Allocation of IP control rights and effective technology commercialization at universities

Thomas Åstebro
Professor of Strategy and Entrepreneurship
HEC Paris

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Rapporten innehåller en litteraturegenomgång samt viss ny intervju-data och omanalys av sekundär-data avseende den samhällsekonomiskt optimala allokeringen av immatrialrätt mellan unversitets-anställda och deras arbetsgivare för kommersialiersingen av teknik och kunskap skapad på svenska universitet och högskolor (framgent "universitet").

Kommersialiseringen av immaterialrätter producerade på universitet har ökat med tiden. Universitet har också fått en uttalad tredje uppgift, att förutom forsking och undervisning också delta mer aktivt i samhället: *"Högskolorna skall också samverka med det omgivande samhället och informera om sin verksamhet."* (SFS 1996:1392). Frågan är om kommersialiseringen av forskning kan påskyndas genom att frångå det svenska lärarundantaget och ge universitet en starkare kontroll-rätt och en större ägarandel över immaterialrätt än nuvarande vilket är noll om ej annat avtalats. (När forskare utför kontraktsforskning för företag eller under civilrättsligt reglerade avtal med sin arbetsgivare kan universitet ta en starkare kontroll-rätt och en större ägarandel, och den anställde kan avskriva sig sina rättigheter, i större eller mindre del.)

I Sverige har det i flera omgångar debatterats om man skall frångå lärarundantaget, vilket i lag sedan 1949 har gett rätten till immaterialtillgångar till anställda på högskolor och universitet. Se till exempel Högskoleutredningen (SOU 1992:7) och SOU (1998:128). Motiveringen till att frångå detta undantag har delvis varit från ett sneglande på de påstådda positiva effekterna av kommersialisering av universitets-uppfinningar genom Bayh-Dole act reformen i U.S.A., den påstått låga patentieringsnivån bland svenska högskoleanställda, och de kopior av Bayh-Dole act reformer som har genförts i Danmark, Norge, Finland, och Tyskland. En utvärdering av Bayh-Dole reformen utförd på uppdrag och överinseende av National Academy of Sciences konstaterar till exempel: "…the system put in place by the Bayh-Dole Act, that is, university ownership of inventions from publicly funded research… is unquestionably more effective than its predecessor system... in making research advances available to the public." (Merrill and Mazza, 2011, p. 61).

Denna rapport kommer till följande 13 slutsatser.

Slutsats 1. Det främsta målet för kunskaps- och teknik-överföring från universitet till samhälle är en snabb och bred spridning av teknik för största möjliga samhällsnytta.

Slutsats 2. Kunskaps- och teknik-överföring mellan universitet och samhälle sker på manga sätt. Dessa mekanismer inkluderar, men är ej begränsade till 1. Högt utbildade studenter som tar arbete i privat och publik tjänst; 2. Publicering av forskningsresultat i öppen akademisk literatur; 3. Personliga möten mellan skapare och användare av ny kunskap (till exempel på konferenser, seminarier, nätverksträffar och andra tillfällen); 4. Företags-finansierad (kontrakts) forskning; 5. Samverkansarrangemang till exempel kooperativa forskningscentra mellan universitet och industri; 6. Personliga konsultuppdrag mellan fakultet eller studenter och företag; 7. Entrepreneuriell aktivitet av fakultet eller studenter som inte innefattar immaterialrätt skapad på universitet; 8. Entrepreneuriell aktivitet av fakultet eller studenter som innefattar immaterialrätt skapad på universitet och 9. Licensiering av immaterialrätt till etablerade företag och nya företag.

Debatten har nyligen intensifierats vad gäller kommersialisering av immaterialrätter skapad på universitet via entreprenöriell aktivitet av dess fakultet. De andra åtta mekanismerna för kunskaps- och teknik-överföring är väl så viktiga för

samhället. Uppdraget för denna rapport var dock att fokusera på entreprenöriell aktivitet av fakultet och resten av slutsatserna fokuseras därför på denna enstaka tekniköverföringsaktivitet.

Slutsats 3. Ett med tiden ökat fokus på att hävda immaterialrätt på kunskap producerad vid universitet av dess forskare har lett till en högre grad av sekretess och fler begränsningar i informationsflödet, direkt motverkande en snabb spridning av sådan kunskap. Begränsningar i informationflödet är mest synlig inom bioteknik och medicin-relaterad forskning men observeras också mer generellt.

Slutsats 4. Inkomster från försäljning och licensiering av immaterialrätt kan inte kompensera för de kostnader som uppstår för universitet för att hävda immaterialrätt och kommer inom den förekommande framtiden inte att vara någon relevant inkomstkälla för universitet. Flera lokala svenska patent-, tekniköverförings- och innovations-kontor har under de senaste 15 åren varit tvungna att stänga eller ändra på sin finansieringsmodell genom att utöka sina inkomster på olika sätt, tex. genom avgiftsbelagda tjänster. Avgiftsbelagda tjänster är ur ett samhällsperspektiv mer optimalt än att ta ägandeandel i immaterialrätt/nya företag.

Slutsats 5. I de tre Europeiska länder som har frångått lärarundantaget ill ett system där universitet istället tar ägande- och kontroll-rättigheter har alla, i mån det har kunnat mätas, erfarit en reducerad patenteringssannolikhet vid dess fakultet, reducerad samarbetsfrekvens mellan dess fakultet och industri, reducerad mängd nystartade företag av dess fakultet, och reducerad kvalitet på de patent som framtagits.

Slutsats 6. Svensk fakultet har varit och är fortfarande speciellt aktiva med att hävda immaterialrätt jämfört med andra europeiska länder och med USA, och de engagerer sig aktivt med industri och företag på många andra sätt, till exempel via konsultuppdrag och samarbetsprojekt.

Slutsats 7. En ökning av forskningsanslag representerar den största källan till ökning av universitetens kunskaps och teknik-överföring till samhället. Alla andra faktorer, som till exempel att skapa en tekniköverföringskontor har mycket mindre betydelse.

Slutsats 8. Forskare och kanske speciellt svenska forskare svarar mer på en ökning av forskningsanslagen till deras laboratorium än en motsvarande värdeökning av deras ägarandel av den immaterialrätt som de producerar i form av att producera mer flertalig och mer värdefull immaterialrätt. Myndigheter kan därför tänkas öka samhällsnyttan genom högre forskningsanslag och lägre ägarandel till fakultet. Det är dock tveksamt om sådana avvägningsbeslut är är trovärdiga då forskningsanslag lätt kan dras in i senare budgetar.

Slutsats 9. Tekniköverföringskontor i USA och Tyskland som operar under Bayh-Dole lagstiftning har på grund av de incitament som lagstiftningen skapat, dess anställdas kvalifikationer, och deras arbetsmetoder ett dominerande intresse av, och är bättre på av att licensiera immaterialrätt till etablerade företag än att hjälpa forskare att starta företag.

Slutsats 10. Det finns ingen tydlig systematisk källa till arbetsmetoder och kostnadsstrukturer för svenska tekniköverförings- och innovations-kontor att jämföra sig mot.

Slutsats 11. Statistik med låg kvalitet och anekdoter föreslår att svenska tekniköverförings- och innovations-kontor är mer orienterade till att understödja skapande av nya företag av akademiker och forskare, och att licensiering av immaterialrätt till etablerade företag praktiseras relativ sett mindre i Sverige än i USA.

Slutsats 12. Systematisk och lätt tillgänglig data på universitets-patent, licenser och spin-offs existerar inte i Sverige.

Akademiskt entreprenörskap (spin-offs) är möjligt att observera i den svenska databasen MONA som tillhandahålls av SCB. Patent tagna av svenska akademiker är möjligt att observera endast genom ett komplicerat manövrerande där man över flera steg slår samman data från European Patent Office med folkbokföringsregister och sedan med data på anställda via efterfrågningar till varje universitet om deras register över anställda. Denna manöver får utföras varje gång man vill uppdatera datan. Licensdata finns ej samlat någonstans.

Slutsats 13. Fallstudier visar på att det går väldigt bra för visa innovationskontor i Sverige och att vissa kontor sannolikt medhjälper till en signifikant utveckling av lokal företagsverksamhet. I andra fall är kontorens effekt på den lokala ekonomin mindre.

Rekommendation 1. Den svenska regeringen bör ej avskaffa lärarundantaget.

Rekommendation 2. Den svenska regeringen bör verka för att skapa ett nationellt samverkansorgan för kunskapsutbyte mellan tekniköverförings- och innovations-kontor i Sverige och med utlandet.[1] Utländska samarbetorgan finns till exempel i USA (AUTM) och i Tyskland(Technologieallianz).

Rekommendation 3. Tekniköverförings- och innovations-kontor i Sverige behöver ha åtminstone 50% av sina inkomster från andra källor än från försäljning och licensiering av immaterialrätt och realisering av andelar I nystartade företag. Sådana inkomster kan vara en mix av fast-pris service till företag och uppfinnare, och basfondering från lokal, regional och statliga källor samt universitet.

