University invention and the abolishment of the professor's privilege in Finland

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Papers in Innovation Studies
Paper no. 2018/06

This is a pre-print version of paper, which is published in Research Policy.

Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE)
Lund University
P.O. Box 117, Sölvegatan 16, S-221 00 Lund, SWEDEN
http://www.circle.lu.se/publications

WP 2018/06

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Abstract

In 2007 Finland changed ownership rights to inventions from its employees – "the professor's privilege" – to universities. We investigate how this change affected academic patenting using new data on inventors and patenting in Finland for the period 1995-2010. Matched sample panel data regressions using difference-in-differences show that patenting by individuals dropped by at least 29 percent after 2007. Unlike other countries studied, in Finland the reform was known before implementation. Adding the period after announcement to the reform period increases the drop in academic patenting to 46 percent. Our and others' results call into question whether the European reform of the professor's privilege were good innovation policy.

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1. Introduction

In 2007, Finland joined other European countries in a trend to switch ownership rights over inventions such that public universities now own the rights to inventions produced by researchers there. This revoked ownership rights previously held by aca-

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demic employees, commonly referred to as the "professor's privilege." Theory highlights two main opposing forces when ownership rights change from the individual to the university. First, patenting may become easier for researchers because of more easily accessible university transfer assistance, which could speed up patenting. Second, through owning patenting rights, universities can tax patent incomes, reducing monetary incentives for researchers to invent.

We investigate the effects of the abolishment of the professor's privilege in Finland. Our investigation utilizes novel data on Finnish inventors collected for this paper, linked to individual employer-employee data in collaboration with Statistics Finland. We examine changes in inventive outcomes for academic researchers, contrasting these changes with those in control groups from institutes and firms, respectively, in difference-in-differences regressions. We rely mainly on matched samples based on coarsened exact matching (CEM) at the individual level.

The paper contributes to the existing literature in several ways. Very few papers in this area of research utilize economy-wide data on inventors. Access to good data allows us to control for demographic composition, education and individual (innate) propensities to patent through fixed effects. Importantly, it also allows the exploitation of the experimental nature of the policy reform through the creation of an appropriate control group against which to compare the effects on academic inventors. This allows the identification of a plausibly causal effect of the policy reform. Although several well-established microeconometric techniques allow the identification of causal relationships, such as instrumental variables, regression discontinuity and differences-in-differences (DiD; see, e.g., Angrist and Pischke, 2009), our paper is only one of three that attempts to causally identify an effect, all applying a DiD approach (Czarnitzki et al., 2015; Hvide and Jones, 2016). The DiD setup enables us to study changes in patenting in academia, which is contrasted with developments at institutes and in the private sector. This gives us the ability to "net out" contributions to the groups studied that, although time varying, are common over time. For instance, technological progress or business cycles can lead to swings in patenting that are common to all three groups. Not controlling for such trends would confound policy reform effects with other trend effects that distort interpretation. This paper therefore helps us understand whether the consequences of changing the IP-patenting regime has effects consistent with the other studies, but in a quite different setting. It is highly policy relevant if we can establish that the results of this major and much debated European reform led to similar outcomes across different countries, each with its own unique combination of institutional features.

We find that the case of Finland differs in many ways from other cases studied. In Finland, the IP-regime change took place in the midst of a major restructuring of the telecom sector. It also took place just before the start of the recession in 2007, which means that the post-reform period could be affected by slower economic development. Another important difference is that our study reveals pre-reform effects in Finland that seem to have influenced academic patenting behavior even before implementation, but after announcement of the reform.

The analysis shows the importance of taking structural factors into account. Our most reliable analyzes use the private sector as the main control group. We also omit the firm with the most patenting to remove trend effects in the control group. The results indicate an adverse effect on university patenting. Contrary to the expectation that the reform would stimulate patenting, we observe a 29 percent drop in university researcher patenting in our matched sample analysis. In addition, by including the period before the reform but after the announcement of it, our preferred specification, the drop increases to 46 percent.

We thus show how the DiD framework can be adapted to deal with circumstances that deviate from the standard DiD setup in an evaluation of academic IP-regime change. In robustness analyses, we delve into the sensitivity of our results by examining two potentially mitigating or reinforcing factors of the Finnish IP-reform. Government funds were raised substantially in order to stimulate commercialization of research and technology transfer after the reform. Although imprecisely measured, as TULI funds can be observed only as part of other government funds from Tekes, the Finnish Funding Agency for Innovation and Technology, our analysis of universities that had large increases in Tekes funds after 2007 experienced no statistically different effect on patenting from other universities in terms of patenting. We also analyze whether academic inventors who moved out of academia could be responsible for the decline but find that this is most likely not the reason. Our and others' results call into question whether the European reform of the professor's privilege were good innovation policy. Our findings also add to existing evidence that any potentially positive effects from increased tech transfer support does not outweigh the downside of eliminating the professor's privilege.

2. Literature review

In much of Europe, until the early 2000s default ownership of inventions by university researchers rested with the individual. The inspiration for the change in Europe in ownership to that of universities came from the United States, which in 1980 through the Bayh-Dole Act set the default rights of invention ownership from federally funded research at the university level (Mowery et al., 2001). It should be noted that the European and American starting points were different, however. The US reform involved a decentralization of ownership, whereas later European reforms implied centralization (Von Proff et al., 2012). A sharp rise in university patenting was observed at American universities in the 1980s and 1990s (Trajtenberg et al., 1997). But it has never been established whether this was due to (a) the reform, (b) other reforms that strengthened patent rights around the same time, (c) increased patentability in, for example, biotech, or (d) a rising rate of academic patenting that had begun already in the 1970s (Mowery et al., 2001). On balance, it seems likely that this decentralization may have helped create better incentives for individual researchers, because the Bayh-Dole Act implied that technology transfer offices were established at many American universities (Audretsch and Göktepe-Hultén, 2015; Coupé, 2003). However, the case for switching from the individual level to university ownership in Europe was less clear-cut. Theoretically, the effects of changing from the individual level to university ownership centers on arguments that university administrations offer efficiency gains. This stems from the assumption that researchers are less capable of finding suitable industry partners than are their technology transfer officers (Verspagen, 2006). The downside to university ownership, however, is higher (transaction) costs, which "tax" university inventors. A common distribution seems to be one in which, net of university costs, one-third of the profits go to the inventor and two-thirds to the university, as in Germany and Norway (Hvide and Jones, 2016, cited below as HJ).

Lowe (2006) highlights some of the trade-offs in a theoretical model. He analyzes the technology transfer process in situations in which the development of an invention requires active tacit knowledge transfer from the inventor. This assumption is realistic, as many observers have concluded that inventions are rarely ready for commercialization "off the shelf" but, rather, need the active assistance of the originator (the researcher) to be developed (Jensen and Thursby, 2001; Zucker et al., 1998). In the model by Lowe (2006), in cases in which a sufficiently high level of tacit knowledge is required, inventors prefer to start their own firm, through which they develop their invention to the point that it is ready for commercialization. This is because tacit effort requires compensation to the inventor in the form of royalties that lower profit and reduce output (given that demand for inventor knowledge is elastic). As in the discussion in the literature, Lowe (2006) stresses three roles through which universities can help inventors. First, they spread fixed costs associated with administration, licensing, and other intellectual property costs across many commercializable inventions. Second, they function as intermediaries bringing licensees together with inventors. That is, they find actors ready to commercialize results that inventors might otherwise not find. Finally, universities may be better negotiators than individual inventors. The trade-offs in costs and gains are thus between those who do not need the assistance of universities, which mainly face losses in the form of "university taxation," vs. otherwise noncommercialized inventions for which inventors may now find an actor willing to commercialize them. It can easily be perceived that the first cost could discourage researchers from inventing (Lowe, 2006; Thursby et al., 2009).

