID numbers for the startups, which allows us to match at firm level with longitudinal, yearly, accounting data collected from Dun & Bradstreet. The accounting data runs through 2012; it identifies which sector the startup operates in and contains annual measures of startup performance such as sales, profits and employees.[13]

[13] Note that we focus on incorporated companies, which does not include self-employment. Levine and Rubinstein (2015) show in the U.S. context that incorporation is an important indicator for locating growth-creating innovators and organizations, while self-employment is misleading for capturing such entrepreneurial firms. As in other industrialized countries, starting an incorporated company in Norway carries tax benefits relative to self-employment (e.g., write-offs for expenses such as home office, company car, and computer equipment). With the exception of very small projects, incorporation is more tax efficient than self-employment status. The formal capital requirement for registering an incorporated company was NOK 100,000 (EUR 13,000) during the study period. Incorporated companies are required to have an external auditor certify annual accounting statements submitted to tax authorities.

The patenting analysis is based on separate data collected from several sources. We first obtained a list of the names of university-sector researchers for the period 1995-2010 from the Nordic Institute for Studies in Innovation, Research and Education (NIFU).[14] There are 14,442 unique individuals in this data. In addition to full names, this dataset contains sociodemograhic information such as gender, age, and PhD type, as well as the specific university employer. From the Norwegian Patent Office (NPO) we obtained a list of all Norwegian patents issued to inventors in Norway from 1990-2014.[15] We then matched the names from NIFU with the inventor names in the patent data to determine which patents had university inventors. These matches are based on employment at the university at the time of the patent application. The matching procedure uses full first names and surnames; robustness checks to account for potential noise in name-matching for the patent data are included below. We further matched all the NPO patents with the European Patent Office's PATSTAT database, to determine the number of citations each Norwegian patent receives.[16]

Table 1A provides summary statistics for start-up firms in Norway between 2000 and 2007. In total there were 48,844 startups and 128 of these were started up by individuals with PhDs employed at a university. We define a university startup as a newly incorporated company where at least one of the initial owners is a full-time university employee with a PhD. By comparison, there were 452 start-ups by individuals with PhDs who were not employed at universities. Overall, we see that university PhD start-ups were somewhat more likely to survive to 5 years than non-university PhDs and substantially more likely to survive than companies started by the broader background population.[17] By contrast, university PhD startups tend to be somewhat smaller in employees, sales, and profits than non-university start-ups, with a closer match to non-university PhD startups.[18] Looking at median outcomes, the firms at five years tend to be very small. The 75th percentile company in each category features 1-3 employees while sales reach 1.2-3.3 million NOK, depending on the population, while the 95th percentile

[14] The NIFU list of university researchers is biannual for 1995-2006 and annual for 2007-2010.
[15] These Norwegian patents include patents that were granted by the European Patent Office and then waived in by the Norwegian Patent Office.
[16] We are indebted to Stefano Breschi for help in matching the NPO and EPO data.
[17] Non-surviving firms are defined as those that stop reporting profits or whose sales fall below 50 thousand NOK after their first year.
[18] Performance at five years is not conditional on survival. The greater survival but lower average performance is consistent, for example, with university PhDs relying less on the start-up for income, given their university employment, and hence being more likely to continue with lower performing firms.

companies are substantially larger, with 5-12 employees and sales of 6.9-16.4 million NOK across categories. Overall, we see greater performance similarity among start-ups by PhDs than with start-ups in the background population. These findings also indicate the relative rarity of substantial entrepreneurial success, which suggests the low likelihood of substantial returns to starting new companies.[19]

Table 1B provides summary statistics on entrepreneurs in Norway. On average, university entrepreneurs are older, are more educated, have higher income, and are more likely to be male and married than non-university entrepreneurs. Compared to non-university PhD entrepreneurs, the university entrepreneurs look much more similar. By construction, individuals in both groups have PhDs. They also have similar average ages (47) when starting companies and similar marital status (74% married). The income and wealth for the non-university PhDs is somewhat larger, and the non-university PhD entrepreneurs are slightly less likely to be male.

Table 1C provides summary statistics for patents. We see that 319 university researchers produced 566 patents over the 1995-2010 period. Although about two-thirds of the university PhD workforce is male, university inventors are 91% male. The background population of Norwegian inventors is estimated to be 95% male. The substantial propensity toward male inventors echoes the similar gender propensity seen in entrepreneurship above. Note that we otherwise have little information about the demographics of the Norwegian inventors, as the inventor data (which gives full names) does not link to the Norwegian census data (which uses anonymized identification numbers).

Based on the Norwegian census data at the end of 2002, there were 3,747 university researchers in Norway, 8,272 PhDs who worked outside universities, and a total Norwegian workforce of 2.501 million. The PhD workforce expanded more rapidly than the broader Norwegian workforce over the period from 2000-2007. In particular, the university PhD workforce, non-university PhD workforce, and total Norwegian workforce grew at rates of 65%, 39%, and 7% respectively.

[19] See Guzman and Stern (2015a, 2015b) for analysis of the rarity of high-growth entrepreneurship in the U.S. and in the environs of U.S. universities.

B. Econometric Approach

Our analyses primarily consider difference-in-difference regressions, using the end of the professor's privilege to divide the sample into pre and post periods and comparing start-up and patenting rates inside the university sector (the treatment group) and outside the university sector (the control group). We first study panel models of the following form:

$$y_{it} = \beta_0 Post_t + \beta_1 Treat_i + \beta_2 Treat_i \times Post_t + \varepsilon_{it} \quad (4)$$

where the dependent variable y_{it} is a count of start-ups or patents, $Post_t$ is a dummy variable equal to 1 in years after the reform (2003 or later), and $Treat_i$ is a dummy equal to 1 if the observation represents universities – i.e. those affected by the end of the "professor's privilege". We start by looking simply at the pre-post difference for university start-up rates and patent counts, before introducing control groups (start-up and patenting behavior in Norway more generally) and using the difference-in-difference specification in (4).

When using data at the sector or individual level, we extend the panel model in (4) to incorporate sector or individual fixed effects (α_i) and time fixed effects (μ_t). In some specifications we will also incorporate time-varying individual characteristics (X_{it}), such as lagged income and wealth. These difference-in-difference regressions thus generally take the form:[20]

$$y_{it} = \alpha_i + \mu_t + \beta_1 Treat_i + \beta_2 Treat_i \times Post_t + \gamma X_{it} + u_{it} \quad (5)$$

In the relevant regression models, we cluster standard errors at the individual level.

IV. Results

In this section we present the main results of the paper. We consider entrepreneurship in Section IV.A and patents in Section IV.B.

A. Startups

The Rate of Entrepreneurship

[20] Note that the time fixed effects absorb the $Post_t$ term. The sector-level fixed effects do not absorb the $Treat_i$ term because treatment status varies within sectors. The individual fixed effects do not in general absorb the $Treat_i$ term because individuals may move between university and non-university employment.

We first consider how the rate of start-ups for university researchers changes after the reform and then compare it to changes in start-up rates for the background Norwegian population. Figure 3A plots the annual number of university start-ups (red line, left vertical axis) and non-university startups (blue line, right vertical axis) over the sample period.[21] While the non-university startup rate is approximately constant across years, the university startup rate drops dramatically from the pre-reform (2000-2002) to the post-reform (2003-2007) period. The pre-reform period averaged 24.7 university start-ups per year, while the post-reform period averaged 10.8 university startups per year, for a drop of 56%.

Figure 3B considers the same data on a per-worker basis for the relevant groups. On average, 0.678% of university researchers started a new firm in a given year prior to the reform, while 0.224% of university researchers started a new firm in a given year after the reform, for a 67% drop in the per-worker rate. The drop is slightly larger on a per-worker basis (Figure 3B) than on a count basis (Figure 3A) because the number of university researchers is increasing relatively rapidly over the period compared to the Norwegian workforce as a whole.

Together, these figures show a sharp drop in entrepreneurship by university researchers that is coincident with the professor's privilege reform. By contrast, the start-up rate for the background population is largely flat, increasing 5.9% comparing the post and pre periods (Figure 3A) and increasing 2.1% on a per-capita basis (Figure 3B). Thus, the large decline in start-up rates by university researchers is not seen in the background Norwegian population.

The "visual" differences-in-differences shown in Figure 3 are explored further by regression. Table 2 presents aggregate analysis, looking at changes in log annual counts per year and log annual counts per worker. The regressions implement the econometric model (4). Examining the $Treat_i \times Post_t$ coefficient, we see that the drops in both start-up counts and start-up counts per worker are statistically significant compared to the Norwegian workforce as a whole (columns 1 and 2). On net, and consistent with the mean changes seen in Figure 3, we see a 69% decline in the start-up rate per worker comparing university PhDs against the Norwegian workforce. Columns 3 and 4 repeat this analysis using PhDs not employed at university as the

[21] The vertical axes in Figure 3 and related figures in the paper begin at 0 so that the percentage changes in the data being compared can be seen visually.

control group. We again see statistically significant declines in startups by university PhDs, with a 52% decline in start-ups per worker comparing university PhDs against non-university PhDs.