Rekommendation 4. Det finns ingen stark anledning för svenska universitet att själva driva tekniköverförings- och innovations-kontor. Resurser för att driva dessa kan delas mellan närliggande universitet och andra organisationer. Sådana kontor -- speciellt de drivna av universitet -- skall ej ges lokala monopol. Fakultet och studenter skall ha möjlighet att fritt köpa tjänster från vilka kontor de behagar. Det skall vara fri konkurrens i tillhandahållandet av tjänster för att kommersialisera immaterialrätt från universitet.

Rekommendation 5. Om rekommendation 1 ignoreras skall en tillräcklig budget avsättas så att en eventuell förändring i ägande och kontroll-rättigheter till immateriella tillgångar kan utvärderas av oberoende part efter dess genomförande. En ekonometrisk modell skall användas som approximerar den kausala effekten av en sån förändring genom att jämföra en population som är påverkad av förändringen med en snarlik population som inte är påverkad av förändringen och båda populationerna skall jämföras

[1] Denna rollen kan kanske fyllas av the Swedish Network for Innovation and and Technology Transfer Support (http://www.snitts.se/om-snitts/), eller av Swedish Incubators and Science Parks (http://sisp.se/) eller Vetenskap och Allmänhet (http://v-a.se/) vilka alla erbjuder olika former av tjänster till tekniköverförings- och innovations-kontor, men vilka inte verkar systematiskt insamla jämförbar data på kostnader, kostnads-struktur, inputs och outputs som patent, licenser, och start-ups, som tex AUTM gör.

före och efter förändringen med avseende på relevanta utkomster såsom antal patent, antal företag och licensinkomster.

Rekommendation 6. Det skall finnas möjlighet för forskare och myndigheter att utvärdera effektiveten på olika tekniköverförings- och innovations-kontor. Möjligheten att genomföra sådan utvärdering är för närvarande begränsad. Detta behov skall vägas mot behovet av tekniköverförings- och innovations-kontor att arbeta effektiv utan stora rapporteringskrav till myndigheter. I avvägningen däremellan skall därför varje kontor åtminstone på årsbasis rapportera till SCB de exakta patentnummer som handläggs vid respektive kontor, och dessa skall registreras av SCB tillsammans med eventuella person- och företags-nummer för at kunna användas av forskare och myndigheter. Detta bör minimera eller helt utesluta behovet av universitet att kräva dess fakultet på att meddela uppfinningar till universiteten.

Data på fondering, licensinkomster, antal licenser, kostnader, etc. skulle kunna delas frivilligt mellan olika kontor genom en nationell organization med en gemensam databas, som beskrivet i rekommendation 2.

Rekommendation 7. Det är viktigt att det existerar en pluralitet av moderna och konkurrensutsatta service alternativ för fakultet interesserade av att kommercialisera sina ideer ideas för att stimulera den övergripande systemeffektiviteten i Sverige.

Forskning har visat att lokal tillgång till företagsänglar och skickliga företagare som samarbetspartners till uppfinnare har ur ett historiskt perspektiv varit mycket viktigt för kommersialisering av teknik från universitet. Det är särdeles intressant för Sverige att utveckligen av moderna innovative versioner av sådana resurser går framåt. Till exempel så erbjuder Chalmers uppfinnare i Västra Götalands Regionen at arbeta tillsammans med ”surrogat” entreprenörer från dess entreprenörskapsskola så att uppfinningaran kan kommersialiseras snabbt och effektivt. För vissa industrier, speciellt appar och internet-mjukvara så håller behovet av sådanan lokala resurser på att minska. Crowdfunding håller på att revolutionera finansiering av nya företag och ideer, och acceleratorer erjbuder extremt snabb kompetensutveckling.

Resten av rapporten är skriven på engelska för att underlätta kunskapsöverföring.

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Introduction

Scientific research at universities have an outstanding impact on industry. For example, a survey of 77 major firms from 7 industries conducted in the 1990s found that over 30% of the new drugs and medical products commercialized between 1986 and 1994 could not have been developed (without substantial delay) in the absence of recent academic research (Mansfield, 1998). The last thirty years has seen an increasing rate of commercialization of university research. For example, the Association of University Technology Managers (AUTM) which collects quantitative data on commercialization activities at U.S. universities and research institutions reports 3,376 spin-offs between 1980 and 2000, another 2,885 between 2001 and 2007, and 4,539 more between 2008 and 2014. This acceleration is not confined to the U.S. There is a concomitant increase in other countries across the world. An increasing fraction of academics are engaging in entrepreneurial activities (Thursby and Thursby, 2007) and more companies are started based on research at universities than these numbers reveal since not all spin-offs are disclosed to universities and faculty may also start up businesses that are not based on university intellectual property rights (IP). [2] While university spin-offs have been increasing in absolute terms, licenses of university patents to *established firms* still strongly dominates over spin-offs as a form of technology commercialization in the U.S. In 2014 there were 7.3 times as many executed licenses to each university spin-off in the U.S. This ratio has been stable since 2007. However, spin-offs are becoming relatively more important as the relationship was even larger 2 decades ago; 12 licenses per spin-off in 1996 (AUTM data).

This literature review spans several areas of research with a focus on the effect of the allocation of Intellectual Property (IP) Rights between universities and their employees on university technology commercialization. There is also some original research; several secondary datasets are re-analyzed and we add some primary interview and case data from a few universities.[3]

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[2] AUTM counts firms based on university IP disclosed to universities' technology licensing office (TLO.) Subscribing members of AUTM reports these data to the AUTM. Thursby et al., (2009) report that only 62.4% of patents by university faculty were assigned solely to universities. Similarly, Markman et al. (2008) estimate that only 58 percent of faculty reports their patent to their TLO. In addition, TLO personnel interviewed indicated that they believe fewer than half of the faculty inventions with commercial potential are disclosed to their office (Thursby et al., 2001). In additon, Allen and Norling (1991) found that 16.2 percent of faculty in science, engineering, business and medicine were involved in starting companies but only 4.4 percent, or roughly one fourth, did so based on their academic research. Furthermore, Fini et al. (2010) show that about two thirds of businesses started by academics are not based on patented inventions. That is, the use of AUTM data to identify university spin-offs does not count a dominant fraction of faculty spin-offs, and only half of all patent. The number of faculty spin-offs may be four times as high as reported by AUTM. Our analysis of data from MIT show that it may even be up to 10 times higher, although that is probably the upper bound since MIT is such a unique institutions.

[3] Detailed case studies have been assembled on Chalmers Tekniska Högskola and Högskolan I Halmstad (both in Sweden), Ludwig-Maximilian University (Germany), Penn State, Massachusetts Institute of Technology, University of Waterloo (Canada), and Université de Nice Cote d'Azur (France). For some of these cases not highlighted in here, see Åstebro (2011). For further European case studies, see Wright et al. (2007).

This is a critical literature review which will question some current dogma. It will not cite or review all previous articles in the field. Instead, for recent comprehensive reviews, please see Rothaermel et al. (2007), Djokovic and Souitaris (2008) and Perkmann et al. (2013). We start with an expose of the history of university commercialization, contrasting the U.S against Europe and Canada, and we provide two case study sections comparing the systems for university commercialization in place in Sweden and Germany. We then continue to review specific research on the various forms of technology commercialization, and finally we focus on the allocation of IP rights between academics and their employers. There is then a concluding policy section, a summary of findings and set of policy recommendations.

This review will start out by analyzing whether social welfare is maximized through private ownership of university research and the impact of the increased private protection of these rights on social welfare. We will ask whether it makes sense for society to have universities increase their direct involvement in commercialization of their research. One such involvement is the creation of Technology Licensing Offices (TLOs). There exist a fair number of studies showing that TLO size, age and expenditures are positively correlated with university licensing revenues and spin-off rates possibly suggesting that such activities should be expanded to promote commercialization (Siegel et al., 2007). But the causation is unclear and we will examine the role of TLOs critically. We will also discuss the matter of unintended consequences of recent regulatory and normative changes with respect to commercialization of university research.

Further, we will discuss which specific goal it would be socially optimal for universities to pursue with respect to commercialization of research, conditionally on engaging in such activities. For example, maximizing licensing revenues may produce greater social welfare than maximizing spin-off rates, or vice versa. Universities can differ regarding these goals (Belenzon and Schankerman, 2009; 2013). It may be difficult for one university to generate spin-offs, for example due to adverse local economic conditions such as lack of local complementary resources (e.g. local industry, venture capital and relevant labour force) or due to strong public-service norms among its scientists. However, licensing of research, theoretically, is not constrained by the availability of local resources, and so may be preferred in such instances. Several additional goal conflicts appear to exist. For example, the royalty share allocated to the researchers has been shown to raise university licensing income (Lach and Schankerman, 2008,) but reduce spin-off rates (Di Gregorio and Shane, 2003). Further, consulting and university-industry collaborative research may not be maximized if a university focuses on maximizing spin-off rates. Finally, the university conditions that maximize the commercialization of research may not maximize research quality or scientific output.