The net contribution by universities is therefore not obvious and may vary from invention to invention. It is determined in part by the skills of the technology transfer office. Theoretically, individuals without patenting experience could gain from advice that universities can offer. However, the willingness to contribute to an invention could decline for inventors with established firm networks (Czarnitzki et al., 2015, cited below as CZ). These theoretical intricacies did not stop European countries from adopting university ownership rights, disregarding the need for a sound empirical basis. In the recent wave, Denmark went first in 2001, closely followed by Germany and Austria (2002), Norway (2005), and Finland (2007).[1] Lissoni et al. (2009) investigate the case of Denmark, but the lack of data on individuals before the reform limits the ability to understand its effects, although it is clear that university ownership of academic patents increased at the expense of patents invented by academic researchers but applied for directly by commercial firms, as expected. In Italy, national legislation decreed a switch from university ownership *to* individual ownership. However, this reform was largely circumvented by local university regulations that effectively reversed the legislation and reinforced university ownership (Lissoni, 2013; Lissoni et al., 2009). Some cases have been evaluated using longitudinal micro data in which university researchers have been observed over time. For example, Von Proff et al. (2012) find that the German reform indicated no increase in patenting after 2002. Although not conclusive, they find indications that patenting might have decreased.

However, one of the major benefits of using longitudinal individual data is that we can find an appropriate control group, because many concurrent trends can be expected to affect different areas of the economy similarly. For example, the dot-com and subsequent fall in the early 2000s and business-cycle effects may have affected overall patenting levels. It is important to try to net out such changes from an overall assessment. Of the several methods for evaluating the abolition, the DiD approach is the most appropriate and is relatively straightforward if data are available. Another option could utilize instrumental variables. For instance, ideally, researchers would somehow randomly be forced to follow such a change. It is hard to see whether any such measures have been taken in the context of academic patenting. Similarly, regression discontinuity analysis utilizes scores assigned to treated and non-treated subjects, which can be used to distinguish the role of selection from treatment effects. Again, we are not

[1] The French innovation act of 1999, examined by Della Malva et al. (2013), does not cleanly fall into a distinct ownership change. Tax incentives to establish technology transfer offices and an institutional recognition of technology transfer activities sought to stimulate universities to become more active partners in commercialization of intellectual property. The authors indeed find evidence of an increased share of ownership of French universities involving university researchers.

aware of the existence of any such data.

The two existing DiDs that have been published as working papers are therefore highly important for this study. CZ undertake an individual-level DiD analysis that compares patenting in matched samples of university and institute researchers before and after the abolishment of the professor's privilege in Germany. CZ is based on the premise that institute researchers constitute a relevant control group because institutes always had patent rights. The authors find a severe downturn in university researcher patenting compared to institute researchers. Because of matching, this result cannot be attributed to compositional factors, such as those associated with life-cycle effects, field, or gender (Huang et al., 2011; Levin and Stephan, 1991). A similar approach, using firm inventors as a control group, by HJ also indicates a strong negative effect in Norway. Their study reveals not only a substantial decline in patenting but also a strong decline in firm start-ups by academics.

A few studies do not explicitly evaluate the shifting reform but provide other evidence. In this respect, Sweden is an interesting country as it is one of the few countries in Europe to retain its professor's privilege. Ejermo and Källström (2016) examine the level of academic patenting in Sweden that results as a consequence of academic R&D (whose exogenous variation is plausibly explained by field-external R&D at the university), which is examined and contrasted with the case of the United States, the only other country for which such evidence exists (Coupé, 2003; Gurmu et al., 2010). The paper reports that university patenting in Sweden responds at least as well, if not better, to academic R&D resources than the United States. Another Swedish-US comparison is made by Åstebro et al. (2016). They examine the entry of STEM (science, technology, engineering, and mathematics) PhDs into entrepreneurship and differentials between university wages and earnings from becoming an entrepreneur in the two countries, contrasting this with the baseline entrance rate by non-academics. They find that Swedish academics are more likely to enter into entrepreneurship than the country baseline, and while average earnings drop in both countries, they drop less in Sweden. Thus, the incentives and revealed entry rates by no means have a greater deterrent effect in the Swedish context. Of course, this evidence only indirectly suggests a positive effect from the professor's privilege, as other system properties could affect the level of patenting. However, in line with this evidence, HJ also report that countries with the highest shares of university patenting in all patenting also have or have had a professor's privilege. Moreover, the result that professor's privilege systems may better stimulate individual incentives is also in accordance with a study by Kenney and Patton (2011), who, in a six-university comparison of North American universities, find that Waterloo University, the only university with a professor's privilege, had substantially more entrepreneurial activity than the other five. Interestingly, the second-best performer, University of Wisconsin, Madison, had a professor's privilege earlier.

3. The Finnish University Patenting Reform

The Finnish university system consists of 14 universities and 25 universities of applied sciences (polytechnic universities). The Finnish university system follows a dual model that distinguishes between research and educational universities. Applied science universities focus their educational mission on bachelor's and master's degrees, and do little research whereas the universities focus on education, at the master's and PhD level, as well as scientific research. When the new Finnish legislation on university patenting became effective at the beginning of 2007 (Ministry of Trade and Industry, 2006), the rights of university researchers and teachers to their own inventions were significantly reduced. In effect, the new legislation prescribed that the university had the right – but not the obligation – to claim patent rights to all inventions made by university researchers when the inventions were conceived during work that was financed in whole or in part with external public research funding. Because of the dominant role of this type of funding in university budgets, the reform had wide-ranging implications for all university researchers, although they could still claim ownership of inventions conceived during "open research", i.e., research conducted without external funding.

The new legislation closed a decade-long effort to shift intellectual property rights to research-based innovations from researchers to universities (Kutinlahti, 2005, p. 71). The key argument of reformers was that university inventions were not utilized because inventors did not have sufficient resources or that the ownership of inventions were too easily subject to dispute (Government of Finland, 2004, p. 9). Moreover, universities of applied sciences already owned intellectual property rights to employees' inventions. However, no report advocating the reform cited evidence or research assessing the extent of the supposed problem with utilization of research. In Finland, the reception to the new legislation has been mixed, and no comprehensive evaluation of it has been carried out so far. The legislative reform was introduced in tandem with an increase in public funding to support research commercialization activities at the universities. Whereas the post-World War II academic culture in Finland took a skeptical view of industry and industrial sponsorship of science, the academic world began to align itself with the broader trend of liberalization and opening up Finnish society and the economy since the mid-1980s. Since then, pressure in Finland to commercialize university research has steadily increased, as has pressure on researchers to patent. One important driver of this trend has been an increased role of external research funding for universities. Whereas in 1985 external research funding accounted for about 8 percent of university budgets, in 2013 it was almost 60 percent (Statistics Finland, 2014).

Several policy instruments have explicitly sought to facilitate commercialization of research since the late 1990s. Tekes, the Finnish funding agency responsible for technology and innovation under the auspices of the then–Ministry for Trade and Industry, introduced a series of targeted programs (TULI) to support the transformation of research based inventions at universities and public research institutes into business. Ever since, a central element in this early-phase funding scheme has been support for inventors to apply for patents. The first program scheme (2002-2006) provided about EUR 2.5 million in overall funding and reviewed in total about 1,000 research-based inventions (Hjelt et al., 2006). The second program scheme (2007-2012) overlapped with the enactment of the university patent reform and had a total value of about EUR 50 million. It was an extensive national program that involved all universities and research institutes. The initiatives, combined with the legislative reform of university inventions raised expectations that they would lead to a substantial impact on licensing and sales of intellectual property, but this seems not to have been realized (Ketonen et al., 2013). A feature of Tekes support for research commercialization has been that VTT (the Technical Research Centre of Finland, a government-owned research institute) has become its primary beneficiary. In addition to Tekes funding, the Ministry of Education provided direct and indirect financial support for the development of university patenting and research commercialization. Between 1999 and 2003, the Ministry provided EUR 11 million to universities to this end, and in 2004-2006, the funding totaled EUR 26 million (Tahvanainen, 2009). In sum, the direct and indirect support for commercialization of research and patenting of academic research was at a significant level well before the new legislation in 2007, but increased dramatically thereafter.

4. Empirical analysis

For our empirical analysis, we use as our base the DiD regression technique. DiD starts with the premise that there is a treated group, in our case the university sector, and control group(s), in our case, institutes and the private sector. Treated and control groups are observed both before and after "treatment," that is, the abolition of the professor's privilege. By comparing changes in the treated group before and after the policy change with the developments of the control group(s), any trend effect that is common to all groups is eliminated. Our main outcome variable is a dummy for whether an individual is listed as an inventor in a specific year. The key identifying assumption in a DiD analysis is the presence of common trends, according to which, without treatment, the main underlying trend would be the same in treated and control groups. In practice, we implement this analysis by observing at which of the three groups (university/institute/private) individuals work, which is captured by dummy variables, and a dummy is added for those who work in academia post-treatment. That last variable is our main variable of interest.