Table 2 further considers sector-level analysis. This analysis can account for compositional changes in the sectors of start-up activity that might otherwise influence the results. In this analysis, the start-up counts are constructed by sector-year for the treatment and control groups, where sector is determined by the 1-digit NACE code.[22] Columns 5 and 6 examine the log start-up count as the dependent variable. Because this approach drops sector-years with zero counts, column 7 repeats the analysis with a Poisson count model that includes the full set of observations. The results are similar regardless of the regression specification and control group. The difference-in-difference drop in university start-up rates, using either control group, is now 43%.

Table 3 considers regression evidence at the individual level, using econometric model (5) and exploiting data for every individual in the Norwegian workforce. The dependent variable is now binary, indicating whether a given individual started a company in a given year. We use a linear probability model, which allows the inclusion of individual fixed effects, with standard errors clustered by the individual. Non-linear models, such as logit or probit, show similar results.[23] Column (1) presents the simplest analysis, with no individual-level controls. Column (2) adds individual and year fixed effects, and column (3) additionally adds time-varying individual-level information, including age fixed effects, fixed effects for highest educational degree, marital status, lagged income, and lagged wealth.[24] The latter two specifications allow us to control for population differences between the treatment and control groups – either via unobservable, fixed individual level characteristics or several observable and time-varying characteristics – that may explain individual startup tendencies, including possible compositional changes with time that might create shifts around the reform year. In practice, we see little change in the $Treat_i \times$

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[22] We use 1-digit sectors because start-up counts for the treatment group are not large enough to allow analysis for more granular sector categorizations.

[23] We present the linear probability model primarily to allow inclusion of individual fixed effects and to compare results with and without these fixed effects. Logit or probit specifications are also presented below as alternatives and typically show more precise results (smaller standard errors). Given the increased precision seen with the non-linear models, we emphasize the linear probability model in the exposition to be conservative. Complete results using non-linear models are available from the authors upon request.

[24] Income and wealth controls for each worker are quadratics in the log of each variable, lagged by one year. Wealth is provided in the registry data due to the Norwegian tax code, which includes a wealth tax.

$Post_t$ coefficient when adding these controls, which suggests that changes in the socioeconomic characteristics of the underlying populations in the treatment and control samples do not drive the results. Given that most Norwegian workers do not start companies, columns (4) and (5) repeat the individual-level specifications while restricting the sample to those individuals who started at least one company in the 2000-2007 period. These regressions show that, conditional on starting a company at some point, university PhD entrepreneurs were far less likely to do so after the reform compared to other active entrepreneurs in Norway. The magnitude of the effect in these individual-level analyses remains very large. For example, using column (1), the propensity for university PhDs to start companies declines by 63% after the reform.[25]

In Table 1A we see that a small minority of Norwegian entrepreneurs have advance degrees, especially PhDs. Table 4 thus presents further individual-level analysis, using control samples of workers who share increasingly similar observable characteristics to university researchers. Column (1) of Table 4 limits the control group to those with at least a Master's degree and shows large declines in startup propensities of university researchers compared to this narrower control group. The remaining columns of Table 4 limit the control group to those with PhDs, who thus match the educational attainment of the university researchers. Column (2) suggests a somewhat less precise effect for this control group using the linear probability model ($p<.10$) while non-linear models show greater precision as shown in column (3) ($p<.001$). Using a propensity score match to find the single nearest neighbor to each university-employed PhD, with matching based on age, PhD type, gender, and marital status, the magnitude and statistical significance using the linear probability model increases, as shown in column (4). This propensity-score sample provides the most closely matched control group to the university workers. In columns (5) and (6), the sample is restricted to those who started at least one company in the 2000-2007 period. Conditional on starting a company at some point, university PhD entrepreneurs were far less likely to do so after the reform compared to other PhD entrepreneurs in Norway.

While the PhD control group shares close observable similarities to the treatment group, which may provide identification advantages, this control group might also be entangled to some degree

[25] To see this magnitude, consider that the mean of the dependent variable in columns (1)-(3) is 0.00389 of Table 3. Looking at column (1), we see that university PhDs, prior to the reform, started companies at a rate 0.00358 higher, or at about twice the background rate for the average Norwegian worker. After the end of the professor's privilege, university PhDs start companies at a rate 0.00450 less than before, which is a 63% decline in their prior rate.

by the reform. For instance, the university's rights may extend to recent PhD students, to the extent their innovations are based on research conducted while at the university. Column (7) thus drops those with recently received PhDs. We see somewhat larger and more precise effects. More generally, to the extent that startups by non-university PhDs (the control group) could be negatively affected by the reform, either because PhDs themselves were recently university-based researchers or because they tend to start companies in partnership with university researchers, the difference-in-difference results comparing university and non-university PhDs would be biased against finding effects, i.e., conservatively. One might alternatively imagine sources of non-conservative biases for this control sample, although the plausibility for the reform positively affecting startups by non-university PhDs may be limited.[26] To the extent that the reform affects non-university PhDs in ways that could lead to biases, one may return toward the analyses using broader control populations, as featured first above.

We can further investigate underlying margins of response by university researchers. One question is whether the decline in entrepreneurship is seen among individuals who remain employed at the university (the intensive margin) versus a decline driven by entrepreneurially minded individuals leaving the university (the extensive margin). The latter case, were it the main story, might suggest substitution in the accounting for university-based entrepreneurship rather than a decline in entrepreneurship from these individuals.

Table 5 provides evidence to tease out these dimensions. We consider a balanced panel of workers with PhDs and define the "stayers" as university researchers who are employed at the university throughout the 2000-2007 period. The control group consists of PhDs who were never employed at universities during the 2000-2007 period. Columns (1) through (3) show that the "stayers" experience a large decline in entrepreneurship; the magnitude (and statistical significance) of the reform effect for "stayers" is in fact broadly similar to the earlier findings for all university employees. That "stayers" drive the overall results is also natural given the stickiness of university employment – "stayers" are the majority of university employees. Thus

[26] One mechanism might be as follows. To the extent that non-university PhD startups compete with university PhD startups, the decline in university PhD startups might potentially encourage more entry by the non-university PhD group. This possibility is hard to test specifically, although the broader evidence and environment does not suggest it. For example, the non-university PhD startup rate doesn't go up in absolute terms after the reform, and more generally university researcher startups are a very small percentage of businesses in any sector, which may limit the plausibility of such competition effects.

there is strong evidence the overall reform effects are largely driven by the intensive margin: the decline in entrepreneurship came among a consistent set of university employees, who started firms at lower rates after the reform than they did before.

Lastly, we can examine whether university researchers attempt to “cheat” by starting firms through their family members and thereby avoid university property rights claims. The structure of our data allows us to look at this possibility, as we can identify family members of university employees, defined as spouses or children. We find no increase in start-ups by family members after the reform (results available upon request).

The Quality of Entrepreneurship

Beyond the quantity of startups, we can also consider the quality of startups and whether this changes after the reform. We examine the rate of survival as well as the sales, employees, and assets of new ventures. Lastly, we consider measures for the technology-orientation of start-up firms and the patenting behavior of university start-ups.

Tables 6A and 6B consider start-up performance before and after the reform. As before, we use differences-in-differences. In Columns 1-4 of Table 6A, the control group is the background population of new ventures in Norway. Column 1 shows the probability of survival to year 5. We see a weakly significant but large decline of 16 percentage points in the probability of survival by university start-ups after the reform. Conditional on survival, sales also become substantially lower for university start-ups, while employment in and the assets of these startups are negative but statistically insignificant. When comparing to start-ups by non-university PhDs in Columns 5-8, the results appear broadly similar in their point estimates but with less precision, so that there is no statistical significance at conventional levels.

Table 6B reconsiders these results at year 5 but uses a binary dependent variable for whether the performance indicator is in the upper quartile of performance among Norwegian new ventures. This analysis can account transparently for changes in the rate of “relatively good” startups, while avoiding upper tail outliers that can otherwise influence the results.[27] The threshold for an

[27] In general, evidence suggests that successful startups are rare, even in clusters around universities (Guzman and Stern 2015a, 2015b), and the evidence about firm size in Table 1A further suggests the thick upper tail in startup growth, so that mean regression may be driven by outliers.

upper quartile start-up is 3.3 million NOK in sales and 3 employees at an age of 5 years.[28] The findings in Table 6B broadly echo the above results. The probability that a university startup surpasses the 75th percentile of sales declines by 12 percentage points at conventional significance levels after the reform, compared to other startups. The probability of surpassing the 75th percentile of assets at year 5 declines by a similar magnitude while employment shows little effects. As before, effects are statistically weaker, but broadly similar in magnitude, when using the non-university PhD start-ups as the control group.