It is important, therefore, to compare the various outcomes from university research on social welfare: free knowledge dissemination, licensing, spin-offs, and consulting. No article has attempted such comparative analysis of opportunity costs, which currently hamper policy conclusions. We will discuss, in particular, the role of university and TLO policies, as well as government policies, focusing on the allocation of IP ownership rights. Starting with the U.S. and the Bayh-Dole act there has been wide-ranging recent changes in such policies across Europe. Some early evidence has been appearing and it is time to take stock whether these policy changes are likely to be effective.

The history of university technology commercialization in the U.S.

Universities have not traditionally been concerned with commercialization of research.[4] Their two long-established goals have been to provide education and to conduct research. In the late 19th century teaching and research at European universities, in particular the British and French systems, was primarily theoretical in nature. In contrast, the key motive for the creation of the natural science- and engineering-based universities in Germany, and later the creation of the Land-Grant universities in the U.S., was to produce students for agriculture and industry (Noble, 1977). These schools catered to local demands for skilled employees and their structure and goals thus varied widely. For example, the University of Akron supplied skilled personnel for the local rubber industry, and became well-known for rubber and later polymer chemistry research (Mowery et al., 2004, p. 12). Contrasting this local dependency of U.S. higher education institutions, federal funding of academic research was not strong and amounted only to 25 percent of total university research funding in the mid 1930s (Mowery et al., 2004, p. 23). The local focus created strong incentives for collaboration between academics and industry both in the U.S., Germany and in the European countries which copied the German system, such as Sweden and Denmark.[5] The university-industry links were, on the other hand, rather weak in countries such as Britain and France. University research rose in importance at unequal paces across Europe and the U.S. but was a well established activity at well over 100 U.S. universities by the start of the First World War (Murmann, 2003).

A third motive for universities has been to provide service to society, where the latter only quite recently has been interpreted to include the commercialization of research. In fact, universities until recently have been barred from conducting profit-making activities, have been prohibited from owning equity and have thus had little stake in the direct commercialization of research. For example, in 1934 the President and Fellows of Harvard University responded to the commercialization efforts by faculty in its medical school by decreeing that "no patents primary concerned with therapeutics or public health may be taken out by any member of the university, except with the consent of the President and Fellows; nor will such patent be taken out by the university itself except for dedication to the public." (Palmer, 1948.) The reasons for this sharp restriction on university actions are a well-known twofold; the economics of science (Nelson, 1959; Arrow, 1962) and the sociology of science (Merton, 1973).

The economic argument states that since research primarily produces information, and the cost of transmitting information is typically quite low, the optimal allocation would be for (close to) unlimited distribution of the information. In this interpretation research is deemed a public good that should be free for all and its generation paid through taxes (Samuelson, 1954). Three difficulties appear if the researcher tries to

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[4] For a fascinating analysis of the history of U.S. universities, their contribution to technical progress, and their patenting policies and activities, see Mowery et al. (2004). This section reviews their main points, adds some new data, and in particular expands on recent changes to national and university policies in countries other than the U.S. This section also offers some new interpretations of existing U.S. debates.

[5] For examples of early 20th-century university-industry collaboration and interactions see Murmann (2003), and Hounshell and Smith (1988.)

commercialize the research. First, the specific feature of research as information makes it difficult to trade: the prospective buyer upon inspection of the good has acquired it for free implying a market failure where information will be under-traded (Arrow, 1962). Second, the economic value of research is difficult to forecast leading to downward pressure on its price (Nelson, 1959). Third, information is very hard to keep private and a large fraction of the private information typically "spill over" to competitors. A large portion of the value of information may thus not be priced but appropriated by other parties for free. All three things considered, the private market for information is assumed to be very problematic, leading to the traditionally assumed underinvestment under a private ownership/market-based model. To counter this underinvestment governments assign property rights to ideas – patents. Nevertheless, patents are not a panacea to the difficulties of trading information as they may not protect the owner sufficiently (e.g. Gans and Stern, 2000). These market failures reinforce the suggestion of an optimal system where the production of information is subsidized by the government and the producer provides the information for free. This has indeed been the main argument for government funding of university-based science for the past 70 years (e.g. Dasgupta and David, 1994; Noll, 1998) and the reason that university scientists were either discouraged or outright prohibited from patenting their discoveries for much of this century, in particular in the field of medicine (Mowery et al., 2004).

In any setting it is important to create appropriate incentives for the researcher to exert maximum effort. When public research is not for sale other incentives than monetary must prevail. Merton (1973) as well as Dasgupta and David (1994) argue that the norms of science to a large extent replace the need for monetary incentives.[6] A key reinforcement of these norms for the researcher in a university is the value of priority of discovery. Being the first to discover in science carries strong positive reputational value and in addition may be directly tied to material rewards such as salary and access to research facilities. Inherent in this system is the need to disclose findings publicly as soon as possible, thus achieving the societal goal of free information dissemination.

In a historical perspective university patenting and licensing of inventions has been largely irrelevant as a vehicle for technical change. Rather, other forms of transfer of knowledge from university researchers have dominated, such as publications and reports, informal contacts, meetings and conferences, consulting, contract research, the movement of students, and cooperative research (Cohen et al., 2002). Patenting was indeed a rare activity among faculty for most of this millennium. Mowery et al. (2004, p. 47) report a total of less than 50 patents granted to Universities in the U.S. in 1925, rising slowly to approximately 100 in 1969.

Reflecting this paucity, relatively few universities were directly involved in managing patenting activities until the 1970s. Two of the earliest patent management organizations in the U.S., the Research Corporation, established 1912, and the Wisconsin Alumni Research Foundation (WARF), established in 1924, were both originated by university researchers but incorporated as independent entities. This organizational form reflected both the lack of interest by university administrators in patenting research, as well the obvious tension it created with the scientific ethos of universities. Land-grant

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[6] In Merton's words, these are: universalism, communism, disinterestedness, and organized skepticism. These are reinforced through socialization in graduate school as well as direct sanctioning as exemplified by the patent policy at Harvard University.

universities were the most active in patenting and several of those created copies of the WARF structure during the 1930s. Notably, most U.S. universities lacked patent policies before World War II. Several that had patent policies either discouraged patenting or outright prohibited it by faculty. Patent policies developed and spread in the 1950s and 1960s but most universities did little to promote patenting or still took a dim view to it. In some universities such as MIT, Columbia (except in medicine) and Stanford the inventors retained the rights to their inventions and could do with these as they pleased.[7]

University research rose to prominence only after World War II, and in the first decades after the war it was primarily in leading institutions such as MIT, where many important war efforts were converted into sustained research efforts. A driving force was the massive expansion of federal research funding. Academic research budgets rose almost six-fold in constant dollars between 1935 and 1960 and more than doubled again by 1965. During this period the federal government became the largest supplier of research funds, providing more than 60 percent by 1960 (Mowery et al., 2004, p. 23).

During the 1970s the rate of patenting at universities rose dramatically and became more dispersed. Close to 350 patents were issued to universities in 1975, compared to approximately 100 in 1969. University patents per research dollar also started to increase in the 1970s (Henderson et al., 1998), reflecting a shift in faculty behavior and incentives during that decade. Further, industry funding of R&D increased from approximately U.S. $200 million per year throughout the 1960s to approximately $500 million per year in 1980 (constant 2000 dollars: National Science Foundation, 2007). All these numbers continued to grow in the 1980s and 1990s. In parallel, and surely a function of this growth, the number of technology licensing offices (TLOs) and the number of spin-offs started to rise. Reflecting this broadening of licensing and spin-off activities Mowery and Sampat (2001) report there were only 6 TLOs in the U.S. in 1960, while rising to 25 in 1980.

A particularly important phenomenon explaining the rising rate of patenting and industry funding of university research was the germination of biomedical research in the 1970s. This was in turn driven by a large increase in federal funding of molecular biology. Thus, while biomedical patents grew in number by 295 percent from 1970 to 1980, other university patents grew "only" by 90 percent during the same period (Mowery et al., 2004, p. 56).

The change in the commercial focus of university research in biomedical research forever altered the way that industry and university researchers work together. Patent applications covering techniques for modifying living organisms had been accumulating at the U.S. Patent Office during the 1970s – U.S.P.T.O. officials refused to examine them until a decision could be reached on the patentability of such matters. Finally in the case *Diamond vs. Chakrabarty* on June 16, 1980 the U.S. Supreme Court decided in favor of patenting living organisms created by mankind.

Prior to 1980 industry and university worked closely together with different goals in mind. For example, one industry representative at *Monsanto*, a large U.S.-based biotech firm, stated "Our scientists are awarded for an economic return… Academic scientists are rewarded and promoted based on publications." (Charles, 2001, p. 22). After the Supreme Court decision universities had to change. One lucid example is the case of Mary-Dell

[7] Faculty at Columbia's medical school were prevented from patenting the results of their research.