There are several threats to identification. The most obvious concerns measurable characteristics that can influence the outcome. The researcher might hope that inclusion of such control variables restores order in terms of a common trend. Routinely, year-dummy effects are included. We also always include individual fixed effects that pick up time-invariant factors, such as innate ability, which influence a person's propensity to patent. Later, we adopt a matched sample analysis using coarsened exact matching (CEM) combined with DiD, in the same spirit as CZ and HJ, in order to standardize the sample. For instance, it is mainly researchers in academia (and not administrative staff) who are likely to patent, and this is likely linked to the type of education, age, gender, and field of work. In the private sector, it is obvious that the vast majority of individuals are very unlikely to patent and should not be in the control group. Matching can therefore go a long way toward removing, in a non-parametric manner, influences that stem from such individual heterogeneity.

There are further problems with identification of the treatment effect. One of those concerns the announcement of the reform prior to implementation. This makes the situation in Finland different from that in Germany. In Germany, CZ argue that the change in legislation came as a surprise and therefore that behavior would not have had time to adjust to it in advance. By contrast, the Finnish reform was announced and known well beforehand. Academic researchers may therefore have reacted by changing their behavior before the actual reform, which can lead to a change in the outcome variable before treatment, commonly referred to as Ashenfelter's (1978) dip. The original example refers to a situation in which unemployed participants in work training programs see a drop in real income *prior* to their program participation. In our case, a drop in patenting before the reform among university researchers would constitute a violation to the common trends assumption, which cannot be accounted for by the inclusion of additional control variables. Applying for a patent can be seen as an investment for the inventor in which the return consists of future license income. News of the reform creates uncertainty about the returns for prospective applicants and academic inventors, because if they file a patent application, the returns may end up with the researcher's employer after granting (in the future). Given that the duration from application to the granting of a patent is typically around four years (Cohen and Merrill, 2003, Table 1, p. 96), such increased uncertainty can be expected to stifle patent application activity.

They could also respond by changing their group of employment, or, conversely, other individuals may enter academia because they are attracted by the possibility of working with skilled university technology transfer officers. In essence, pre-treatment behavioral change leads to a violation of the common trends assumption needed for identification in the DiD framework.

Another difference with the German case is that the research institutes are more difficult to motivate as a control group. This is because of the potentially strong dominance of one actor, the VTT. For instance, the VTT may have had specific IP policies that influence their outcome, which disturbs the comparison. For this reason, we will also compare university researcher patenting with that of firms. Yet again, there is a complication that patenting may be influenced by the IP strategy of major patenting firm(s). On the positive side, we can more easily deal with this, as there are many other firms with which we can compare patenting development. In robustness analyses, we deal with this by examining whether the results differ if we exclude the firm with the most patenting. Finally, as reported earlier, universities in the applied sciences were not affected by the reform. Unfortunately, our data do not allow us to analyze universities and universities in the applied sciences separately.[2] Therefore, given that we include applied science universities in the treatment group, our estimates might be biased toward zero, although this bias is likely to be small.[3]

4.1. Data

The most important piece of information for this project was data on Finnish inventors that we compiled and organized by linking inventor data with employee registers. This step is crucial and more difficult for countries in which universities generally do not own patents. In fact, a distinct result of research in this area has been in showing that differences between European and US academic patenting can be explained largely by these ownership patterns, in which patents on university inventions patents include those with inventors working in academia but for which the patent owner is generally a firm (or sometimes individuals) outside academia (Lissoni et al., 2008; Meyer, 2006). Thus, to identify Finnish academic patents, we cannot rely on applicant information. An important difference in our identification of inventors is that we extensively rely on their home address, a highly unique identifier, in combination with Statistics Finland

[2]We thank one of our reviewers for bringing this issue to our attention.

[3]Their impact on the estimates is likely to be small, given their low weight in overall R&D in the higher education sector. According to data from Statistics Finland, their share was only a constant 9 percent in both 2004-2006 and 2007-2009.

registers on the home address of the entire population, rather than the firm's address. As an example of "hidden" academic patents, prior to the new legislation in 2007, Finnish universities applied for or held few patents (cf. Meyer, 2006). It has been estimated that, just before the new legislation, Finnish universities held 20 patents and had about 37 pending applications –of which 37 were from the Helsinki University of Technology (Hjelt et al., 2006, p. 32).

For our purposes, we first extracted each patent record from OECD PATSTAT data in European Patent Office (EPO) records listing at least one inventor with a Finnish address (henceforth, Finnish inventor). All records were sent to Statistics Finland for linking with register data. The EPO records the full home address, which is almost invariably listed, whereas other patent offices (e.g., the USPTO) typically list only the name and city. Online Appendix A gives an overview of the different matching methods used. Basically, a large range of parameters was available for matching, including variants of the first name, different employers during the year, home address, and the associated company listed on the patent. The last method could be used because Statistics Finland had information on the companies where individuals worked, which could then be used to uniquely identify individuals with a specific name. Statistics Finland could also vary the year of its home address registry as the inventor address listed on a patent registered in a specific application year may not necessarily reflect the correct address according to their register of the population in that year, say, if an individual moved that year. The strictest matching methods, which demand matches on many parameters, were used first and then successively fewer parameters were used. Exact matching was used, which does not allow for spelling variations. One of the constraints set in matching was that only adults were allowed to be linked from the population records. The final result was a nearly 91 percent match rate on Finnish inventors. To these data were added information on whether the individual was working at a university, an institute or a firm, and demographic characteristics from register data. Finding out whether the individual was a university, institute, or a firm employee was not trivial and involved a judgement on the choice of indicator to use. To determine this, a priority order was created in which information on firm affiliation, firm owner, legal form, and NACE code was used. Online Appendix B gives more detail on this allocation.

4.2. Descriptive information

Figure 1 plots the number of patent applications and the number of inventors among universities, institutes, and in the private sector (firms), with 1995 = 1. The figure has several noteworthy features. Generally, the two series are similar in showing positive trends among institutes and in the private sector. Strong dips in academia occur in the period 2004-2005 for patent applications and in 2005-2008 for inventors. As these dips (partially) occur before the reform in 2007, they suggest that university researchers may have reacted even before the reform—for for example, in 2004 when it was announced, in line with our previous discussion.

Other clear patterns also emerge. For instance, we observe an extremely strong positive trend among institutes. This could be the result of more active patenting behavior by the VTT—for example, of a changed patenting strategy or perhaps due to the movement of university researchers to the VTT following the reform. Indeed, following an email inquiry, the VTT's present IP manager confirms that campaigns to raise disclosures were in effect in 2009-2010. He also indicates a second reason, a shift toward higher-quality patenting, which would raise the level of patenting at the EPO after the initial priority year. Second, the strong dominance in patenting in Finland by just one firm, whether including this firm or not, may have a large impact on the baseline comparison. We consider this in our analyses.

Table 1 shows developments in the number of individuals linked to universities, firms and institutes, number of inventors, and inventors as a share of all linked individuals by group. Over the period 1995-2010, we allocated nearly 5 million unique individuals to one of the three groups. We observe more than 13,000 individuals who were ever inventors in 1995-2010, or 0.3 percent of individuals for whom we could delineate an affiliation. Large differences in inventor shares exist among the three groups. The highest share of inventors is found at institutes, about 1.6 percent, or more than 500 individuals. At universities, the corresponding share is 1.1 percent, or about 1,200 inventors. Among firms, the share is the lowest, only 0.2 percent, but this corresponds to nearly 11,700 inventors. Therefore, the incentives and motivations to be an inventor and strategies toward patenting vary substantially by group, such as subsector and field of research.