Separately from accounting performance, and with the caveat that sample sizes become small, we can further examine whether there is a specific decline in higher-technology start-ups. To perform this analysis, we examine start-up counts again but now use the Eurostat classifications of 2-digit NACE codes to exclude (a) manufacturing sectors that are defined as "low-technology" and (b) service sectors that are considered "less knowledge intensive."[29] Table 6C considers the aggregated counts, using the same regression as in Table 2 but now counting only the remaining, higher-technology firms.

Table 6C column 1 indicates a substantial decline in higher-technology startups by university researchers after the reform when compared to higher-technology startups in Norway as a whole. Column 2 shows a negative but insignificant decline compared to non-university PhDs. In both column 1 and column 2, the Post dummy is notably negative and significant, indicating that higher-technology start-ups declined more generally in Norway after the reform. This decline is driven by the decline in information and computing technology (ICT) startups across Norway.[30] Columns 3 and 4 show, removing such ICT startups from the sample, the Post coefficient is no longer large or significant. These columns further show large, negative effects of the decline in technology-oriented startups from university researchers, with similar size effects using either control group.[31] Poisson models (not reported) rather than OLS show similar effects with

[28] The upper quartile is determined across the set of all new ventures (i.e., including those that do not survive to five years, for which we impute a value of 0 for sales, assets, and employees).
[29] The Eurostat sectoral classifications by technological-intensity can be found at: http://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an2.pdf.
[30] Startups in "computer and related activities" (NACE code 72) were frequent in the early 2000s in Norway, as they were elsewhere.
[31] These findings are also consistent with the findings in Table 2, which analyzed counts at the 2-digit sector level. Overall, PhDs are more active in higher-technology sectors than the general population and were more active in ICT startups as well. When controlling for sector, the results become more similar across the control groups. See columns 5-7 of Table 2 as well as Columns 3 and 4 in Table 6C.

increased precision. The decline in higher-technology start-ups by university researchers can also be seen in individual-level analysis, controlling for individual level characteristics.[32] Notably, the difference-in-difference decline in technology start-up rates in columns 3 and 4 implies a 71% drop. This decline is larger than the decline for university start-ups generally, indicating that these university technology startups fell proportionately more on average, although this excess decline is not statistically significant.[33]

Lastly, we collected the incorporation documents for all university start-ups to search for patents by these young firms. In particular, we searched the Norwegian Patent Office database for patents where the start-up was listed as either the applicant or the assignee. We found that, among startups by university researchers founded prior to the reform, 12% obtained a patent within five years of founding. Among university startups founded after the reform, only 1.9% percent obtained a patent within this window. This decline is significant at the 1% level using a simple t-test.

Overall, integrating across performance measures based on accounting data, technology-intensity of the sector, or patenting, these results indicate that start-up performance measures, if anything, declined after the end of the professor's privilege.

Summary

In sum, we see a large drop in entrepreneurship by university researchers starting in the year of the "professor's privilege" reform. This decline (56%) appears in a simple pre-post of university researcher start-up behavior, and it appears similarly large when compared to the background startup rates for a range of control groups. Detailed individual-level controls do not change this conclusion, which is driven on the intensive margin of researchers who are employed at universities both before and after the reform and started firms at a substantially lower rate after the policy reform. We also see a decline in some accounting performance measures for new ventures started by university researchers and, separately, a substantial decline in university start-ups in higher-technology sectors or with associated patents. Thus, not only does the quantity of

[32] These further analyses follow those in Tables 3 and 4. Results are available from the authors upon request.
[33] Prior to the reform, 27% of university-based start-ups were in higher-technology sectors (41% including ICT); after the reform only 17% of university-based startups were in these sectors (33% including ICT).

startups by university researchers decline, but there are declines in several quality measures for these startups as well.

B. Patents

To study patenting, we follow similar lines as the entrepreneurship analysis above but with more limited data. Recall that university-based patents were determined by matching Norwegian inventor names with the NIFU registry of Norwegian university researchers (see Section 3.A). The resulting dataset cannot be linked to the Norwegian census data; therefore, the patent analysis allows comparisons among inventors only (university vs. non-university inventors) and does not contain demographic information, beyond name and address, for non-university inventors.[34]

The Rate of Patenting

Figure 4A plots the annual number of university patents (red line, left vertical axis) and non-university patents (blue line, right vertical axis) over the 1995-2010 period, with the year defined by the patent application date.[35] We see that the non-university patent rate rises through the late 1990s and then falls somewhat after 2000. The university patent rate rises similarly in the late 1990s before showing a peak in 2002, the pre-reform year, before falling more steeply in the post-reform period. Figure 4B considers the same data on a per-worker basis for the relevant groups.[36] Given that the number of Norwegian university researchers rose relatively rapidly over the 1995-2010 period, the per-worker measures show a larger differential drop for the university patenting rate. On average, 1.43% of university researchers applied for a patent per year prior to the reform, while 0.61% of university researchers applied for patents per year after the reform, for a 57% drop in the per-worker rate. By contrast, the broader Norwegian workforce averaged 0.032% patents per year prior to the reform and 0.026% after the reform, for a 20% drop in the

[34] The Norwegian census and business registry data use an anonymized numerical identifier for each individual, while the Norwegian Patent Office data does not use such identifiers. Thus we do not have socio-demographic information for Norwegian inventors in general (although, via NIFU, we do have detailed information about the university researchers, including age, gender, PhD year, PhD type, and academic department).
[35] We define a patent as a university patent if at least one inventor on the patent matches with a university researcher.
[36] For non-university inventors, this normalization is the number of non-university patents divided by the size of the non-university Norwegian workforce.

per-worker rate. Together, these figures show a sharp drop in patenting by university researchers that is coincident with the professor's privilege reform.

Table 7 considers regression results, looking at changes in log annual patent counts per year and log annual patent counts per worker. Columns (1) and (2) show that the log number of university patents declines relative to non-university patents. The first column includes a dummy to indicate the post period which the second column includes application year fixed effects to better capture the background dynamics seen in Figure 4. The $Treat_i \times Post_t$ coefficient indicates a 25% decline in patenting by universities. Column (3) considers the count of unique inventors rather than unique patents and shows similar results. Column (4) repeats the analysis for patents per-worker. Consistent with the larger visual difference-in-difference in Figure 4B, the $Treat_i \times Post_t$ coefficient now indicates a 52% decline in the patenting rate per university worker, compared to the background per-worker rate.

The last two columns of Table 7 analyze the data in technology-class by year form, with the patent counts now constructed at the 1-digit IPC code level.[37] This analysis can help account for compositional changes in the technologies receiving patents. Column 5 uses the log patent count as the dependent variable in OLS, while column 6 presents a Poisson count model that includes the full set of observations (i.e., including observations with zero counts). We see that these technology-class level analyses and the aggregate count analyses in columns 1 and 2 shows extremely similar results.

Table 8 considers regression evidence at the individual level. In these regressions, all individuals are inventors and the question is how the patenting rate per inventor changes for university inventors compared to non-university inventors. The dependent variable is a dummy variable indicating whether an individual applies for one or more patents in a given year.[38] Column (1) shows that university-based inventors show a large drop in their patenting after the reform, where the individual university researcher (conditional on being an inventor at some point) sees a 4.4 percentage point drop in their probability of producing a patent during the post period.

[37] As with the start-up analysis, we use 1-digit categories because patent counts for the treatment group are not large enough to allow analysis for more granular technology categorizations.

[38] Count data models, where the dependent variable is the patent count for the given individual-year as opposed to a dummy variable, show similar results. In practice, conditional on patenting in a given year, 87% of inventors apply for one patent only.

Interestingly, this decline almost exactly offsets the tendency for university researchers to produce patents more regularly than non-university inventors. Thus university inventors move from being unusually prolific in their patenting rate prior to the reform to being rather ordinary in their patenting rate after the reform. This finding is virtually identical whether or not we control for individual fixed effects or application year fixed effects in columns (2) and (3), so that the findings are not driven by dynamics in Norwegian patenting or compositional changes as individual inventors move in or out of university employment. Column (4) provides a robustness check by reducing the sample (both inside and outside universities) to "rare names" – those individuals whose names appear three or less times in the Norwegian population as a whole. We again see that the results are virtually unchanged.