Chilton whom arrived at Washington University in St. Louis in 1980 to lead a lab working on using a microbe, *Agrobacterium*, as a vehicle for transforming plant cells. *Monsanto* offered funds to help Chilton's transition to Washington University and continued to pay her as a consultant. There were no formal conditions placed on this funding. Monsanto's headquarter was located just eight kilometers away and their researchers had full access to her lab's work, participated in meetings, obtained lab samples, and freely discussed ideas. "We weren't even required to write a report" one university researcher stated and another said "We talked to those guys two or three times a week" (Charles, 2001, p. 17-18). Very little information about what was going on at *Monsanto* flowed back though. At *Monsanto* they were busy writing patents on experiments based on the ideas and materials obtained from Washington University. It all came to a head at the Miami Winter Symposium on Molecular Genetics of Plants and Animals 18th of January, 1983 where Chilton and a competing university lab in Ghent together announced findings on how to genetically alter plants. However, a representative of *Monsanto* who was unannounced also climbed the stage and joined in the announcement. *Monsanto* that day distributed a press release stating they had filed a patent on the process one day earlier. *Monsanto* stole the thunder, and within days the news was on *Wall Street Journal*'s front page crediting *Monsant*o as the inventor. However, Chilton had secretly heard that *Monsanto* were going to release something "big" and had sent in a patent application a few days earlier.[8] The colleague at Ghent had learned the same and while their filing reached the U.S.P.T.O on the day of the conference, one day after *Monsanto's*, their European application reached the E.P.O. before *Monsanto's* and they were subsequently awarded priority in Europe. Several other crucially important patent applications that were submitted during the 1970s, such as Cohen and Boyer's application on recombinant DNA were awarded shortly after the *Diamond vs. Chakrabarty* ruling and further cemented the new norm that patenting of university biomedical research was from now on big business.

In parallel, U.S. federal policy towards patenting of university research had become a topic of debate in the 1970s after the release of several federal reports.[9] Since there was no federal policy but university patenting were increasing, especially in the biomedical field, federal agencies started to define their own policies, which varied. By the 1970s U.S. universities were able to patent the results of federally funded research, sometimes under restrictions. The lack of uniformity (Senators Bayh and Dole testified that federal "policy" in fact consisted of more than twenty different agreements with various federal agencies) created a pressure for standardization. Attention also was rising on patenting restrictions imposed on research funded by agencies such as the Department of Health, Education and Welfare (HEW). In September 1978 Senator Dole criticized HEW for "stonewalling" university patenting. Testimony at hearings also focused on lagging U.S. productivity growth and innovativeness, suggesting that improvement could be accomplished by further regulation, a rather unusual position taken in the U.S. Other witnesses suggested that giving ownership to universities would create greater incentives for inventors and universities to commercialize their research. The result was the Bayh-Dole Act, signed into law Dec. 1980. It replaced the 22 institutional agreements with a uniform policy

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[8] Charles (2001, p. 22) describes that Chilton was not able to get Washington University's patent lawyer interested in filing her claims. On the advice of her corporate lawyer father she went to the university chancellor and with the help of her department head and a few chosen words obtained a meeting with the patent agent the next day.

[9] This paragraph borrows heavily from Mowery et al. (2004, Chapter 5.)

giving universities rights to any patent resulting from grants funded by federal agencies and expressed support for negotiation of exclusive licenses between universities and industry based on such grants. Further amendments and subsequent regulations removed some restrictions and added that universities should share licensing royalties with inventors.

After the implementation of the Bayh-Dole Act in 1980 the distribution of commercialization activities have both deepened but also widened considerably across universities. While 96 patents were granted to 28 US universities in 1965, U.S. university patenting grew to 386 patents granted to 79 US universities in 1980, continuing to grow to 3,258 patents granted to 155 universities in 2007, to reach 5,833 patents granted to 155 universities in 2014. Patenting intensity changed from about 3.5 patents per patenting university in 1965, to 4.9 per patenting university in 1980, to about 21 per patenting university in 2007 and to about 38 per patenting university in 2014. Following this growth, twenty-one universities established TLOs before 1980, with the majority being added in the next two decades; 55 TLOs were added in the 1980s, 66 were added in the 1990s and only 12 new between 2000-2007, to a total of 154 in 2007. The growth of TLOs obviously has abated and we will see only a smattering of universities add TLOs in the next decade.

The number of university spin-offs has risen concomitantly. The yearly number of recorded spin-offs has risen from approximately 59 spin-offs in 1991 reported by 98 universities, to 366 spin-offs from 141 universities in 2000, to 502 spin-offs from 155 universities by 2007, and to 840 spin-offs from 155 universities in 2014. These numbers reflects an increase both in the number of institutions reporting data and increases for each reporting entity.

Little systematic data about spin-offs exists before the Association of University Technology Managers (AUTM) started collecting such in 1991. For example, MIT faculty reported two spin-offs to their TLO in 1980. Of course, reporting to the TLO was voluntary at this time and there could be unreported entities. Indeed, using an alternative data source we find vastly larger spinoff counts. A survey by Roberts and Eesley (2009) of MIT alumni indicate that 42 responding faculty at MIT who prior to that were MIT students self-reported starting 3 firms that year. Using this base and correcting for survey non-response rates the total number of faculty spin-offs by MIT alumni in 1980 was 28.[10] Adding an equivalent spin-off rate by non-MIT alumni among the MIT faculty results in a count of 54 spin-offs by all MIT faculty in 1980.[11] This exercise tells us two things: a) the AUTM/TLO reported data may only cover a tenth of the actual spin-offs by faculty at spin-off active institutions, and b) already by 1980 there was substantial spin-off activity by faculty at leading research institutions.

A number of studies claim that the Bayh-Dole Act promoted a surge in innovation in the U.S. (e.g., OECD, 2003; Stevens, 2004; Merrill and Mazza, 2011).[12] For example, the

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[10] According to special data extract from the survey by Charles Eesley. We used a scale-up factor of 2,425*3,906=9.47. Many thanks to Dr. Eesley for his help.

[11] Forty-seven percent of Mechanical and Electrical Engineering faculty in 2000, respectively, were non-MIT alumni. We took this fraction as a rough indicator of non-MIT alumni among the MIT faculty for all years and across all departments and also assumed that non-MIT alumni were equivalent to MIT alumni in their spin-off propensity.

[12] See also Mowery and Sampat (2005) and So et al. (2008).

report from the National Academy of Sciences commissioned by the National Research Council (NRC) and titled *Managing University Intellectual Property in the Public Interest* concluded that "…the system put in place by the Bayh-Dole Act, that is, university ownership of inventions from publicly funded research… is unquestionably more effective than its predecessor system... in making research advances available to the public." (Merrill and Mazza, 2011, p. 61).

Others have been more skeptical, arguing that the Bayh-Dole act coincided with a number of other major policy changes, e.g. with regard to the tax regime, increased federal resources to university research and a more flexible investment policies for pension funds, all being instrumental in improving commercialization of university based research (David, 2007; Kenney and Patton, 2009; Lissoni et al., 2009; Litan et al., 2007). Rather, the Bayh-Dole system has been argued to foster a monopoly like system deterring the dissemination of knowledge and having marginal or insignificant effects on patenting (Crespi et al., 2006; Geuna and Nesta, 2006; Verspagen, 2006; Lissoni et al., 2009).

To examine the alleged negative consequences of the effectiveness of the Bayh-Dole system, the National Research Council commissioned the previously mentioned review to examine how the new U.S. system impacted *technology licensing* from the universities (Merrill and Mazza, 2011). The conclusion was to continue with the existing system. Based on observations over a 30 year period, the NRC study claimed that no empirical evidence could be provided that motivated a return to the old system. That did not imply that the present Bayh-Dole regulation was considered optimally designed, as the investigation resulted in six findings and 15 recommendations to improve the current system.

Unintended consequences of increased commercialization of university research

The increased focus, efforts, and money spent on the commercialization of university research certainly have had direct positive effects on university commercialization activities, it would be foolhardy to conclude anything else. However, in this section we would like to bring up potential negative unintended consequences. This is not to say that it might not be warranted to further stimulate commercialization efforts. But one should always be cognizant of unintended consequences and design regulation having carefully considered such potential effects.

To form a starting point, from a positive perspective increased private protection of research results increases the incentives to commercialize the research by the owner of the property right. It may also increase the efficiency of the market for ideas, encourage further investment in the idea by the owner, and mitigate disincentives to disclose and exchange knowledge (Merges and Nelson, 1990; Gans and Stern, 2000).

However, Merges and Nelson (1990) and Scotchmer (1991) highlight the possibility that the assertion of property rights on key upstream, foundational discoveries may significantly restrict follow-on research. In a general model of comparative statics, it is possible to show that under plausible parameter values society will lose out while the owner benefits when obtaining private rights to upstream research that will be utilized in follow-on research (Mukherjee and Stern, 2009). Further, Heller and Eisenberg (1998) and Shapiro (2000) suggest that in the specific case of patents granted on research tools which are needed to conduct research (such as the "OncoMouse"),[13] barriers have been created to the acquisition of licenses and other rights that may make it too burdensome to permit research that would otherwise have been scientifically and socially valuable.