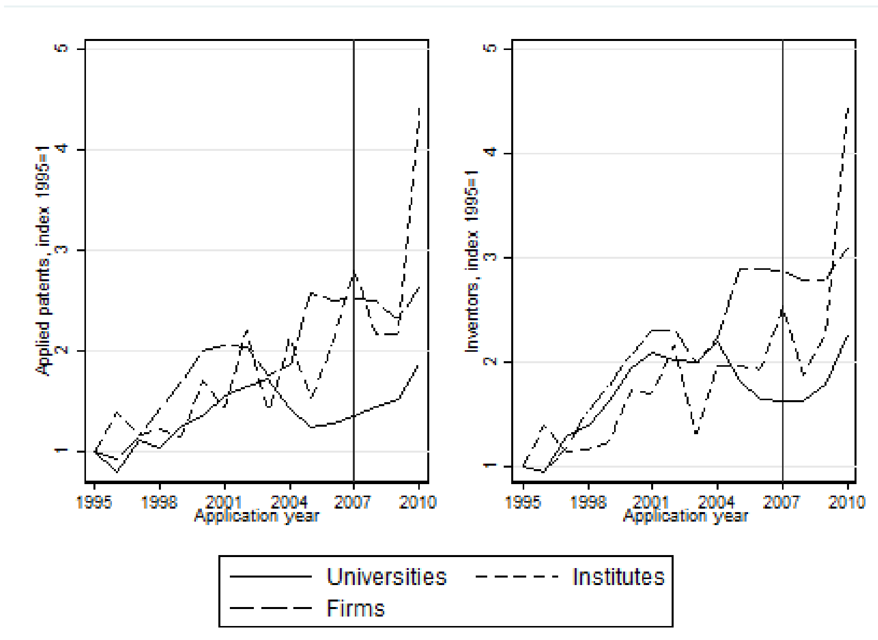

Figure 1: Patenting (left) and inventor (right) developments among universities, institutes, and private firms in Finland, 1995-2010.

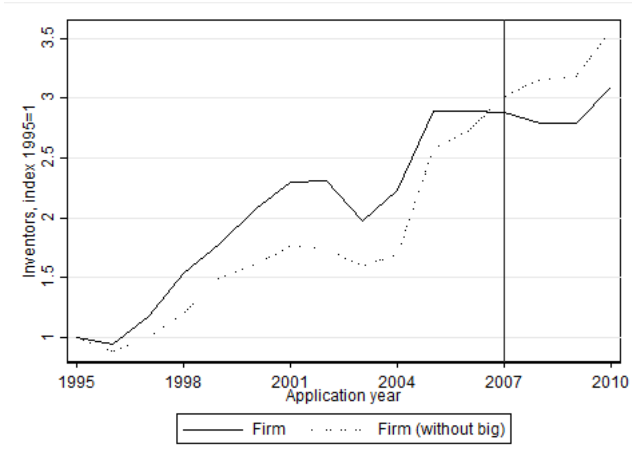

Figure 2: Finnish firm patenting with (solid line) and without (dotted line) the firm with most patenting.

$<$ TABLE 1 ABOUT HERE $>$

Large firms are more likely to have a greater influence on overall patenting in small countries than in larger countries. This sensitivity is illustrated in Figure 2, which shows inventor trends with and without the firm with the most patenting in our data.

Clearly, inventor developments rose much faster at the firm with the most patenting than for other firms until about 2005. After 2005, the number of inventors started to decline overall and did not pick up until 2010. Removing this firm shows a much more consistent pattern. With the exception of the slump in patenting in 2001-2004, inventor rates rose throughout. Later, we run our regressions, removing the biggest firm from the analysis to gauge how this affects our results.

4.3. Regression analyses

4.3.1. Difference-in-differences regressions on the full sample

Our first set of estimated regressions takes the form:

$$Pat_{it} = \alpha + \beta_0 Post_t + \beta_1 Uni_i + \beta_2 Uni_i \cdot Post_t + \beta_3 Inst_i + \beta_4 Inst_i \cdot Post_t + \varepsilon_{it} \quad (1)$$

where Pat_{it} is a count variable that shows on how many applied patents in year t an individual i is listed as an inventor. $Post_t$ takes a value of 1 beginning in 2007, and Uni_i is the treated group of individuals, that is, university researchers, $Inst_i$ is a dummy for institute employees, with firm employees in the omitted category. We chose patent counts as our main outcome variable, as it also takes the heterogeneity of patenting into account. Our individual panel regressions modify this slightly as

$$Pat_{it} = \beta_1 Uni_i + \beta_2 Uni_i \cdot Post_t + \beta_3 Inst_i + \beta_4 Inst_i \cdot Post_t + \gamma_i + \lambda_t + \varepsilon_{it} \quad (2)$$

where, $\beta_0 Post_t$ is fully accounted for through year-fixed effects, λ_t. We also include a full set of individual fixed effects γ_i to account for time-invariant heterogeneity among individuals that absorb α. Individual-fixed effects are redundant only when individuals do not change to another group (and hence $Uni_i, Inst_i$ are time invariant). Therefore both sets of variables are initially included, and we later examine the effects of the reform on mobility out of academia.

One threat to identification in DiD frameworks concerns violations of common trends. This can happen if, for instance, the rate of patenting increases more rapidly among university employees before the reform than in other groups. Post-reform patenting in relation to other groups would then appear to be an increase, in which this would result only as part of a persistent trend. Of greatest concern for our case is the pre-announcement of the reform and strong institute trends. A simple way to test for pre-reform trends is to multiply group effects by a trend variable and add them as separate variables (Angrist and Pischke, 2009; Besley and Burgess, 2004):

$$\begin{aligned} Pat_{it} = {} & \beta_1 Uni_i + \beta_2 Uni_i \cdot Post_t + \beta_3 Inst_i \\ & + \beta_4 (t \cdot Uni_i) + \beta_5 (t \cdot Inst_i) + \gamma_i + \lambda_t + \varepsilon_{it} \end{aligned} \quad (3)$$

where t is a time trend variable. A change in our coefficient of interest β_2 because of the inclusion of the trend variable suggests that post-reform changes are mainly due to trend effects. Table 2 reports the regressions based on equations (2) and (3). The models are estimated using the Poisson model with individual-fixed effects. The first presented regression suggests that university employees invent more after the reform in 2007. However, as we suspected, including trend effects alters the coefficient, turning it insignificant in the second regression (model 2). It is clear that we have to look much further into our data.

$<$ TABLE 2 ABOUT HERE $>$

4.3.2. Matched sample regressions

Our first set of regressions revealed that trend effects were important, but it is not clear exactly why. We now turn to matched sample analyses, which reduces problems in interpretation that depend on the composition of treated and non-treated groups. For instance, different individuals may react differently to the reform, and it could be that the group composition in populations systematically leads to differences that have nothing to do with the reform. It could also be that changing to a matched sample reduces the trend problems observed above. A first step is to examine the education characteristics of inventors at universities, firms, and institutes, as we know that inventive activity is highly dependent on the level of education (Giuri et al., 2007; Jung and Ejermo, 2014; Toivanen and Väänänen, 2015). Tables 3-4 show education data for individuals who were ever inventors, at the time of their first invention.

$<$ TABLE 3 ABOUT HERE $>$

$<$ TABLE 4 ABOUT HERE $>$

Table 3 shows that the education background of most inventors is in technology fields, followed by the natural sciences and then health-related fields. About 4 percent of inventors came from other education backgrounds. In relative terms, technology education is more common among firm inventors, health-related education is more common among university inventors, and agriculture and forestry education is more common among institute researchers, where this is more common than health-related backgrounds. Table 4 also shows that most inventors, in particular at universities, are very highly educated. In fact, 56 percent of university inventors have a PhD (or the equivalent) education, and only 7 percent have less than higher-degree tertiary education. This indicates that inventive activity in academia is generally closely linked to research. It is therefore natural to derive our matched sample by retaining university individuals with a technology, natural sciences, or health-related education and those with higher-degree tertiary education or higher. This means that our matched samples consist of individuals with the highest propensity to invent.

Following recent papers in the literature that use individual patent and publication data (e.g., Azoulay et al., 2010), we use a routine called coarsened exact matching (CEM) in Stata, which allows the researcher great flexibility in the matching process in choosing between exact or non-exact matching. CEM also has the advantage of guaranteeing common support over the entire distribution, whereas, in more standard propensity score matching, this has to be checked after matching. We use one-to-one matching for the purpose of finding for each university employee a similar individual in the other groups. Our strategy of focusing on highly educated university employees who are more likely to invent is in line with other recent contributions. CZ used propensity scores to match German professors to "nearest neighbors," choosing as match parameters publication counts, publication subject field, and career age. HJ used propensity scores to find the single-nearest neighbor to each university-employed PhD. They matched on PhD type, gender, and marital status.