Lastly, Table 9 considers the effect on "stayers', following the start-up analysis above to ask whether the overall quantity effects appear on the intensive margin among those who are consistently employed at university in the post period. Column 1 considers panel models at the individual x year level with no controls, while column 2 includes individual and application year fixed effects. We see that the effect on stayers is very similar to the overall effects (Table 8). University-based inventors produced patents at unusually high rates prior to the reform but became very similar to non-university inventors after the reform (compare the $Treat_i \times Post_t$ and $Treat_i$ coefficients). Overall, we see large effects operating on the intensive margin, so that a consistent set of individual university inventors patent much less often after the end of the professor's privilege.

The Quality of Patenting

Table 10 considers changes in the quality of patenting using a standard proxy measure, the number of citations that a patent receives (Trajtenberg 1990, Hall et al. 2005). Observations are individual patents, and we again use difference-in-differences, comparing patents by university researchers to patents by non-university researchers, before and after the reform. The dependent variable is the count of citations each patent has received through 2014 using the PATSTAT database. Given the presence of count data, we consider a Poisson model (column 1), negative binomial model (column 2), and for comparison OLS (column 3). Application year fixed effects are included to capture non-linearities in the flow of citation counts over time.[39]

Across specifications, we see a robust decline in citations received by university patents. Using either the Poisson or negative binomial model, there is an approximate 30% decline in citations received. As shown by the OLS model, this change represents an average loss of 2.5 patent citations. Interestingly, the treated coefficient in all specifications indicates that, prior to the reform, university patents were more highly cited than non-university patents. The reform acts to largely offset this advantage (compare the Treated x Post coefficients with the Treated coefficients), so that university patents went from being extraordinary to ordinary in their citations.

Summary

In sum, we see a large drop in patenting by university researchers after the "professor's privilege" reform. This decline is commensurate on many dimensions with the findings for start-ups. The patent rate per worker falls by approximately 50%, which is broadly similar to the decline in the start-up rate. The decline in patenting, like the decline in entrepreneurship, appears to be largely driven on the intensive margin of researchers who are consistently employed at universities but patented substantially less after the reform. Lastly, citations received per patent also declined for university patents after the reform. Overall, and like the start-up analysis, university patenting exhibited a decline in both quantity and quality measures.

V. Discussion

In this section, we discuss the empirical results in light of the literatures on university commercialization policy, rent-sharing in innovation, and taxes and entrepreneurship.

A. University Commercialization Policy

[39] Patenting later in the period provides less time to be cited, leading to the usual pattern of declining observed citations in more recent application years. Application year fixed effects help account for this dynamic. An alternative approach is to only include citations that come within N years after publication of the focal patent, and end the sample N years prior to 2014. In this approach, citations are only considered when they come within a common length of time. This alternative approach, for various N, yields extremely similar results to those shown in Table 10 (results available from authors upon request).

University researchers are often viewed as potential wellsprings of innovative ideas that may deliver substantial social returns. A large literature has sought to understand policies that influence innovative activity by this workforce, and the design of these policies remains the subject of substantial debate (National Academy of Sciences 2010). This paper investigates a large change in national commercialization policy that compares two distinct policy regimes. In the first regime, under the "professor's privilege", university-based researchers enjoyed full rights to their inventions and new ventures. In the second regime, after the reform, Norwegian university researchers moved to a one-third / two-third income split with the university. The post-reform regime was designed to look similar to the U.S. today.

The empirical findings suggest that the policy reform had several, measurable effects. First, there was an approximate 50% drop in the rate of new venture formation by university researchers. Second, there was a similar drop in patenting. Third, the quality of new ventures and patents also appeared to decline. These stark findings appear in sharp contrast to the motivations behind the Norwegian policy reform. The findings may also raise questions about similar reforms in other European countries that eliminated the professor's privilege: were the Norwegian results representative, one would imagine that the rates of start-ups and patenting by university researchers would rise substantially, as would the quality of these innovations, should universities give the researchers full rights. More generally, since the post-reform regime looks like the U.S. regime, among others, the interest in the external validity of these findings may broaden further.

To provide some guideposts on external validity beyond Norway, some descriptive facts may be informative. Lissoni (2008) examines the share of academic patenting among domestic patenting for several countries. Among the surveyed countries, the academic patenting share in professor's privilege countries, when the policy is in place, appears quite high (Sweden is 6%, Finland is 8%, and Norway is 9%) while countries in Europe that did not feature the professor's privilege showed considerably less academic patenting over similar time periods (France was 3%, Italy was 4%, and the Netherlands was 4%). The U.S. academic patenting share is not clear, but university-owned patents in the U.S. are 4% of all U.S. patents and samples suggest that these patents represent perhaps 65-80% of all U.S. patents with academic inventors (Fabrizio and DeMinin 2005, Lissoni 2008). Thus, while these statistics are crude and do not control for many possible conflating factors across countries, it is interesting that the professor's privilege countries had academic patenting shares that were approximately double those in the other European countries and also higher than estimates for the United States.

Two new working papers, one studying patenting and the other studying entrepreneurship, also consider the professor's privilege and find evidence in some broadly similar directions. Czarnitski et al. (2015) study patenting in Germany and find that university researchers patented less after the professor's privilege was eliminated. The decline among university researchers is greater than the decline among researchers in public research organizations that were not affected by the reform, although a puzzling feature in the German case is that the decline in patenting for both groups appears to start 5 years in prior to the reform and there is little change in the rate of decline around the reform year (2002) per se. Separately, a recent study by Astebro et al. (2015) considers PhDs who exit university employment in the U.S. with Sweden, which unlike other European countries has maintained its professor's privilege. The paper finds that Swedish academics are twice as likely to exit universities and start firms as U.S. academics are, compared to the background rates for non-university PhDs in their respective countries.

Overall, the difference-in-difference estimates established for Norway in this paper are echoed to some extent in other evidence. While the effect of the professor's privilege is difficult to isolate in cross-country data, and there are few related analyses to draw upon, the limited evidence suggests that professor's privilege countries have tended to see greater rates of new venture and patenting activity by academics, often by similar magnitudes as seen through the Norwegian policy shock. These commonalities in turn may suggest broader external validity from the natural experiment we study.

Nonetheless, important caveats are in order as one assesses both representativeness and potential policy implications. To the extent that Norway's researchers, technology orientation, university systems, access to complementary inputs (e.g., venture financing), and broader institutions may differ from those in other countries, the findings may not generalize. More difficult challenges to policy prescriptions involve the complexity of welfare analysis in this setting. This study has not examined tradeoffs with other activities by university researchers (such as basic research or teaching) where the social returns may be large but in general are unknown and very difficult to estimate; nor has it examined all types of commercialization outcomes (such as patent licensing or consulting).[40] Thus a complete welfare description is infeasible. With those caveats in mind, one can say that the policy change appeared to have large, negative effects on the engagement of university researchers in key components of technology transfer that are often sought by policymakers.

B. Rights Allocations in Innovation

The appropriate allocation of property rights between investing parties is a classic question in economics and provides canonical perspectives in studies of innovation (Aghion and Tirole 1994, Green and Scotchmer 1995, Hellmann 2007). This paper provides basic evidence for the proposition that rights allocation considerations matter substantially for innovative outcomes.[41] Conversely, specific models emphasizing rights allocations can provide frameworks for interpreting the results. For example, the finding that researcher commercialization activity appears much greater under the professor's privilege is consistent with the view that (1) the researcher's investment is more important than the university's investment and (2) the rights allocation should favor the party whose investment matters more (e.g., Aghion and Tirole 1994).

At the same time, splitting rights will be second-best compared to an approach that can solve the contractibility problem and let one party make the decision over both investments. In particular, greater commercialization surplus would be achieved by choosing:[42]

$$(s^*, x^*) = argmax_{s,x}[v(s,x) - \theta h(s) - rx] \tag{6}$$

In practice, this approach could mean giving all the rights to either the researcher or the university, depending on which investments are contractible. Giving the rights to the researcher would be appealing if the university cannot easily observe or contract on the researcher's effort level (s) while the researcher might feasibly control and internalize the start-up, patenting or licensing costs that the university might otherwise choose (x). To some extent, the problem in (6) may approximate what university researchers already did under the professor's privilege,

[40] Although we do not have data on patent licensing, the drop in the rate and quality of patenting after the reform suggests that the pipeline for licensing is substantially diminished. Moreover, the decline in the quantity of patenting suggests that TTOs did not successfully "search the closets" to find latent patentable matter.
[41] And even in the university setting, where the non-profit nature might have suggested that rights considerations would be less important.
[42] Since by definition the choice (s^*, x^*) maximizes the commercialization surplus, commercialization surplus in this regime must at least weakly exceed that of the decentralized outcome $(\hat{s}, \hat{x})$ analyzed in Section II.C.

where the university provided little if any help and the researcher internalized all the costs. In short, if the individual researcher can mimic the university function, then a rights allocation perspective tends to suggest that the professor's privilege may be first best. The question then is whether the university does in fact have advantages that the researcher cannot easily mimic. For example, the university may be able to lower the unit cost of x (e.g., through scale) compared to the price a researcher faces or provide unique capabilities, such as investing in relevant laboratory space or commercialization infrastructure. Some analyses of commercialization practices, emphasizing incentive conflicts between the parties and putting little store in university capabilities, have argued for sharply curtailing the role of TTOs and increasing researcher's property or control rights (Litan et al. 2007, Kenney and Patton 2009). The empirical analysis in this paper appears broadly consistent with this perspective. That said, the empirical setting only considers two policy regimes ($\alpha = 1$ and $\alpha = 1/3$). Within the property rights framework, values of α between these two points may show greater commercialization output.