In a clear example of such unintended consequences, Louis et al. (1989) examined the effect of scientific norms and commercialization incentives on secrecy. They surveyed 847 clinical and non-clinical life sciences faculty across 49 U.S. top-funded universities who had published at least one article and had received research funding from industry.[14] Forty-three percent of the basic researchers replied that they had been denied access to materials or software from other researchers in the past three years while only 27 percent of the applied researchers replied so to be the case. Basic researchers were also significantly more likely than applied researchers to deny others' requests for access of their own results or material. Evidently, and maybe unexpectedly fast,[15] the prior Mertonian ethos of free access to information had by the late 1980s largely disappeared and been replaced by a culture of secrecy even stronger among basic researchers than among those working directly with established companies testing their new drugs.

In multivariate analysis, the higher probability of *being denied* research material for basic researchers held up after controlling for research budget, tenure, gender, and entrepreneurial involvement, the latter being insignificant. However, being a basic researcher was not a significant predictor for *denying* others' request, while the coefficient for entrepreneurship was positive and significant in denying others' request, all else equal. As well, the more successful the researcher in terms of obtaining funding the more secretive they were. Our interpretation of these regressions is that those that engage in commercializing their research become more secretive about their research results, and that this effect trumps whatever culture of openness that exists in that community. That is, individual-level business incentives are far stronger than scientific norms. The more researchers become engaged in commercializing their research the less sharing of research materials and results can we expect. The net effect on social welfare is unclear; society may gain by providing increased private benefits and thus greater incentives to commercialize for the inventor, but may also lose due to increased secrecy and thus less information diffusion.

Confirming the increased secrecy observed by Louis et al. (1989), Walsh et al. (2007), survey 507 academic researchers in genomics and proteomics and find that researchers that have a history of commercial activity are likely to deny one percent more requests to their research material (cell lines, reagents, etc.) to other researchers than

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[13] The OncoMouse or Harvard mouse is a type of laboratory mouse that has been genetically modified using modifications designed by Philip Leder and Timothy A Stewart of Harvard University to carry a specific gene called an activated oncogene. The activated oncogene significantly increases the mouse's susceptibility to cancer, and thus makes the mouse suitable for cancer research. The rights to the invention are owned by DuPont. "OncoMouse" is a registered trademark. (http://en.wikipedia.org/wiki/Oncomouse).

[14] For ease of understanding the results we label the clinicians conducting "applied" research and the non-clinicians conducting "basic" research, although this can be somewhat of a misnomer. An important difference between these groups is that the potential personal monetary payoff to the individual is much higher for the basic researcher, while the applied researcher functions more as a consultant/contract researcher.

[15] Recall the case of Mary-Dell Chilton previously mentioned.

those who are not commercially active. Their research also shows that if a TLO is involved in fielding a request there is a two percent *lower* probability of receiving a requested material. While denials are still relatively infrequent they may affect research considerably when appearing if the technology is sufficiently important. Walsh et al. (2007) focus on three very important proteins and find that approximately 15 percent of projects exhibit adverse effects due to patents on the material and three percent abandoned projects due to inability to access the material. While these results may appear small to the outsider, insiders are voicing considerable concern about the delays caused on research from the added bureaucracy to scientific material transfers imposed by the Bayh-Dole act.[16]

In a more recent and broader study of academic secrecy in the U.S. and Japan, it was shown that in both countries the individuals who are commercially active are indeed less likely to share their research results through publication (Walsh and Huang, 2014). In addition, increased research funding from industry has been found to jeopardize public disclosure of academic research (Czarnitzki et al., 2014). Further, even without secrecy, the effect of granting patents to scientific projects appears to lead to between a 10 to 20 percent reduction in the amount of citations to the research publication related to the patent (Huang and Murray, 2009; Murray and Stern, 2007) illustrating broader negative effects of (potential) commercialization of research than simply denial of access to research material or secrecy. The effect measured by Murray and collaborators show a general dampening of incentives for conducting follow-on research to research that is protected by private ownership rights.

To sum up this and previous sections, there are several explanations for the increasing trend toward more technology commercialization in the U.S. These include the rising importance of the biotech sector, the passage of the Bayh-Dole Act, judicial decisions that have expanded what is patentable and provided stronger protection for patents, increased financing of research by industry, changing university guidelines and behaviour, changes in the scientific ethos of faculty and researchers, policy makers' growing pro-spin-off attitudes and the general public's increasing acceptance of a university that engages in/produces commerce. The increasing trend is not limited to the U.S. It is widespread across industrialized countries, which in several cases have implemented replica versions of the Bayh-Dole act as well as created many other programs to stimulate technology commercialization.

However, it is far from clear that this is an optimal situation for society. The well-known arguments for why the market fails to appropriately price university inventions remains. Researchers have stronger incentives to claim ownership of research and do so more often than before.[17] The increased tendency by researchers and their universities

[16] At http://sciencecommons.org/projects/licensing/empirical-data-about-materials-transfer/ we learn that the Science Commons Materials Transfer Project tries to reduce delays caused by legal transaction costs by introducing standardized agreements and procedures for transferring scientific materials. This site report several otherSome studies on the increased delays in obtaining research materials which(Campbell et al., 2000; 2002) show greater delays and rates of denials than those reported by Walsh et al. (2007).

[17] Warning bells have been rung that the increased commercialization of research may have shifted the focus of productive researchers away from research and towards business, or at least driven them to more applied research. In a world where university researchers typically have the greatest comparative

to claim private ownership rights to research appears to reduce overall rates of technological change by limiting or delaying future researchers' rights to follow-on invention or access to materials that were previously exempt from limits to use. The increased involvement by universities to control IP appears to stifle such access even further. The increased role of commerce has also changed incentives to researchers to become more secretive. The institutional scientific norms that worked in favour of free dissemination of research results have permanently changed, at least in the biotechnology field. It is probably too late to reverse most of these trends. However, it is important to at this time discuss whether this trend should be reinforced by new government regulation to further strengthen commercialization activities at universities, or whether there might be regulation or policies put in place that would slow down or even redirect the path of development towards potentially more socially efficient outcomes.

Recent developments in Europe and Canada

Changing pro-research-commercialization attitudes have meant regulatory changes also in Europe and elsewhere in the last decade. For example, university charters have changed to include a stronger role of universities to participate in societal activities both in Belgium (in 1996) and Sweden (first in 1975 in rather vague terms and then in 1996 in more explicit terms).[18] These changes directly have led to more open reporting by universities of their activities, but also indirectly changing interpretations by university administrators of the role of universities. The 1996 change in Sweden has been interpreted as mainly being about increasing the commercialization of university research (Goldfarb and Henrekson, 2003; Jacob et al., 2003).

Europe did not start from the same position as the U.S. European faculty inventors typically owned their IP through what is commonly referred to as the *Professor's Privilege*. The incentive problem referred to in the US as the major reason for the creation of the Bayh-Dole act was thus not present in Europe; inventors knew they had the right to their ideas and were free to commercialize them without fearing holdups by funding agencies. Nevertheless, a government task force appointed by the Swedish Government (SOU, 1998) still recommended a Bayh-Dole act copy in 1998.[19] In fact, the recommendations in SOU

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advantage to conduct research while commerce has the greater comparative advantage to commercialize it (David, 2007), this sounds like bad news. But a number of articles show that the most productive researchers are also those that patent the most (controlling for fixed individual effects), and that patenting appears to increase scientific productivity, although in the latter case researchers have not yet adequately removed potential common causes (Azoulay et al, 2006; 2007; Breschi et al., 2005; 2007; Buenstorf, 2009; Calderini et al, 2007; Crespi et al. (fortcoming); Goldfarb et al. 2008; Stephan et al., 2007).

[18] There was an extension in 1975 in the university charter to include "service to the society" and in 1996, two government appointed task forces stated the need for a clear mandate for universities to interact with industry and the rest of society (SOU 1996:70 and SOU 1996:89). The university charter's third task was subsequently changed from "I forskning och utvecklingsarbete ingår att sprida kännedom om verksamheten samt om hur sådana kunskaper och erfarenheter som har vunnits i verksamheten skall kunna tillämpas" to *"Högskolorna skall också samverka med det omgivande samhället och informera om sin verksamhet."* (SFS 1996:1392). [From "Research and development work includes diffusing knowledge about activities and about how such knowledge can be applied " to "Universities should cooperate with society and inform about their activities."]

[19] Such an act has already been tabled in 1992 by Högskoleutredningen (SOU 1992:7).

1998:128 were supporting even stronger university control than what the U.S. regulators found acceptable: the Swedish task force recommended that universities in their right as employer could withhold publication of research results of their employees until a patent application had been submitted.[20] Neither the suggested change of the Professor's privilege, nor the publication limitation on research stood up to critique. Indeed, the Swedish government subsequently rejected the fundamental idea that commercialization of university research should trump traditional objectives. They stated "It is important from an overall aspect of quality that universities develop good collaboration with external interests… without jeopardizing their integrity." (Regeringens proposition 1998/99:94, p. 3).