Lacking data on publications, we use the following matching criteria: exact match on gender, education type and education level, and coarsened matching on age and cumulative patent count. We attempted to construct three matched samples, in which we matched (a) university employees with institute employees; (b) university employees with firm employees; and (c) same as (b) without including firm employees from the firm with the most patenting in the control group. For all matched samples, we use the characteristics of employees in 2003. Table 5 shows descriptive data in 2003 for all individuals by group. This table makes it clear that the institute population is quite small in relative terms. Furthermore, when we attempt to match with institute researchers, we end up with only 3,252 matched pairs, much less than when we draw the control individuals from the firm population, in which we match 8,850 pairs. Combined with the earlier recognition that the institutes are so strongly dominated by one actor, we continue the analyses using only the (b) and (c) matched samples.

Table 6 shows descriptive data for the firm matched samples. For secrecy reasons, we cannot show the descriptive data on how excluding the firm with the most patenting changes the characteristics. The resulting matching properties show that in the main firm-matched sample (b), 39 percent have a technology education background, and 45 percent have a natural sciences background. Health education background is at 16 percent. Thirty-seven percent of the individuals have a PhD-level education. The average age is 38. The firm matched sample raises the average share of individual inventors from close to zero in the general population of firm employees to 2 percent. It also raises the cumulative patent application rate to an average of 0.15. The corresponding shares in the general population is close to zero for an individual patenting in 2003 and 0.01-0.06 for cumulative patent application counts, depending on the group.

$<$ TABLE 5 ABOUT HERE $>$

$<$ TABLE 6 ABOUT HERE $>$

Table 7 reports on matched sample estimations using Poisson regressions and the setup in equation (2). We include the firm with the most patenting in models 1-3 and exclude it in models 4-6. We follow equation (3) by including trend effects in models 2 and 5. We see that, compared to firm employees, the rate of patenting by university employees drops by 22 percent (model 1) when we include the firm with the most patenting, and by 29 percent (model 4) when we exclude it. The inclusion of trend variables changes the result quite dramatically when we include the firm with the most patenting (model 2), in which the coefficient turns positive but is not significant. Instead, when we exclude the firm with the most patenting, the effects remain almost identically negative at -29 percent (model 5). It remains significant at the 5 percent level. These conflicting results suggest that researchers may either have changed behavior prior to the reform or that the firm sample without the firm with the most patenting is the more relevant one. In order to get a better understanding of the existence of pre-reform behavior and post-reform dynamics, we include lead and lag effects for the treated university researchers (cf. Angrist and Pischke, 2009; Granger, 1969). This is done by augmenting equation (2) with university-specific year effects and removing the $Uni_i \cdot Post_t$ term (as it is captured by the lag effects) as in:

$$\begin{aligned} Pat_{it} &= \beta_1 Uni_i + \beta_2 Inst_i + \gamma_i + \lambda_t \\ &\quad + \sum_{\tau=1}^{4} \delta_{+\tau} D_{i,t+\tau} + \sum_{\tau=0}^{3} \delta_{-\tau} D_{i,t-\tau} + \varepsilon_{it} \end{aligned} \tag{4}$$

The first summation term captures dummies for lead effects in 2003-2006 for the university sector, and the second summation term captures post-reform period year effects

(2007-2010) for the university sector. The estimated models are given as models 3 and 6 (with/without the biggest firm). Gauging from model 3, we see that there is some evidence of pre-reform changed behavior since the leading effects for both 2005 and 2006 (and also 2004 to some extent in model 6) are strongly negative and significantly different from zero, even without the firm with the most patenting. This makes it plausible that university researchers reacted upon announcement of the reform by reducing their inventive activity.

4.3.3. Shifting the reform start period

We have now seen that there might be a pre-reform decline not explained by demographic composition. This means that the start of the reform period becomes debatable. In particular, word of the 2007 reform that surfaced in 2004 could have affected the patenting behavior of Finnish university researchers. We now modify our analysis to change the pre- and post-periods such that "before" ends in 2003 and "after" begins in 2004, that is, the year of the announcement. With this change, and using the same regression setup as earlier, in Table 8 we find a significant negative effect on researcher patent counts by 37 percent for the full sample, after 2004 (model 1). Including trend variables (model 2) again renders the reform effect insignificant for the full matched sample. The lead and lag effects indicate, as before, a strong effect for 2005 in models 3 and 6, but no pre-2004 changes in behavior. For the models in which we exclude the biggest firm, we find a 46 percent decline in patenting in model 4 from 2004 onward. This strongly suggests that the firm comparison should be made without the firm with the most patenting. Apparently, this firm's patenting pattern deviates from that at other firms and has had strong swings over time. Also, lead and lag effects show a consistently significant negative effect, at the 10 percent level, in each of the years 2005-2010 in model 6. They are barely affected by the inclusion of trend effects, as before. In sum, these results indicate a strong effect on patenting by university employees. Combined, the results in model 5 from Tables 7 and 8 suggest a decline in patenting of about 29-46 percent, depending on whether we include the announcement period in the comparison.

$<$ TABLE 7 ABOUT HERE $>$

$<$ TABLE 8 ABOUT HERE $>$

4.4. *Robustness analyses*

We have found evidence that, although the setting for Finland differed in many respects from the main comparison cases, the main results were similar. But we have also seen that the announcement of the reform seemed to affect university researcher patenting prior to the reform. We now conduct additional analyses of[4] (1) those who leave academia ("leavers"), and (2) the role of technology transfer (TULI) funds that accompanied the reform.

4.4.1. *Leavers from academia*

Budding inventors may have chosen to remain in or leave academia because they anticipated changing conditions for invention in academia—for instance, as a result of increased "taxation" on academic patenting. Alternatively, inventors may have chosen to leave academia after the reform was implemented, after the practical consequences became clear. Ideally, one would somehow redo the regressions to examine whether patenting behavior changed in any way. But it is not trivial to use a DiD framework to define to which group a "leaver" belongs. Instead, it is more straightforward to re-run the regressions on those who remain ("remainers"). However, if we define a remainer as someone who worked in the same group throughout the 2003-2010 period, using the main firm-matched sample, we lose more than 80 percent of observations, creating great difficulty in generalizing the results. We therefore pursue a different and arguably more direct analysis by making mobility (whether one leaves) the outcome variable itself and therefore examine whether mobility changes as a result of the reform. The hypothesis here is that university employees, in general, are not necessarily affected by the reform, but that individuals with invention experience might leave the university sector. Our first regression, shown in Table 9, model 1, shows year-by-year effects for all university employees (in all regressions, we retain only observations of those who leave the university sector for the first time). The baseline, captured in the constant term, is the period before 2004. Clearly, mobility shows an increasing trend over the

[4]One extension could have been to analyze the effects on citation-weighted patents or other patent-quality characteristics. Unfortunately our data has only very incomplete coverage of quality characteristics.

years 2004-2010. This is unlikely to be the result of the patenting reform but could be the result of, for example, funding systems. However, cohort effects should be captured in the individual-fixed effects included. Model 2 looks only at university employees who have invented. We also see a slightly increasing trend in mobility for this group, but it is not as strong as for the general group of university employees. Therefore, any increased mobility among inventors may be the result of a general increase in mobility by university employees. We directly test whether inventors are different from the general population of university employees in model 3, in which we add year dummies interacted with a dummy for whether the individual has invented. Significant interaction effects would indicate that inventors have a different propensity to leave than the general group of employees. We find only three significant effects. For 2004, we find a weakly positive and significant effect for inventors, but for 2009 and 2010 it is negative and quite significant. The effect for 2010 is substantial, but it seems hard to link these year effects to the reform in 2007. The general conclusion is therefore that mobility among inventors was not the primary cause for the drop in university patenting.

$<$ TABLE 9 ABOUT HERE $>$

4.4.2. Does technology transfer funding matter?

We have already reported that, in 2007, concomitant to the abolishment of the professor's privilege, Finland increased funding for technology transfer from so-called TULI funds from EUR 2.5 million in 2002-2006 to EUR 50 million in 2007-2012. Did it help in boosting patenting? According to our earlier results, we have found dramatic drops in patenting. However, TULI funds may have helped mitigate an otherwise much more negative trend. To examine this, we collected data on the sources of university R&D funding. Although Finland was severely affected by the economic crisis in 2008, it is noteworthy that government research funding for universities increased by 16 percent in 2007-2009 compared to 2004-2006. Thus, financial constraints are unlikely to explain the downturn in university patenting that we have uncovered so far.