Broadening the theoretical frame, the decline in commercialization may also be related to other problems when rights become split; namely, transaction costs may increase. It is plausible that the university researchers may curtail their commercialization activity because they find haggling with the university onerous, and it is also plausible that external funders or licensors are dissuaded when multiple university-based parties become involved (National Academy of Sciences 2010). Such transaction costs could provide additional reasons why the professor's privilege – acting to unify the rights, could be attractive from a commercialization point of view, and would raise further questions about the motives for the policy reform.[43]

C. Taxes and Entrepreneurship

The end of the professor's privilege acted, in part, to increase the tax rate on researcher's commercialization income by two-thirds. The policy reform may thus provide potential insight into how university researchers respond to income incentives. Indeed, in motivating lower

[43] Empirically, the findings seem less consistent with at least one view on transaction costs, if one thinks of bargaining as a fixed cost. With variation in the value of ideas, changing the fixed costs of commercialization should make the quantity and quality of ideas move in opposite directions. For example, if the professor's privilege reform acted to raise bargaining costs prior to entry, then one would expect less entry but higher quality conditional on entry. The empirical findings thus appear inconsistent with this mechanism.

income shares to researchers, one view may have been that university researchers do not especially care about formal rights to their ideas: taking scientific norms of openness seriously, where scientists place the typical fruits of their labor (i.e., research articles) in the public domain (Merton 1957), one might imagine that scientists have weak pecuniary interests or otherwise would care little if rights were transferred to the university. The evidence in this paper, by contrast, suggests that the loss of rights severely diminishes the commercialization activity of university researchers.

Taking a property rights view as modeled in Section II.C, the decline in α can be thought of in part as increasing the tax rate on researcher's commercialization income. At the same time, the policy change was not simply a tax, because it simultaneously strengthens the incentives for the university to invest, and complementary investments by the university 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 general conditions of the model in Section II.C, the shift in α provides a lower bound on the effect of an equivalent tax.

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

$$y = \tau(\alpha v(s,x) + G) \tag{7}$$

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 rent are of equivalent size.

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

Proof. See appendix.

Intuitively, if the investment of the researcher and university are complements, then the effect of reducing the researcher's income share via α can be offset to some extent by increasing university investment, which in turn promotes more researcher investment. This indirect effect is, by contrast, turned off for a simple tax.

Based on this reasoning, one would conclude that 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. This appears to be a very large effect.

One caveat in this interpretation is that it relies on a property rights view of the problem, so that the effort effects come via income. While the formalization in Section II.C is quite broad and builds on canonical theories in the economics of ideas, a specification based on control rights or behavioral issues may loosen the relationship with and inference about tax effects. For example, if the researchers are annoyed by the loss of control rights or stop investment for fear of ex-post bargaining problems, the mapping with taxes may be less clean. Alternatively, one might imagine some kind of loss aversion or pique over the removal of their prior privileges.

More generally, and integrating across potential theories, the policy experiment indicates that these university researchers appear very sensitive to their inventive rights. While scientists might broadly value freedom over income and operate largely according to scientific norms that emphasize open access to their ideas (Merton 1973, Stern 2004), there is at least a subset of university researchers – those on the margin of important technology transfer avenues – who respond with high elasticity to their rights allocations.

VI. Conclusion

This paper has considered the reform of the "professor's privilege", coupling a large change in innovation policy with census data on new ventures and patenting in Norway. The policy change transferred two-thirds of the property rights enjoyed by university researchers to their university employer. The basic empirical finding is a large decline, by approximately 50%, in the quantity of both start-ups and patenting by university researchers. We also see declines in measures of quality for start-ups and patents. The declines are robust to using various control groups for the natural experiment and are broadly similar when looking across both start-ups and patents.

The paper further discusses potential implications of these findings for university commercialization policy. Broader interpretations in light of literatures on rent-sharing in innovation and taxes and entrepreneurship are also considered. The basic finding is that the "professor's privilege" policy regime in Norway saw far more university-based start-ups and patenting than the regime where the university owns the rights and gives one-third of the income to the researcher. This finding raises fundamental questions about whether much of the world, which uses university commercialization policies that look like the ex-post regime in this study, are producing far less university-based innovation than they could and that many policymakers desire. Studies of additional policy reforms in Europe and the potential for formal experimentation in the rights regimes employed by universities are key areas for future research.

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Appendix: Proofs

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 $\tau\alpha v_1(\hat{s},x) = \theta$. 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 $\hat{x}'(\alpha) \leq 0\ at\ \alpha = 1$.

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

$$v_1\big(\hat{s}(1,c),x(1,c)\big) = v_1\big(\hat{s}(c,1),x(c,1)\big). \qquad (8)$$

Now note that $x(c,1) \geq x(1,c) = 0$, since the university does not invest when it has no rights (see (1)). Therefore, with $v_{12} \geq 0$ (i.e. maintaining the assumption that investments are complements), (8) can only hold if $\hat{s}(1,c) \leq \hat{s}(c,1)$. Hence the Lemma.

Table 1A: Summary Statistics for Start-Up Firms in Norway, 2000-2007

		Non University	Non University Ph.D.	University
Number of Start-Ups		48,844	452	128
Fraction Surviving at 5 years	Mean	0.74	0.83	0.87
Sales at 5 years	Mean	3,813	1,910	2,306
	(St Dev)	(11,640)	(4,431)	(9,290)
	Median	655	277	82.3
	75^{th} ptile	3,337	1,635	1,224
	95^{th} ptile	16,434	8,991	6,928
Employees at 5 years	Mean	2.99	1.56	1.18
	(St Dev)	(7.45)	(3.07)	(2.85)
	Median	1	0	0
	75^{th} ptile	3	2	1
	95^{th} ptile	12	7	5
Profits at 5 years	Mean	146	182	86.8
	(St Dev)	(484)	(551)	(559)
	Median	0	0	0
	75^{th} ptile	164	204	125
	95^{th} ptile	1,117	1,514	1,398

Notes: Sales, Employees, and Profits are conditional on survival at year 5. Profits and sales are measured in 1000 NOK.

Table 1B: Summary Statistics for Entrepreneurs in Norway, 2000-2007

	Non University	Non University Ph.D.	University
Number of Entrepreneurs	69,496	413	125
Age of Founder, Mean	41.6	47.4	47.8
(St Dev)	(9.95)	(8.98)	(8.90)
Median	40	46	47
Fraction with highest degree			
Bachelors	0.23	1	1
Masters	0.09	1	1
Ph.D.	0.006	1	1
Income, Mean	422	752	609
(St Dev)	(675)	(513)	(265)
Median	343	631	527
Wealth, Mean	1,520	1,610	1,140
(St Dev)	(12,200)	(2,910)	(1,550)
Median	449	731	581
Marital Status, Mean	0.59	0.74	0.74
(St Dev)	(0.49)	(0.44)	(0.44)
Median	1	1	1
Fraction male	0.79	0.88	0.94

Notes: Income and wealth are measured in 1000 NOK. Income, wealth, marital status, and age are measured in year prior to founding of firm.

Table 1C: Summary Statistics for Patenting in Norway

	All Norway	University
Number of Patents	7,162	566
Number of Unique Inventors	6,597	319
Percentage Male, workforce	50.4%	65.9%
Percentage Male, Inventors	94.7%*	90.9%
Period	1995-2010	1995-2010

Notes: *Male percentage for all inventors is estimated using gender for common names in Norway. (Other gender calculations are not estimates; gender for university sample is given directly by NIFU database and for Norwegian workforce from census data.)