A similar discussion was simultaneously waged in Canada and also there the authorities decided that no change was motivated in the current regulation allowing universities to decide whom takes control rights of IP. However, in many other countries Bayh-Dole-type acts invoking *de jure* ownership by the employer (university) were enacted in Belgium in 1999, Denmark in 2000, in Germany and Austria in 2002, in Norway in 2003, and in Finland in 2007. (The cases of Denmark, Germany and Norway will be analyzed in a subsequent section.) Italian legislators, however, bucked the trend and *introduced* the Professor's Privilege in 2001 on the reverse intuition that individual scientists may have a greater incentive to patent than the university which employs them.[21]

Several authors have been critical of the rapid and uncritical adoption of Bayh-Dole-type legislation in parts of Europe (e.g. David, 2007; Mowery and Sampat, 2005; Kenney and Patton, 2009; Jacobsson et al., 2013). Some critics have argued that it is unrealistic to assume that burdening the university with the task of producing commercial-relevant output will have anything but marginal effects on technological change (David, 2007). Others have shown that the Bayh-Dole act was not responsible for the growth in patenting in the U.S. and is on this ground not a reason to be emulated (Mowery and Sampat, 2005; Mowery et al., 2004). Yet others have pointed to data showing that even under the Professor's Privilege, European scholars do transfer their knowledge to industry. For example, Lissoni et al. (2008) find that the presumed dearth of patents assigned to universities due to the Professor's Privilege in France, Sweden and Italy; can be explained by the high rate by which businesses are assigned patents by academics; approximately 60 percent.[22] However, that does not mean that European university researchers are lagging their U.S. counterparts. Rather, European academic

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[20] SOU (1998: 128) recommend that "Universities should make sure that intellectual property stemming from [university] research is made use of and that research results are made of practical use" (p. 142) and "The committee considers it important that the role of universities are strengthened when it comes to economic exploitation of research results…The committee recommends an agreement where universities rights to patents and other IP are transferred to universities and that rules for economic compensation to the Professor are stated. Associated with this should be an agreement regarding the possibility that publication of research results is held back until a patent application has been submitted. (p. 143)

[21] The legal situation in Italy has been rather complex and the path to promote university researchers to patent convoluted. For an historical review, see Baldini et al (*forthcoming*) and Lizzoni et al (2013).

[22] In France, and to a lesser extent in Italy, a sizeable share of academic patents is also owned by large governmental research organizations, reflecting the importance of these actors in these countries.

inventors are about as active at patenting their research as their U.S. counterparts.[23] Computing the share of Professors that patent, Lissoni et al. (2008) find approximately 4 percent in Sweden, Italy and France, while the comparable figure for the U.S. for the same period is 2.3 percent (Thursby et al, 2009).[24]

It should further be noted that in Europe, and particularly in Sweden, university researchers have typically collaborated freely and frequently with industry, and, as already stated, often assigning ownership of their IP to the industrial collaborator. For example, one study find that as much as 50 percent of Swedish university researchers report on-going research collaborations with private firms (Lööf, 2005). Another study (Klofsten and Jones-Evans, 2000) report that during the late 1990's at Linköping University, Umeå University, Luleå Technical University and Chalmers University of Technology, 61 percent had been approached by industry and 58 percent had themselves initiated contact with industry, with 45 percent conducting contract research, 51 percent doing consulting, while a more modest fraction (12%) forming a spin-off and another 12 percent patenting or licensing during the last five years (percentages not mutually exclusive).

In the biotech drug discovery sector industry-university collaborations seem particularly prevalent. Valentin and Jensen (2007) report that among biotech firms specialized in drug discovery, Swedish firms have university co-inventors on patent applications on average 43 percent of the time, while their Danish counterpart firms have university co-inventors on patent applications on average only 22 percent of the time.[25] These outcomes appear to be based on interactions where the industrial partner typically makes available access to the firm's research capabilities, may support a Ph.D. student, provides consulting income or laboratory funding, and takes ownership rights of IP but relinquishes publication rights (Goldfarb and Henrekson, 2003).

Commercialization of university research through spin-offs may be less frequent in Europe than in the U.S. but even that assumption can be questioned. For example, approximately 13 percent of Swedish university scientists have had some experience commercializing their own research, either through licensing, spin-offs or other forms. Approximately 35-40 percent of those, or 5 percent, commercialized their research through starting a new business (Lööf, 2005).[26] These data appear to be of approximate equal magnitudes to the U.S. where close to 90 percent of university ideas were commercialized by methods other than the establishment of new firms (Goldfarb and Henrekson, 2003).

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[23] Academics represent 3 percent of Italian European Patent holders (Balconi, Breschi, and Lissoni, et al., 2004), 8 percent of all Finnish patent assignees (Meyer, 2003), and almost 10 percent of all Norwegian assignees (Iversen, Gulbrandsen, and Klitkou et al., 2007).

[24] The U.S. and European data represent considerable efforts to count patents by academics *not* assigned to universities.

[25] Valentin and Jensen (2007) report that the degree of university-industry interaction is the major difference between the two countries; they are otherwise very similar with respect to their size, history, number of inventions, and in the number of inventors per invention in this industry.

[26] Data from Klofsten and Dylan-Jones-Evans (2000) are very similar. In addition, Wiberg and Wahlbin (2007) report from a survey that 2.5% of Swedish researchers had formed a business during 2006 and that 15.6% had been involved in developing a product which is sold or is targeted for sales.

As is well known, government financial and administrative support to increase university technology commercialization has been increasing in Europe in many ways. For example, France started supporting 31 incubators in 2000. As another example, the German Bundesministerium for Wirtschaft und Technologie (Federal Ministry of Economics and Technology) announced in March 2001 a broad program "AktionsProgramm Wissenschaft Märkte" with several actions (and some proposals) to improve commercialization of university IP. Most important might have been the introduction of a Bayh-Dole style IP regime in 2002. In a subsequent section we will describe how the German system of university technology commercialization was reorganized as a consequence of the new law.

As a final list of examples, there have been a broad range of initiatives in Sweden during the last fifteen years to increase commercialization of research, for example the creation of seven regional Teknikbrostiftelser in 1999 receiving approximately 110 million euros, changes in University charters to allow Swedish Universities to incorporate and invest in spin-offs, the creation of Innovation Offices, and the creation of Innovation and Entrepreneurship educational programs. These and other various efforts have together certainly increased the commercialization orientation of Swedish Universities and its researchers. This report will not be able to review or evaluate all these different initiatives. However, we will spend a short section on the development of one TLO in Sweden, using this case study as an illustrations.

University technology commercialization productivity

We now continue by examining the "invention productivity" of universities assuming that patent disclosures acts as inputs and that patent licensing revenues, number of spin-offs, and earnings from spin-offs in the form of retained equity and dividends are outputs. We do this to convincingly show that it is not important from a simple private benefits perspective for the University to promote the direct commercialization of its scientists' research.

Using AUTM data for the 12 year period from 1996 to 2007 for which 20 engineering schools consistently report data, the number of invention disclosures increased by approximately 6.1 percent per year, the number of patent applications increased by 13.7 percent per year, while executed licenses and the number of start-ups increased by 7.1 percent and 8.2 percent per year, respectively.[27] These schools spun off an average 3.6 firms per year.

Looking at the same institutions from 2007 to 2014, the number of invention disclosures increased by approximately 1.8 percent per year, the number of patent applications increased by 2.8 percent per year, while executed licenses and the number of start-ups increased by approximately 2.9 and 2.1 percent per year, respectively. These schools now spin off an average 4.6 firms per year. Data from U.S. medical schools which

[27] We chose not to use the AUTM data from 1991-1995 since these were described by AUTM as lacking somewhat in quality and having variable definitions different than the subsequent period.

continuously report data show similar trends.[28] These schools spun off an average 3.5 firms per year from 1996 to 2007 and now spin off an average 7.2 firms per year.

These data show some consistent patterns across the engineering and medical schools.

- The percentage of patents issued per disclosure has been going up, from approximately 33.5 percent to 61.5 percent (73.5 percent for engineering) over 19 years from 1996 to 2014, indicating increased TLO efficiency, or increased disclosure quality, or both.
- The number of licenses executed per patent has been going down from 76.5 percent in 1996 (83.5 percent for engineering) to 47.9 percent in 2014 for both types of schools indicating a decrease in TLO efficiency, market saturation, or a decrease in commercialization quality of patents, or all three.
- The number of licenses executed per disclosure has been relatively flat over the years at approximately 30 percent because the above two trends cancel each other out.
- The number of spin-offs per patent has been going down from 6.9 percent (8.1 percent for engineering) to 4.8 percent in 2007 for both types of schools indicating a decrease in TLO efficiency, market saturation, or a decrease in patent quality, or all three. This ratio has, however, increased during the last years reaching 6.5 percent (7.8 percent for medical schools and 4.4 percent for engineering schools) in 2014.