TULI funds are administered by Tekes, and unfortunately we do not have information on TULI funds as such, only the total level of Tekes funds. Tekes funds account for a constant 8.9 percent of university funding, but there is substantial variation. In general, technically oriented universities attract more Tekes funding, and so do (somewhat surprisingly) the Hanken School of Economics and the Helsinki School of Economics, especially in the later period. Since we cannot separately analyze the TULI contribution, we look for evidence of whether Tekes funds, broadly, were associated with a greater decline in patenting. To test for this, we create a dummy variable with a value of 1 after 2007 if the following conditions are met: (a) Tekes funds are a substantial share of all R&D funds, (b) the nominal level of Tekes funds increased substantially in 2007-2009 compared to 2004-2006, and (c) technical, natural sciences, or medical research must be taking place at the university, contributing to patentable research. Five universities clearly satisfy these conditions: Helsinki University of Technology, University of Oulu, Tampere University of Technology, Åbo Akademi University, and Lappeenranta University of Technology. All these universities (a) had Tekes shares in 2007-2009 of more than 10 percent, (b) increased Tekes funds more than 15 percent, and (c) hosted faculties that could produce patentable research.

We then coded a variable "$HiTekes$" as 1 for researchers active at those universities and re-ran the firm matched sample regression with and without the biggest firm (cf. Table 7), including this dummy. The result is shown in Table 10. The dummy HiTekes effectively captures any differential effect on patenting that distinguishes universities highly supported by Tekes funds after 2007 from other universities. First, it should be noted that the result for the *Dummy (2007- x university)* is largely unchanged compared to Table 7, that is, those results are stable with the inclusion of the HiTekes dummy.

Second, the coefficient for HiTekes is never significant. Although it is positive in all four cases, the standard errors are relatively large. This means that we cannot discern any specifically strong effect on the five universities after 2007 mentioned above that are not captured by individual characteristics or any of the other variables. Note that we would not have made any causal claim on statistically significant coefficients in these regressions. For instance, universities with strong patenting may well be more able to attract additional Tekes funds. This reverse-causality argument should, however, have led to a biased and more positive coefficient, if patenting and Tekes funds are positively correlated. This bias in effect emphasizes even further that no specific Tekes effect occurs after 2007, although the effect of Tuli funds specifically is not addressed.

< TABLE 10 ABOUT HERE >

5. Conclusions

This paper aligns with earlier evidence on the abolishment of the professor's privilege in Germany and Norway, providing individual-level longitudinal information on the level of patenting. The Finnish case is a bit different, because of a clear pre-reform announcement. Also, the comparison with institutes is hard to justify because of a fairly small comparison group. For firms, we have chosen to exclude the firm with the most patenting from our comparisons. After these considerations, we show that the evidence for Finland demonstrates a decline of 29 percent if we set the reform year to that of the change in patenting rights in 2007, but a decline of 46 percent if we set the reform year artificially at 2004—that is, we include the announcement period before the reform as part of the change. As noted earlier, these estimates probably somewhat *underestimate* the negative effect, as we cannot remove applied science university researchers (which never had a professor's privilege) from the estimations, although this effect is likely to be small. These results put Finland in between but also in line with the evidence in Norway (-48 percent) and Germany (-19 percent), as found by Czarnitzki et al. (2015) and Hvide and Jones (2016).

We also analyzed, first, whether mobility among researchers could explain the Finnish decline and, second, whether technology transfer funds helped mitigate the negative effects. We find no evidence that mobility among inventors increased substantially, at least not relative to the general group of university employees, although we see an increasing trend of outward mobility among university inventors (and non-inventors) over time. We also find no strong evidence that technology transfer funds changed patenting outcomes relative to recipients who did not receive increased funds, although these results build on somewhat imprecise data.

Given the reform's negative impact on university patenting, we can consider its feasibility and broader potential implications for incentives for university researchers to invent. Should the reform be reversed? Almost a decade has passed since its introduction, and the potential effects of a reversal should receive careful consideration. Moreover, by now, the universities have had sufficient time to implement new research commercialization practices. Most importantly, our study does not cast any light on recent developments, something that would be necessary to consider in any major policy reform.

However, it is clear that the immediate outcome of the reform, the negative impact on patenting, was the exact opposite of what had originally motivated it and thus calls into question the extended policy-making process that led to it. Clearly, such sweeping policy reforms should be preceded by more careful and analytical preparatory work, especially as the literature on technology transfer and research commercialization has identified several fundamental problems with university ownership. For Finland, and other countries, it is imperative to create sustainable incentives for scientists to engage in inventive activity and thereby contribute to technical change in the economy.

References

Angrist, J. D., Pischke, J.-S., 2009. Mostly harmless econometrics. Princeton: Princeton University Press.

Ashenfelter, O., 1978. Estimating the effect of training programs on earnings. Review of Economics and Statistics 60 (1), 47–57.

Åstebro, T., Braguinsky, S., Braunerhjelm, P., Broström, A., 2016. Academic entrepreneurship: Bayh-dole versus the ’professor’s privilege’. Report, HEC Paris.

Audretsch, D., Göktepe-Hultén, D., 2015. University patenting in Europe - does faculty ownership of intellectual property impede university technology transfer? In: Link, A. N., Siegel, D. S., Wright, M. (Eds.), The Chicago Handbook of University Technology Transfer and Academic Entrepreneurship. Chicago: University of Chicago Press, pp. 188–217.

Azoulay, P., Graff Zivin, J. S., Wang, J., 2010. Superstar extinction. Quarterly Journal of Economics 125 (2), 549–589.

URL http://qje.oxfordjournals.org/content/125/2/549.abstract

Besley, T., Burgess, R., 2004. Can labor regulation hinder economic performance? Evidence from India. Quarterly Journal of Economics 119 (1), 91–134.
URL http://qje.oxfordjournals.org/content/119/1/91.abstract

Cohen, W. M., Merrill, S. A. (Eds.), 2003. Patents in the knowledge-based economy. National Academies Press, Washington, DC, includes bibliographical references.
URL http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=101990

Coupé, T., 2003. Science is golden: Academic R&D and university patents. Journal of Technology Transfer 28 (1), 31–46.
URL http://dx.doi.org/10.1023/A:1021626702728

Czarnitzki, D., Doherr, T., Hussinger, K., Schliessler, P., Toole, A. A., 2015. Individual versus institutional ownership of university-discovered inventions. Report, ZEW.

Della Malva, A., Lissoni, F., Llerena, P., 2013. Institutional change and academic patenting: French universities and the innovation act of 1999. Journal of Evolutionary Economics 23 (1), 211–239.

Ejermo, O., Källström, J., 2016. What is the causal effect of R&D on patenting activity in a "professor's privilege" country? Evidence from Sweden. Small Business Economics 47 (3), 677–694.
URL http://dx.doi.org/10.1007/s11187-016-9752-7

Giuri, P., Mariani, M., Brusoni, S., Crespi, G., Francoz, D., Gambardella, A., Garcia-Fontes, W., Geuna, A., Gonzales, R., Harhoff, D., Hoisl, K., Le Bas, C., Luzzi, A., Magazzini, L., Nesta, L., Nomaler, Ö., Palomeras, N., Patel, P., Romanelli, M., Verspagen, B., 2007. Inventors and invention processes in Europe: Results from the patval-eu survey. Research Policy 36 (8), 1107–1127.

URL http://www.sciencedirect.com/science/article/B6V77-4PMT5H0-1/1/31449351a579f11c289c998bb0381483

Government of Finland, 2004. Government Proposal 259/2004. Parliament of Finland, Helsinki.

Granger, C. W., 1969. Investigating causal relations by econometric models and cross-spectral methods. Econometrica: Journal of the Econometric Society 37 (3), 424–438.

Gurmu, S., Black, G. C., Stephan, P. E., 2010. The knowledge production function for university patenting. Economic Inquiry 48 (1), 192–213.

Hjelt, M., Niinikoski, M. L., Syrjänen, M., Valovirta, V., Törmälä, T., 2006. Julkisten tutkimustulosten kaupallinen hyödyntäminen. Tekes, teknologiakatsaus. Tech. Rep. 192/2006, Tekes, Helsinki.