Table 2: Startups, Aggregate and Sector Level Analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Aggregate				Sector	
	Log Startups	Log Startups Per Worker	Log Startups	Log Startups Per Worker	Log Startups	Log Startups	Startups
Treated x Post	-0.909***	-1.169***	-0.603**	-0.737**	-0.567**	-0.561**	-0.606***
	(0.172)	(0.199)	(0.232)	(0.257)	(0.264)	(0.228)	(0.209)
Treated	-5.481***	1.041***	-0.961***	-0.223	-5.180***	-0.498***	-0.944***
	(0.0547)	(0.0712)	(0.110)	(0.132)	(0.226)	(0.170)	(0.101)
Post	0.0493	0.0136	-0.258	-0.419**	--	--	--
	(0.0671)	(0.0650)	(0.170)	(0.175)			
Year FE	--	--	--	--	Yes	Yes	Yes
Sector FE	--	--	--	--	Yes	Yes	Yes
Control Sample	Norwegian Workforce	Norwegian Workforce	PhD workforce	PhD workforce	Norwegian Workforce	PhD workforce	PhD workforce
Period	2000-2007	2000-2007	2000-2007	2000-2007	2000-2007	2000-2007	2000-2007
Model	OLS	OLS	OLS	OLS	OLS	OLS	Poisson
Observations	16	16	16	16	119	104	160
R-squared	0.997	0.849	0.909	0.800	0.97	0.80	--

Notes: Columns (1) and (3) consider aggregate counts per year for the treatment and control groups. Columns (2) and (4) consider aggregate counts per worker. In columns (5)-(7), observations are sector x year for the treatment and control groups, with sector determined by the 1-digit NACE code. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Startups, Individual Level, All Workers

	(1) All Workers	(2) All Workers	(3) All Workers	(4) Entrepreneurs only	(5) Entrepreneurs only
Treated x Post	-0.00450***	-0.00457***	-0.00431***	-0.131***	-0.114***
	(0.000974)	(0.00110)	(0.00111)	(0.0283)	(0.0285)
Treated	0.00358***	0.000343	-0.000142	-0.000436	-0.0136
	(0.000914)	(0.00156)	(0.00160)	(0.0440)	(0.0450)
Post	-0.000275***	--	--	--	--
	(2.88e-05)				
Observations	19,937,044	19,937,044	19,937,044	535,039	535,039
R-squared	0.000	0.164	0.165	0.029	0.032
Year FE	NO	YES	YES	YES	YES
Individual FE	NO	YES	YES	YES	YES
Age FE	NO	NO	YES	NO	YES
Individual time-varying controls	NO	NO	YES	NO	YES
Period	2000-2007	2000-2007	2000-2007	2000-2007	2000-2007

Notes: The dependent variable is an indicator for whether the individual started a company that year. Estimates are the linear probability model. Non-linear probability models (Probit or Logit) produce similar results but must be estimated without individual fixed effects. The individual time-varying controls include lagged marital status, lagged total years of education dummies, log income, and log wealth. Standard errors are clustered by individual (*** p<0.01, ** p<0.05, * p<0.1).

Table 4: Startups, Individual Level, Similar Workers

	(1) Masters or more	(2) Ph.D.	(3) Ph.D. Logit	(4) Ph.D. Propensity Score Match	(5) Ph.D. Entrepreneurs only	(6) Ph.D. Entrepreneurs only	(7) Ph.D. Earned pre 2000
Treated x Post	-0.00336***	-0.00241*	-0.513***	-0.00382**	-0.0932***	-0.0962***	-0.00295**
	(0.00119)	(0.00142)	(0.199)	(0.00190)	(0.0297)	(0.0345)	(0.00151)
Treated	-0.00131	-0.00130	0.00318	-0.00142	0.0477**	-0.00133	-0.00111
	(0.00174)	(0.00192)	(0.143)	(0.00267)	(0.0203)	(0.0503)	(0.00214)
Observations	1,040,291	97,645	97,049	55,376	3,439	3,439	78,493
R-squared	0.191	0.177	--	0.271	0.021	0.062	0.165
Year FE	YES	YES	YES	YES	YES	YES	YES
Individual FE	YES	YES	NO	YES	NO	NO	YES
Age FE	YES	YES	YES	YES	NO	YES	YES
Individual time-varying controls	YES	YES	YES	YES	NO	YES	YES
Period	2000-2007	2000-2007	2000-2007	2000-2007	2000-2007	2000-2007	2000-2007

Notes: The dependent variable is an indicator for whether the individual started a company that year. Estimates are the linear probability model, except in column (3) which compares Logit. Non-linear probability models (Probit or Logit) produce similar results in general but must be estimated without individual fixed effects. Column (1) restricts sample to Norwegian workers with at least a master's degree. All other specification restrict sample to Norwegian workers with a least a Ph.D. The individual time-varying controls include lagged marital status, lagged total years of education dummies, log income, and log wealth. Propensity score matching predicts treatment status (university employment) using age fixed effects, detailed Ph.D. type fixed effects, gender, and marital status. Standard errors, in parentheses, are clustered by individual (*** p<0.01, ** p<0.05, * p<0.1).

Table 5: Startups, Individual Level, Intensive Margin

	(1) Stayers All	(2) Stayers Ph.D.	(3) Stayers Ph.D., Logit
Treated x Post	-0.00465***	-0.00295*	-0.00209***
	(0.00125)	(0.00155)	(0.000679)
Treated	-0.00531	-0.00632	0.000250
	(0.00677)	(0.00686)	(0.000663)
Observations	17,481,824	73,674	73,547
R-squared	0.161	0.161	
Year FE	YES	YES	YES
Individual FE	YES	YES	NO
Age FE	YES	YES	YES
Individual time-varying controls	YES	YES	YES
Period	2000-2007	2000-2007	2000-2007

Notes: The dependent variable is an indicator for whether the individual started a company that year. Estimates are the linear probability model, except in columns (3) and (6), which uses Logit. Control group is either all Norwegian workers (columns (1) and (4)) or Norwegian Ph.D. workforce (other columns). The individual time-varying controls include lagged marital status, lagged total years of education dummies, log income, and log wealth. Standard errors, in parentheses, are clustered by individual (*** p<0.01, ** p<0.05, * p<0.1).

Table 6A: Start-up Performance at Year 5

	(1) Survive	(2) Log Sales	(3) Log Employees	(4) Log Assets	(5) Survive	(6) Log Sales	(7) Log Employees	(8) Log Assets
Treated x Post	-0.1598*	-0.9366**	-0.0337	-0.5341	-0.1260	-0.9282	0.0166	-0.6739
	(0.0863)	(0.4489)	(0.1274)	(0.3557)	(0.1051)	(0.5782)	(0.1794)	(0.4251)
Treated	0.0320	-0.4647	-0.2682***	0.0758	-0.0142	-0.3220	-0.1828	0.1528
	(0.0574)	(0.2916)	(0.0878)	(0.1962)	(0.0712)	(0.3991)	(0.1304)	(0.2729)
Observations	48,917	36,172	32,830	36,199	580	441	441	441
R-squared	0.0382	0.1441	0.1570	0.0437	0.144	0.2058	0.1844	0.2166
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
2-digit sector FE	YES	YES	YES	YES	YES	YES	YES	YES
Control Sample	Norway	Norway	Norway	Norway	Non-Uni PhD	Non-Uni PhD	Non-Uni PhD	Non-Uni PhD

Notes: Dependent variables are indicated at top of each column and indicate performance at year 5 after the founding year. Firms all founded 2000-2007, and performance data is then 2005-2012. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Table 6B: Probability of Achieving 75th Percentile Performance at Year 5

	(1) Sales	(2) Employees	(3) Assets	(4) Sales	(5) Employees	(6) Assets
Treated x Post	-0.1198**	0.0170	-0.1303*	-0.1091*	0.0155	-0.0695
	(0.0490)	(0.0536)	(0.0757)	(0.0628)	(0.0663)	(0.0933)
Treated	-0.0262	-0.1032***	0.0810	0.0169	-0.0418	0.0507
	(0.0452)	(0.0373)	(0.0550)	(0.0547)	(0.0484)	(0.0684)
Observations	48,972	48,972	48,972	580	580	580
R-squared	0.0591	0.0585	0.0283	0.1197	0.1036	0.0813
Year FE	YES	YES	YES	YES	YES	YES
2-digit sector FE	YES	YES	YES	YES	YES	YES
Control Sample	Norway	Norway	Norway	Non-Uni PhD	Non-Uni PhD	Non-Uni PhD

Notes: Dependent variables are binary indicators for achieving at least the 75th percentile of performance in the indicated measure, where the 75th percentile is defined for Norwegian startups as a whole. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Table 6C: Start-up Sectors

	(1) Log Startups	(2) Log Startups	(3) Log Startups	(4) Log Startups
Treated x Post	-0.727**	-0.277	-1.239***	-1.245*
	(0.322)	(0.391)	(0.352)	(0.632)
Treated	-4.046***	-0.484*	-3.201***	0.520
	(0.263)	(0.243)	(0.265)	(0.434)
Post	-0.252*	-0.701**	-0.0305	-0.0240
	(0.117)	(0.251)	(0.0809)	(0.531)
Observations	16	16	16	16
R-squared	0.987	0.673	0.978	0.386
Control Sample	Norwegian Workforce	PhD workforce	Norwegian Workforce	PhD workforce
Startup Type	Higher Tech	Higher Tech	Higher Tech, No ICT	Higher Tech, No ICT