A more rigorous analysis on the sources of growth in university licensing was performed by Thursby and Thursby (2002). (They exclude however an analysis of spin-off rates). They formally model technology commercialization as a three-stage production process; 1. disclosure, 2. patenting, 3. licensing, involving multiple inputs in each stage. Using AUTM data for the period 1994-1998 they find that much of the growth in university commercial activity stems from input growth. A negative growth rate in licensing is interpreted as that as the number of disclosures and patents goes up per university the marginal commercial quality of inventions goes down, rather than a change in research focus by faculty. Much of the average growth in disclosures and patenting over the period is due to marginal and average performing universities catching up in activity to the most prolific universities by increasing their inputs.[29] In a related paper Ejermo and Källström (*forthcoming*) analyze the R&D-to-patent productivity of Swedish academics. They find that the responsiveness to R&D inputs is higher in Sweden than corresponding estimates found in US studies.

[28] The number of invention disclosures increased by approximately 6 percent per year, patent applications increased by 11.7 percent per year, while executed licenses increased by 5.4 percent per year, and the number of start-ups increased by 9.1 percent per year for 1996-2007. For the period 2007-2014, the number of invention disclosures increased by approximately 3 percent per year, the number of patent applications increased by 1.6 percent per year, while the number of executed licenses and the number of start-ups increased by 5.7 and 8.4 percent per year.

[29] Differences in commercial quality and novelty of disclosures and patent applications across universities may also explain the catching up. Thursby and Thursby (2002) include faculty quality in the input function for licensing agreements in an attempt to adjust for such possible differences.

While university spin-offs have been increasing in absolute terms it should be noted that licenses of university patents to established firms strongly dominates over spin-offs as a form of research commercialization in the U.S. In 2014 there were 7.3 times as many executed licenses to each university spin-off at the above fixed set of universities, a level which has been stable for the past 7 years. However, spin-offs are slowly becoming relatively more important as the relationship was even larger two decades ago; 11 licenses per start-up in 1996 (AUTM data). Today, the average number of spin-offs from the top U.S. universities is about 4, as reported above. But the mode, the most likely outcomes is still zero spin-offs in any given year.

Thursby and Thursby (2007) use data from the 2004 AUTM and report annual median licensing income including cash–in of spin-off equity stakes per university to be less than $360,000.[30] This return is hardly worth the effort if one considers the median legal fees ($462,000) and salary costs ($638,000) for operating a TLO. The same poor returns hold true in Germany and Canada from which some numbers have been obtained. For example, in 2003, Canadian universities spent CAD 36.4 million on IP management, with an average distribution of institutional base funding (29 percent), institutional one-time allocations (10 percent), IP commercialization revenues (licensing and cashed-in equity) (36 percent), and external sources (25 percent) (Read, 2005). That is, although there exists a rather large state involvement to promote commercialization of research, the licensing revenues and cashed-in equity from spin-offs covered only up to 1/3 of university IP management costs in the early millenium.

However, in 2014, the median licensing net income at the top-150 U.S. universities had risen to $2.4 million, a substantial increase from ten years earlier. At the same time, the median legal fees were $882,000 and the median annual salary were approximately $1,168,500.[31] Therefore, the annual median licensing net income had risen from negative in 2004 to a small positive amount of about $190,000. That is, after over 30 years of experience with technology licensing, the top-150 U.S. universities still only make marginal income on their TLO activities. Of course, some do make a lot. While 25% of the institutions had an annual licensing income lower than $480,000, the top 25% gained more than $8.8 million and the 95% percentile licensing income was $75 million, reflecting the skew distribution of returns to invention.

Reflecting the recent change in the IP regime in Germany from the Professor's Privilege to a Bayh-Dole type regulation in 2002, there is now about ten years of data to evaluate the impact of this change on university technology commercialization productivity. I report on the evaluation studies of this reform in the section "Effects of technology commercialization of introducing Bayh-Dole type regulation in Europe". In this section it is, however, pertinent to mention the economic productivity of this new German regime in terms of licensing income and cost-effectiveness. In fact, The German Expert Commission for Research and Innovation states (2012, p. 55): "Germany's patent exploitation agencies [PVAs] do by no means operate on a cost-covering basis; and it is

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[30] Calculated as total licensing income – licensing income paid to other institutions + reimbursed legal fees. This number *includes* income later disbursed to the inventor, typically representing 30% of total net licensing income.

[31] The median annual salary for an office is calculated on the basis of one director, one associate director, one licensing associate, 2.6 licensing staff and 6.6 other FTE, where we have added in a 24 percent fringe benefit rate.

highly likely that also in the future they will still be dependent on public basic funding. When looking at comparable models in other countries, it appears that even long-established exploitation systems such as those that can be found in Great Britain or the United States are still making a loss after 15 or even 30 years." To exemplify this imbalance the report further notes: "In the 2011-2013 funding period, the Federal Government and the *Länder* governments are supporting higher education networks which finance patent exploitation agencies' [PVA] services with EUR 9.1 million and EUR 16.4 million respectively, excluding higher education institutions' own contributions... Thus the annual funding volume amounts to EUR 8.5 million. In 2010, commercial exploitation returns amounted to EUR 4.9 million." The Universities typically fund 50% of the operations of the PVAs and the PVAs typically take a 40% ownership stake in all patents, indicating that 10 years into the new regulation, the licensing income to the universities amount to less than half of their costs for managing the IP, and less than ¼ of all system-wide costs for managing the IP. There is similar corroborating evidence from a German Parliamentary debate (Deutscher Bundestag, 2011). According to the parliamentary records, the estimated cost of a patent application were 23,200 euros, a fairly large amount. The results are 898 issued patents and 870 licensing agreements over the period 2002 to 2011, with a median total income of 15,000 euros per license.

The evidence consistently shows that universities are confronted with a "jackpot" economy. They may earn spectacular return as that demonstrated by Stanford University and University of California combined licensing revenues from the Cohen-Boyer patent on recombinant DNA of U.S. $255 million up until 2001 (Bera, 2009) or in the case of Google, in which Stanford's 2% ownership share returned $33.4 million on the day of Google's Initial Public Offering in 2004.[32] But the likelihood that this happens is extremely low. For example, Thursby and Thursby (2007) report that only 0.48 percent of all active licenses generated licensing income of $1 million or more. In fact, universities need to produce a *very large* number of patentable inventions every year in order to break even on their TLO activities (Scherer and Harhoff, 2000). The data from the Research Corporation in the U.S. (Mowery et al., 2004) suggests that a steady flow of over 300 disclosures a year, many in the most commercially interesting biomedical technology field, does not guarantee financial break-even. Note that only MIT, recently with 702 disclosures per year and Stanford with 496 disclosures per year (last three year averages) clearly surpass this flow.[33]

Swedish universities therefore cannot expect to break even on their technology commercialization operations. For all but the very largest U.S. universities with large

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[32] The all-time top earning inventions for Stanford (between 1975 and 2001) appear to be recombinant DNA, chimeric receptors ($124.7 million), fluorescent conjugates for analysis of molecules ($46.4 million), functional antigen-binding proteins ($30.2 million), fiber optic amplifier ($32.6 million) and FM sound synthesis (22.9 milion). See Page (2007). Created in 1970, Stanford's TLO is considered the "gold standard" for TLO effectiveness (Bera, 2009; Page, 2007). Nevertheless, from 441 disclosures and 458 patent applications in 2008, the TLO "generated" only 87 licenses and only three licenses with income more than $1 million a piece. For a short popular description of Stanford's approach to licensing research see Bera (2009). For detailed econometric research on research project-level commercialization data at Stanford, please see Goldfarb and Colyvas (2005); (2006); Goldfarb, Marschke and Smith, (2008).

[33] Both Stanford and MIT practice extremely 'soft' versions of the Bayh-Dole act, not asking any questions if their employee decide to bypass the formal process and the TLO. (Stanford and MIT both expressly used the Professor's Privilege before the Bayh-Dole act.) On the other hand, both TLOs are extremely active in marketing technology, should the inventor disclose (Nelson, 1999; 2007; Page 2007).

research funds it is both risky and privately wasteful to spend money on promoting licensing and spin-off creation. This conclusion then begs the question what other form of administrative support a university might provide to stimulate, or at least assist, their researchers who would like to commercialize their inventions.

Some suggest that letting the market rule will produce more appropriate mechanisms (Kenney and Patton, 2009; Litan, Mitchell, and Reedy, 2007). An alternative currently practiced in Germany is to enlist the PVAs which pool invention commercialization services across a number of universities. Their raison d'etre and introduction will be described. There are other alternative ways to organize commercialization activities, such as that offered by Chalmers which supplies the whole of Västra Götaland with an Innovation Office with a non-mandated menu of services. This is a mixed private-public offer, where base funding comes from a mix of public sources, and where customers are charged fees, often in terms of equity sharing.