Huang, W.-L., Feeney, M. K., Welch, E. W., 2011. Organizational and individual determinants of patent production of academic scientists and engineers in the united states. Science and Public Policy 38 (6), 463–479.
URL http://spp.oxfordjournals.org/content/38/6/463.abstract

Hvide, H., Jones, B., 2016. University innovation and the professor's privilege. Report, Centre for Economic Policy Research.
URL http://www.cepr.org/active/publications/discussion_papers/dp.php?dpno=11139

Jensen, R., Thursby, M., 2001. Proofs and prototypes for sale: The licensing of university inventions. American Economic Review 91 (1), 240–259.
URL http://www.aeaweb.org/articles.php?doi=10.1257/aer.91.1.240

Jung, T., Ejermo, O., 2014. Demographic patterns and trends in patenting: Gender, age, and education of inventors. Technological Forecasting and Social Change

86 (July), 110–124.
URL http://www.sciencedirect.com/science/article/pii/S0040162513001911

Kenney, M., Patton, D., 2011. Does inventor ownership encourage university research-derived entrepreneurship? a six university comparison. Research Policy 40 (8), 1100–1112.
URL http://www.sciencedirect.com/science/article/pii/S004873331100093X

Ketonen, J., Juvonen, L., Gabrielsson, N., Kuusisto, M., Koponen, P., 2013. Path to creating business from research. Evaluation of TULI programmes. Tech. Rep. 2/2013, Tekes Report.

Kutinlahti, P., 2005. Universities approaching market. intertwining scientific and entrepreneurial goals. Tech. rep., VTT, Espoo.

Levin, S. G., Stephan, P. E., 1991. Research productivity over the life cycle: Evidence for academic scientists. The American Economic Review 81 (1), 114–132.
URL http://www.jstor.org/stable/2006790

Lissoni, F., 2013. Academic patenting in Europe: A reassessment of evidence and research practices. Industry and Innovation 20 (5), 379–384.
URL http://dx.doi.org/10.1080/13662716.2013.824190

Lissoni, F., Llerena, P., McKelvey, M., Sanditov, B., 2008. Academic patenting in Europe: New evidence from the KEINS database. Research Evaluation 17 (2), 87–102.

Lissoni, F., Lotz, P., Schovsbo, J., Treccani, A., 2009. Academic patenting and the professor's privilege: evidence on Denmark from the KEINS database. Science and Public Policy 36, 595–607.
URL http://www.ingentaconnect.com/content/beech/spp/2009/00000036/00000008/art00003http://dx.doi.org/10.3152/030234209X475443

Lowe, R. A., 2006. Who develops a university invention? The impact of tacit knowledge and licensing policies. The Journal of Technology Transfer 31 (4), 415–429. URL http://dx.doi.org/10.1007/s10961-006-0003-y

Meyer, M., 2006. Measuring science-technology interaction in the knowledge-driven economy: The case of a small economy. Scientometrics 66 (2), 425–439.

Ministry of Trade and Industry, 2006. Laki oikeudesta korkeakouluissa tehtävin keksintöihin. Parliament of Finland, Helsinki, 369th Edition.

Mowery, D. C., Nelson, R., Sampat, B. N., Ziedonis, A., 2001. The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh-Dole act of 1980. Research Policy 30 (1), 99–119.

Statistics Finland, 2014. Suomen virallinen tilasto: Tutkimus- ja kehittämistoiminta. Korkeakoulusektorin tutkimus- ja kehittämistoiminta. [Available at http://www.stat.fi/til/tkke/2013/tkke_2013_2014-10-30_kat_004_fi.html; accessed 23-September-2015].

Tahvanainen, A.-J., 2009. Yliopistollinen teknologiansiirto muutosten pyörteissä. näkemyksiä korkeakoulukeksintölain vaikutuksista tutkimus- ja innovaatiotoimintaan. Tech. rep., ETLA, Helsinki.

Thursby, J., Fuller, A. W., Thursby, M., 2009. US faculty patenting: Inside and outside the university. Research Policy 38, 14–25.

Toivanen, O., Väänänen, L., 2015. Education and invention. Review of Economics and Statistics 98 (2), 382–396.

Trajtenberg, M., Henderson, R., Jaffe, A., 1997. University versus corporate patents: A window on the basicness of invention. Economics of Innovation and new technology 5 (1), 19–50.

Verspagen, B., 2006. University research, intellectual property rights and european innovation systems. Journal of Economic Surveys 20 (4), 607–632.

Von Proff, S., Buenstorf, G., Hummel, M., 2012. University patenting in germany before and after 2002: what role did the professors' privilege play? Industry and Innovation 19 (1), 23–44.

Zucker, L. G., Darby, M. R., Brewer, M. B., 1998. Intellectual human capital and the birth of U.S. biotechnology enterprises. American Economic Review 88 (1), 290–306.

Acknowledgement

We acknowledge funding by Vinnova,Sweden's innovation agency, grant nos. 2014-06082 and 2016-04993 and Tekes, the Finnish Funding Agency for Innovation, grant no. 40204/174, which funded this research as part of a larger project RAID (Radical and incremental innovation in industrial renewal). We thank Statistics Finland for excellent data assistance, in particular, Hannu Karhunen, for assisting us with the matching of inventors, and Olavi Lehtoranta, for enabling contacts with Statistics Finland and helping us get the right data in place. We thank Dirk Czarnitski, Katrin Hussinger, Otto Toivanen, and Andrew Toole and seminar participants at the R&D management conference in Leuven, Belgium, the ZEW conference in Mannheim, Germany, Vinnova, Stockholm, Sweden, the Royal Institute of Technology, Stockholm, the Ministry of Employment and the Economy, Helsinki, Finland, and the EU-SPRI conference in Helsinki. The usual caveats apply.

Table 1: Developments in employees, number of inventors, and inventor shares by sector, 1995-2010.

1995-2010

	all (A)	inventors (B)	B/A	B/Total
Universities	109,990	1,201	1.1%	9.0%
Institutes	33,066	530	1.6%	4.0%
Firms	4,816,761	11,685	0.2%	87.1%
Total	4,959,817	13,416	0.3%	100.0%

2003-2006

	all (A)	inventors (B)	B/A	B/Total
Universities	50,077	426	0.9%	8.2%
Institutes	16,974	167	1.0%	3.2%
Firms	3,968,455	4,626	0.1%	88.6%
Total	4,035,506	5,219	0.1%	100.0%

2007-2010

	all (A)	inventors (B)	B/A	B/Total
Universities	50,046	396	0.8%	6.8%
Institutes	16,121	261	1.6%	4.5%
Firms	4,052,867	5,197	0.1%	88.8%
Total	4,119,034	5,854	0.1%	100.0%

Table 2: Poisson difference-in-differences regressions on the full sample.

	(1)	(2)
VARIABLES	Patent applications in t	Patent applications in t
Dummy (2007- x university)	0.317***	0.128
	(0.0783)	(0.104)
Trend x university		-0.00187
		(0.0165)
Trend x institute		0.0265**
		(0.0114)
Observations	182,321	182,321
R^2	0.000	0.000
Unique individuals	13,108	13,108
University/insitute/private sector FE	YES	YES
Individual FE	YES	YES
Year FE	YES	YES

Standard errors, in parentheses, are clustered by individual.

*** p<0.01, ** p<0.05, * p<0.1

Table 3: Education field for inventors at the time of first invention.

		Sector			
Education field		Firm	Institute	University	Total
Natural sciences		1,060	141	340	1,541
	%	9.81	27.38	30.41	12.39
Technology		7,767	321	517	8,605
	%	71.88	62.33	46.24	69.18
Agriculture		185	26	12	223
and forestry	%	1.71	5.05	1.07	1.79
Health		303	20	178	501
	%	2.80	3.88	15.92	4.03
Other/unknown		1,491	7	71	1,569
	%	13.80	1.36	6.35	12.61
Total		10,806	515	1,118	12,439
	%	100.0	100.0	100.0	100.0

Table 4: Education level for inventors at the time of first invention.