Notes: Dependent variables are log of start-up counts for the indicated startup-type in the last row of table. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Table 7: Patents, Annual Rates, Aggregate and Technology Level Analysis

	(1)	(2)	(3)	(4)	(5)	(6)
		Aggregate			Technology	
	Log Patents	Log Patents	Log Inventors	Log Patents per Worker	Log Patents	Patents
Treated x Post	-0.286*	-0.286***	-0.287*	-0.742***	-0.315**	-0.284**
	(0.143)	(0.0951)	(0.165)	(0.127)	(0.148)	(0.125)
Treated	-2.353***	-2.353***	-2.748***	4.030***	-2.362***	-2.332***
	(0.104)	(0.0697)	(0.121)	(0.0822)	(0.111)	(0.085)
Post	-0.123*	--	-0.131	--	--	--
	(0.0623)		(0.0794)			
Application Year FE	NO	YES	NO	YES	YES	YES
Tech Class FE	--	--	--	--	YES	YES
Control Sample	Non University Inventors	Non University Inventors	Non University Inventors	Non University Inventors	Non University Inventors	Non University Inventors
Model	OLS	OLS	OLS	OLS	OLS	Poisson
Observations	32	32	32	32	233	256
R-squared	0.978	0.995	0.978	0.996	0.877	--
Period	1995-2010	1995-2010	1995-2010	1995-2010	1995-2010	1995-2010

Notes: In columns (1)-(4), observations consider aggregate patent counts for the treatment and control groups, by year. In columns (5)-(6), observations are technology class x year for the treatment and control groups, with technology class determined by the 1-digit IPC code. In column (3), the dependent variable is the log count of unique inventors per year. In column (4), dependent variable is count of unique patents per worker, where worker count is the Norwegian workforce for the control sample and worker count is the university researcher workforce for the treatment sample. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Table 8: Patents, Individual Level, Inventors

	Dependent variable: Indicator for patenting in given year			
	(1)	(2)	(3)	(4)
	All Inventors	All Inventors	All Inventors	Rare Names
Treated x Post	-0.044***	-0.043***	-0.047***	-0.045***
	(0.012)	(0.012)	(0.012)	(0.017)
Treated	0.045***	0.045***	0.043***	0.047**
	(0.010)	(0.010)	(0.013)	(0.019)
Post	-0.010***	--	--	--
	(0.002)			
Application Year FE	NO	YES	YES	YES
Individual FE	NO	NO	YES	YES
R^2	0.00	0.00	0.00	0.00
Obs	123,536	123,536	123,536	84,160
Period	1995-2010	1995-2010	1995-2010	1995-2010

Notes: Standard errors clustered by individual (* p<0.1; ** p<0.05; *** p<0.01).

Table 9: Patents, Intensive Margin

	(1) Stayers	(2) Stayers
Treated x Post	-0.049***	-0.048***
	(0.013)	(0.013)
Treated	0.047***	0.041***
	(0.011)	(0.016)
Post	-0.010***	--
	(0.002)	
Application Year FE	NO	YES
Individual FE	NO	YES
R^2	0.00	0.00
Obs	120,576	120,576
Period	1995-2010	1995-2010

Notes: Standard errors clustered by individual (* p<0.1; ** p<0.05; *** p<0.01).

Table 10: Patents, Citations Received

	Poisson	Negative Binomial	OLS
Treated x Post	-0.306*	-0.325**	-2.511***
	(0.166)	(0.166)	(0.957)
Treated	0.355***	0.358***	2.652***
	(0.102)	(0.101)	(0.877)
Application Year FE	YES	YES	YES
R^2	--	--	0.04
Obs	7,162	7,162	7,162

Notes: Robust standard errors in parentheses (* p<0.1; ** p<0.05; *** p<0.01).

Figure 1: Researcher Utility Maximization and Effort at Commercial Innovation

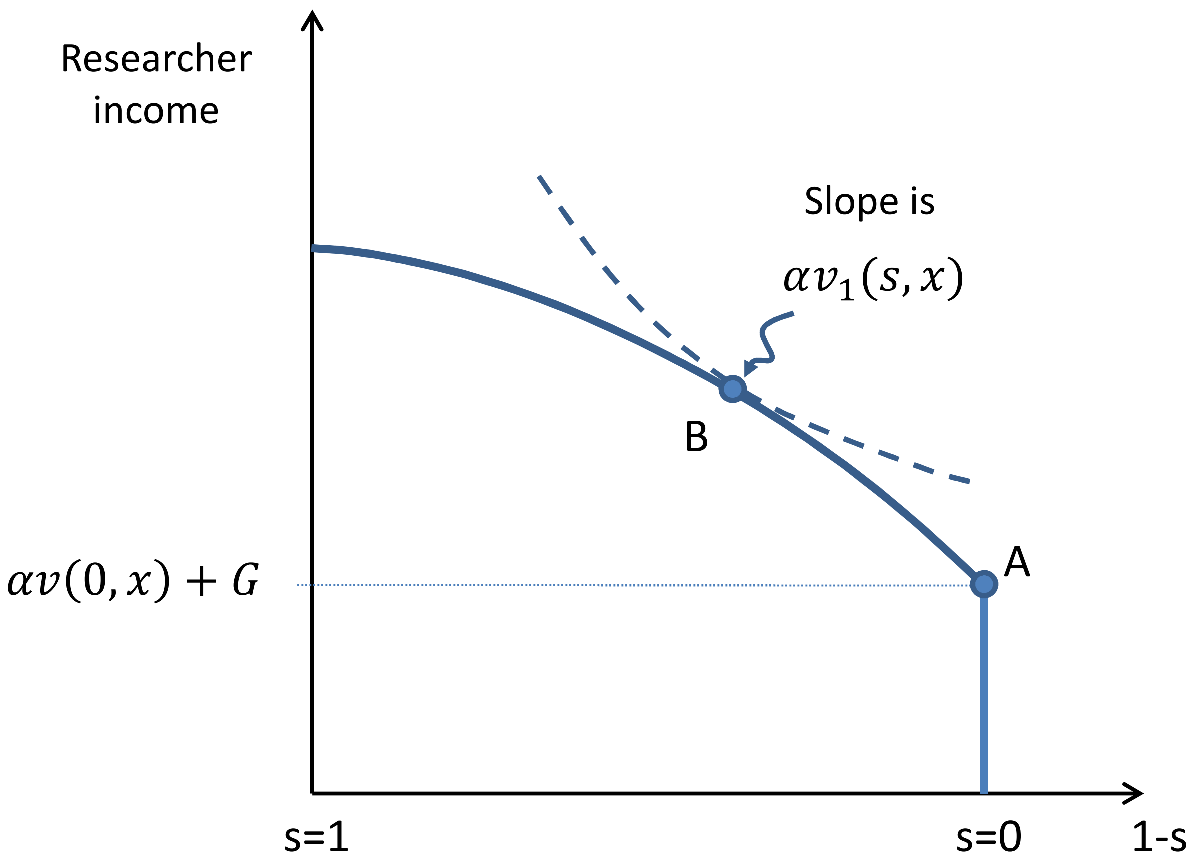
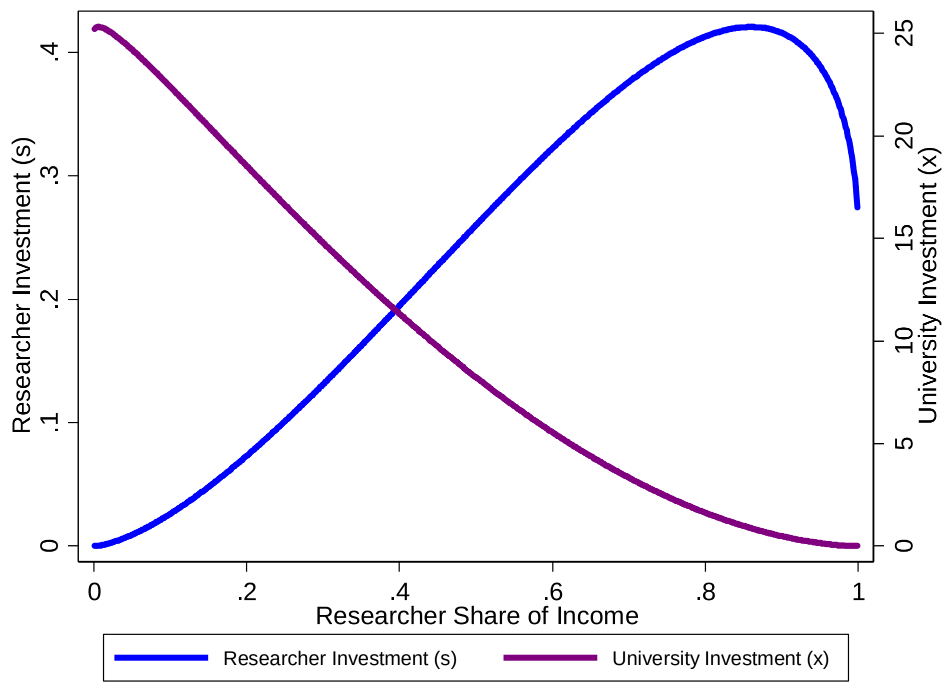
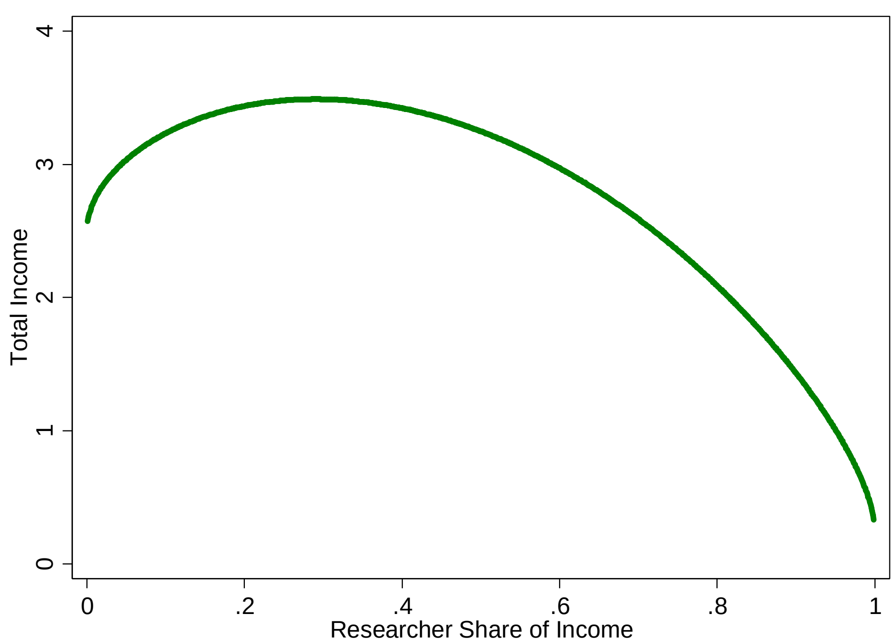


Figure 2: Investment and Innovation as Function of Researcher Rent Share (α)

CES Example





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

Figure 3A: University Startups vs. Non-university Startups

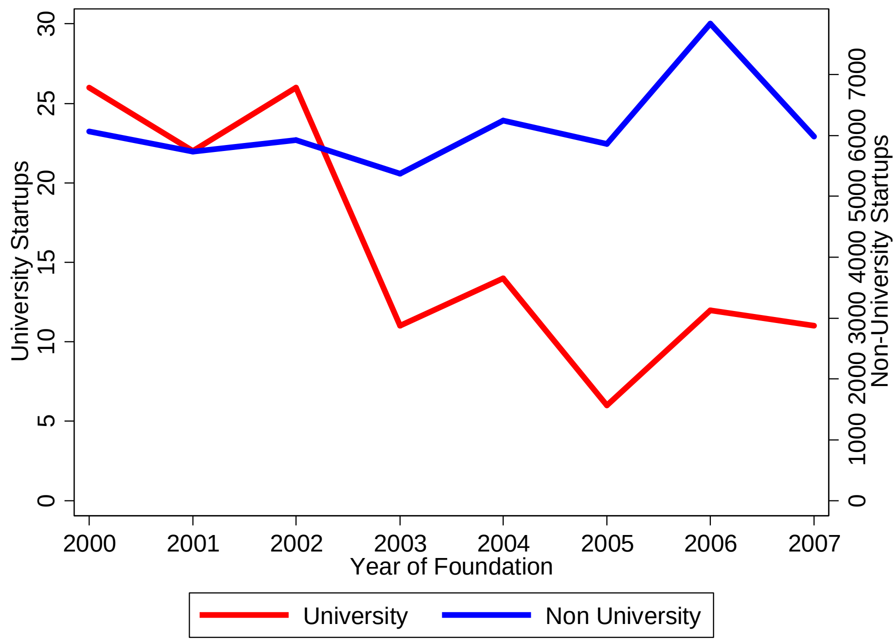


Figure 3B: University vs. Non-university Startups, per Worker

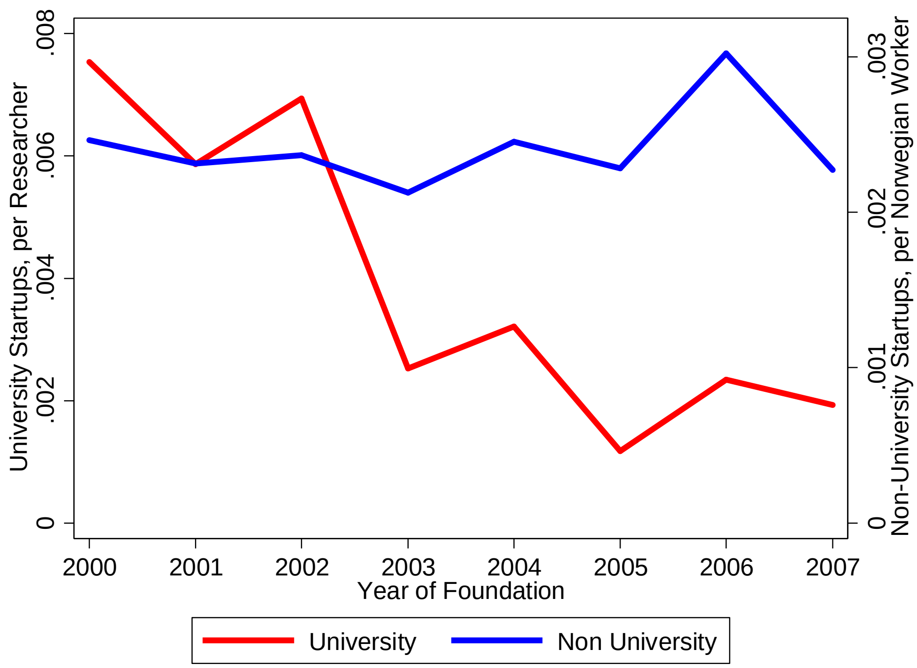


Figure 4A: University Patents vs. Non-university Patents

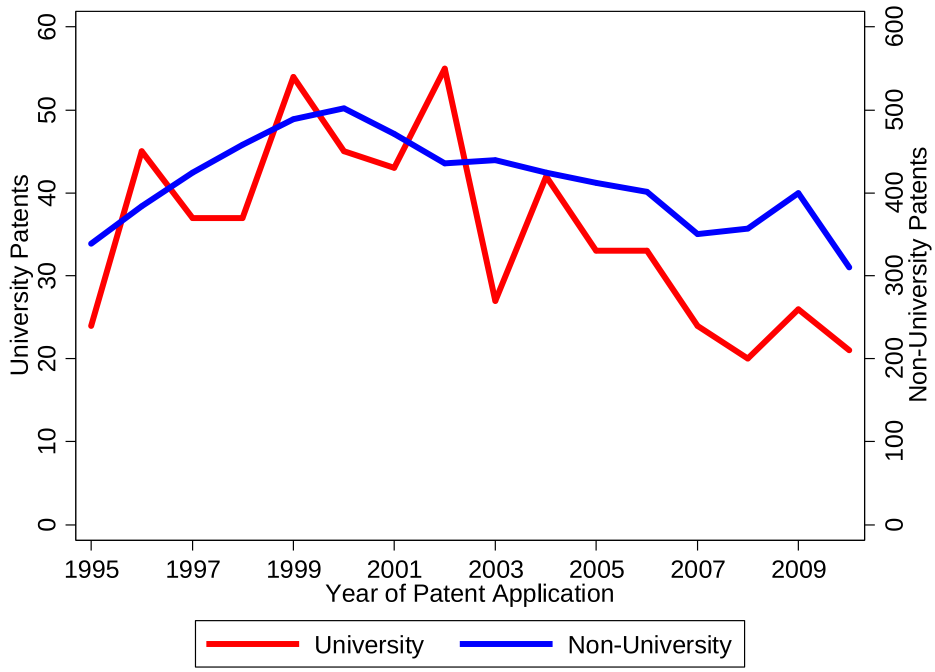


Figure 4B: University Patents vs. Non-university Patents, per Worker