		Sector			
Education level		Firm	Institute	University	Total
Upper secondary		1,597	14	61	1,672
	%	14.78	2.72	5.46	13.44
Lowest-level tertiary		968	7	7	982
	%	8.96	1.36	0.63	7.89
Lowest-degree tertiary		2,312	15	11	2,338
	%	21.40	2.91	0.98	18.80
Higher-degree tertiary		4,879	250	412	5,541
	%	45.15	48.54	36.85	44.55
PhD (or equivalent)		1,050	229	627	1,906
	%	9.72	44.47	56.08	15.32
Total		10,806	515	1,118	12,439
	%	100.0	100.0	100.0	100.0

Table 5: Characteristics of all individuals in Finland allocated to a firm, institutes, or universities in 2003.

	Firms			Institutes			Universities		
Variable	mean	sd	N	mean	sd	N	mean	sd	N
Inventor specific year	.00	.02	2,840,482	.00	.06	9,729	.00	.06	33,487
Appl pat. cumul.	.01	.22	2,840,482	.06	.58	9,729	.04	.52	33,487
Age	41.71	16.39	2,840,462	43.54	10.55	9,729	39.57	11.59	33,487
Female	.46	.50	2,840,462	.49	.50	9,729	.53	.50	33,487
Natural sciences	.01	.12	1,742,549	.20	.40	8,902	.16	.36	31,149
Technology	.35	.48	1,742,549	.31	.46	8,902	.18	.39	31,149
Health	.08	.27	1,742,549	.06	.24	8,902	.07	.25	31,149
Higher-degree tertiary	.07	.25	1,742,549	.35	.48	8,902	.38	.48	31,149
PhD education	.00	.07	1,742,549	.18	.39	8,902	.24	.43	31,149

Table 6: Firm-university matched sample descriptive data for 2003.

N=8,850	Firms		Universities	
Variable	mean	sd	mean	sd
Inventor specific year	0.02	0.12	0.01	0.10
Appl pat. cumul.	0.15	0.72	0.11	0.65
Age	38.03	10.78	37.95	10.80
Female	0.38	0.49	0.38	0.49
Natural sciences	0.45	0.50	0.45	0.50
Technology	0.39	0.49	0.39	0.49
Health	0.16	0.37	0.16	0.37
Higher-degree tertiary	0.63	0.48	0.63	0.48
PhD education	0.37	0.48	0.37	0.48

Table 7: Poisson difference-in-difference regressions using a firm matched sample. Dependent variable individual-level applied patent counts.

	(1)	(2)	(3)	(4)	(5)	(6)
		With big			Without big	
VARIABLES		trend	lead/lags		trend	lead/lags
Dummy (2007- x university)	-0.221* (0.117)	0.201 (0.160)		-0.292** (0.116)	-0.290** (0.159)	
Trend x university		0.010 (0.0970)			0.124*** (0.0197)	
Trend x firm		0.076 (0.0966)			0.124*** (0.0204)	
Dum 2003 x university (SE)			-0.135 (0.158)			-0.217 (0.178)
Dum 2004 x university (SE)			-0.225 (0.148)			-0.290* (0.172)
Dum 2005 x university (SE)			-0.554*** (0.158)			-0.694*** (0.178)
Dum 2006 x university (SE)			-0.457*** (0.167)			-0.528*** (0.186)
Dum 2007 x university (SE)			-0.355 (0.226)			-0.481*** (0.184)
Dum 2008 x university (SE)			-0.579*** (0.184)			-0.725*** (0.204)
Dum 2009 x university (SE)			-0.352* (0.196)			-0.464** (0.218)
Dum 2010 x university (SE)			-0.353* (0.189)			-0.446** (0.198)
University/institute/private sector FE	YES	YES	YES	YES	YES	YES
Individual FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Observations	24,667	24 667	24 667	19 657	19 657	19 657
Unique individuals	1 654	1 654	1 654	1 335	1 335	1 335

Standard errors, in parentheses, are clustered by individual.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8: Matched sample regressions when the reform year is shifted to 2004.

	(1)	(2)	(3)	(4)	(5)	(6)
		With big			Without big	
VARIABLES		trend	lead/lags		trend	lead/lags
Dummy (2004- x university)	-0.374*** (0.0996)	-0.158 (0.162)		-0.460*** (0.108)	-0.459*** (0.172)	
Trend x university		0.0369 (0.0993)			0.112*** (0.0219)	
Trend x firm		0.0699 (0.0961)			0.112*** (0.0142)	
Dum 2001 x university (SE)			0.0452 (0.184)			-0.0562 (0.210)
Dum 2002 x university (SE)			-0.126 (0.166)			-0.252 (0.185)
Dum 2003 x university (SE)			-0.156 (0.177)			-0.289 (0.199)
Dum 2004 x university (SE)			-0.245 (0.167)			-0.361* (0.192)
Dum 2005 x university (SE)			-0.574*** (0.174)			-0.764*** (0.195)
Dum 2006 x university (SE)			-0.477*** (0.179)			-0.598*** (0.200)
Dum 2007 x university (SE)			-0.375 (0.234)			-0.549*** (0.198)
Dum 2008 x university (SE)			-0.599*** (0.197)			-0.794*** (0.219)
Dum 2009 x university (SE)			-0.372* (0.209)			-0.514** (0.213)
Dum 2010 x university (SE)			-0.372* (0.202)			-0.514** (0.213)
University/institute/private sector FE	YES	YES	YES	YES	YES	YES
Individual FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Observations	24 667	24 667	24 667	19 657	19 657	19 657
Unique individuals	1 654	1 654	1 654	1 335	1 335	1 335

Standard errors, in parentheses, are clustered by individual.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 9: Mobility of university employees.

	(1)	(2)	(3)
VARIABLES	All univ	Invented	All univ
Constant	0.095*** (0.000)	0.062*** (0.004)	0.095*** (0.000)
Dum 2004	0.006*** (0.002)	0.002 (0.011)	0.005*** (0.002)
Dum 2005	0.095*** (0.002)	0.059*** (0.012)	0.096*** (0.002)
Dum 2006	0.065*** (0.002)	0.050*** (0.011)	0.066*** (0.002)
Dum 2007	0.088*** (0.002)	0.069*** (0.012)	0.088*** (0.002)
Dum 2008	0.102*** (0.002)	0.085*** (0.012)	0.102*** (0.002)
Dum 2009	0.101*** (0.002)	0.077*** (0.012)	0.102*** (0.002)
Dum 2010	0.165*** (0.002)	0.088*** (0.011)	0.168*** (0.002)
Dum 2004 x invented			0.017* (0.010)
Dum 2005 x invented			-0.016 (0.011)
Dum 2006 x invented			0.001 (0.011)
Dum 2007 x invented			0.001 (0.012)
Dum 2008 x invented			-0.010 (0.011)
Dum 2009 x invented			-0.024** (0.011)
Dum 2010 x invented	0.165	0.088	-0.087*** (0.010)
R^2	0.0004	0.0003	0.0003
Individual FE	YES	YES	YES
Observations	575 138	10 166	575 138
Unique individuals	109 908	1 891	109 908

Standard errors, in parentheses, are clustered by individual.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 10: Testing for TULI effects.

VARIABLES	(1) With big	(2) With big lead/lags	(3) Without big	(4) Without big lead/lags
$HiTekes$	0.0132 (0.187)	0.0348 (0.200)	0.0930 (0.190)	0.120 (0.198)
Dummy (2007- x university)	-0.226 (0.141)		-0.355*** (0.135)	
Dum 2003 x university (SE)		0.318 (0.205)		0.262 (0.234)
Dum 2004 x university (SE)		0.229 (0.191)		0.240 (0.223)
Dum 2005 x university (SE)		-0.0978 (0.194)		-0.151 (0.222)
Dum 2007 x university (SE)		0.0873 (0.264)		-0.0915 (0.240)
Dum 2008 x university (SE)		-0.136 (0.232)		-0.319 (0.257)
Dum 2009 x university (SE)		0.0899 (0.244)		-0.0585 (0.271)
Dum 2010 x university (SE)		0.0981 (0.220)		-0.0161 (0.239)
University/institute/private sector FE	YES	YES	YES	YES
Individual FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observations	24 667	24 667	20 433	20 433
Unique individuals	1 654	1 654	1 375	1 375

Standard errors, in parentheses, are clustered by individual. *** $p<0.01$, ** $p<0.05$, * $p<0.1$