Despite the gloomy direct income data there seems to be a qualitative difference between university-based spin-offs and start-ups in general. The propensity of university-based spin-offs to become listed as a public company is estimated by Goldfarb and Henrekson (2003) to at least eight percent, 114 times the rate for all U.S. start-ups during the same period. This propensity is much higher for MIT; 257 times (Shane, 2004, p. 30). In Canada, approximately 10 percent of all university spin-offs have gone public which is a larger fraction than among university spin-offs in the U.S.

University spin-offs also seem to create more jobs than the typical start-up. For example, AUTM data show 83 employees per spin-off during the period 1980 to 1999 while the number of employees for the typical start-up with employees is 3.8 (Shane, 2008, p. 65). However, these very high numbers have not held up. AUTM reports for FY 2103 and FY 2012 instead report average number of employees per spin-off of 10.9 and 11.4 employees, respectively. Other countries also show high rates of employment from spin-offs. One study found an average of 44 jobs in the U.K. (Charles and Conway, 2001), spin-offs from University of Linkoping in Sweden appears to have generated on average 12.3 employees, University of Twente in the Netherlands 4.8, University of Liege in Belgium 10, and Queens University in Northern Ireland 10.6 (Blair and Hitchens, 1998). Moreover, Blair and Hitchens estimated that the spin-offs in Northern Ireland and the U.K. employed three times the fraction of university graduates than regular firms.

But comparing apples and oranges is not the right way to make a case for supporting university spin-offs. University spin-offs are usually high-tech firms with considerable upside opportunities and should not be compared against the typical start-up, but to a comparable group of firms.

In fact, Ensley and Hmieleski (2005) showed that university spin-offs were significantly *lower* in performance than a comparison sample of new technology-based firms in terms of cash-flow and revenue growth and that their top-management teams were less dynamic and more homogenous. Unfortunately the tests were simple t-tests and not in a multivariate setting. However, in multivariate regression of venture-backed firms Zhang (2009) finds that university spin-offs that were venture-backed (8.6 percent of all venture-backed start-ups, the vast majority in biomedical and software) have a higher survival rate but are not significantly different from other venture-backed start-ups in terms of the amount of venture capital raised, the probability of completing an initial public offering (IPO), the probability of taking a profit, or the size of employment. Similarly, examining data on licensing from the University of California system Lowe and

Ziedonis (2006), found that spin-offs took longer to terminate a failed technology (not a good thing), and that economic returns from licenses to spin-offs were similar to those to more established firms. They also find that the majority of returns associated with the technologies licensed to spin-offs are realized subsequent to the acquisition of the spin-off by an established firm, leading them to conclude that many academic spin-offs serve as a "transitional" organizational form in the market for university technology commercialization.

Comparative data between the U.S. and Sweden are provided by Åstebro et al. (2015). They compare academic entrepreneurship in the U.S. post Bayh-Dole using a nationally representative sample of U.S. university-employed scientists with a Ph.D. from the Natural Sciences, Medicine and the Engineering (STEM) disciplines during the period 1993–2006, to similar data from a comprehensive national register of all Swedish university-employed scientists in the same disciplines. More precisely, they compare a) the fraction of academics who quit their employment to become full-time entrepreneurs, b) earnings from academic entrepreneurship relative to prior university wages, and finally, c) the business survival rate of academic entrepreneurs.

They found that the biannual rate of academics turning entrepreneurs is low in both countries: 0.88% in the U.S. and 1.09% in Sweden, with the U.S. entry rate lagging behind Sweden by approximately 24%. However, a direct comparison between the entry rates of American and Swedish academics is not altogether appropriate since there are other obvious significant differences outside the IP right regimes that may also explain differences across the two countries. They therefore compute the *relative* entry rate in each country, defined as the entry rate by academics into entrepreneurship as a fraction of the entry rate by non-academics into entrepreneurship. They compare academics with individuals having a Ph.D. in the same disciplines but not employed by universities. The comparison group functions like a "control" group in that the non-university employed in both countries do not own the property rights of the ideas they develop at work, those right are *de jure* allocated to their employer. This provides a within-country benchmark.

Data from a control group shows that non-academic U.S. employees on the other hand clearly outperform their Swedish counterparts in terms of the rate of entrepreneurship. The biannual entry rate into entrepreneurship by Ph.D.s not employed by universities is 4.0% in the U.S., much higher than the 2.5% in Sweden.

Therefore, the entry rate of academics *relative* to their placebo group in each country is 22% in the U.S., while it is 44% in Sweden. That is, Swedish academics are twice as likely as their fellow U.S. peers to enter entrepreneurship, after controlling for the average entry rate in their respective countries. Since the authors control for everything that differs across the two countries in the denominator, we may conclude that giving academics the privilege to outright and fully own their IP (the Professor's Privilege) apparently is associated with a much higher willingness by academics to commercialize their IP and to leave their university to start a new business.[34] The differences in entry rates, however, do not show up when the authors look at earnings. They find that mean earnings deteriorate between 10% (Sweden) and 15% (the U.S.) when academics switch from university employment to become full-time entrepreneurs. These earnings reductions are significantly different from zero, but they are not different from each other.

[34] The authors also find higher failure rates of academic entrepreneurial projects when compared to Ph.D.'s not employed at universities and entering entrepreneurship.

We summarize available data which compares the invention productivity of U.S. and Swedish universities in Table 1. Data are unfortunately from different sources and are not necessarily directly comparable. We warn especially for the comparison on spin-offs to patents and licenses to spin-offs statistics. The U.S. data are built on counts of patents, licences and spin-offs where licenses and spin-offs are self-reported from a survey. The Swedish data build on a survey asking whether the researcher had been involved in starting a business, had submitted a patent, or obtained a license in 2006, and where we divided the fractions of the percentages answering yes to various questions. Nevertheless, the differences in magnitudes are probably indicating an underlying difference between Sweden and the U.S.

Table 1. Summary of technology commercialization productivity in the U.S. and Sweden.

	U.S.	Sweden	Relative Percentage in Sweden
Percentage of EPO or USPTO patents by academics	4.5% [a]	6% [b]	+33%
Fraction of licences per patent	48% [c]	81% [d]	+72%
Fraction of spin-offs per patent	4.8% [c]	139% [f]	Comparison not made
Number of licenses to number of academic spin-offs	7.3 [c]	0.12 [f]	Comparison not made
Bi-annual entrepreneurship rate of academics in STEM	0.9% [e]	1.1% [e]	+24%
Earnings difference switching from academia to entrepreneurship	-15.1% [e]	-9.7% [e]	+36% (n.s.)
Bi-annual entrepreneurship rate for non-academics with Ph.D.s in STEM	4.0% [e]	2.5% [e]	-44%

Sources: a) Lissoni et al (2008), b) Ejermo (2012), c) AUTM various years, d) Geuna and Rossi (2001, Table 5), e) Åstebro et al (2015), f) Wiberg and Wahlbin (2007, Bilaga 7). Third column is percentage of U.S. as base. Note that in 1996 the number of licenses / patent in the U.S. was 76 percent, which is similar to the time period from which the number 81 percent was obtained for Sweden.

To conclude this section, data shows that universities are not likely to earn any money on promoting the commercialization of their research. In fact, it appears that only the top two producers of IP disclosures in the U.S.; Stanford and MIT, are likely to have large revenues from managing their IP. While a few universities sporadically have made large earnings from technology commercialization, most have not, simply because the number of valuable licenses and spin-offs are very few. From a strict revenue perspective universities should thus be advised not to pursue commercialization efforts.

While university spin-offs apparently generate more IPOs and employment to the economy than start-ups in general, they appear no different than other high-tech start-ups. A broader perspective for governments of promoting high-tech startups in general rather than focusing on university spin-offs in particular thus seems warranted.

Swedish organization of university technology commercialization

There is unfortunately no systematic evidence on the organization or operations of Swedish university technology commercialization efforts.[35] For the purposes of continued improvement of TLOs in Sweden it would be useful if there was an organization that helped to share systematic data on best practises among TLOs. Such systematic data sharing could be modelled on the data collection and sharing provided by AUTM in the U.S. (http://www.autm.net/). Maybe this role could be filled by the Swedish Network for Innovation and and Technology Transfer Support (http://www.snitts.se/om-snitts/), or by the Swedish Incubators and Science Parks (http://sisp.se/) or by Vetenskap och Allmänhet (http://v-a.se/) which all service various aspects of TLO and Innovation Center activities, but which to my knowledge do not seem to systematically collect and share comparable data on costs, cost structures, inputs and outcomes such as patents, start-ups, licenses and licensing income the way AUTM does. Lacking comprehensive Swedish data we use the case of Chalmers to illustrate best-practise, and some other more sparsely documented cases of failures.

Early history 1960-1995

The early history of spinoffs from Chalmers has been well documented by Wallmark (1997). Torkel Wallmark obtained the first Chair in Innovations in 1983, which he held until retirement in 1989. During his tenure, Chalmers never bothered to create any significant support structure for commercializing inventions. Nevertheless, Wallmark claims that the creation of the Chair "brought goodwill to the university and led to university donations well exceeding reasonable profit levels." (p. 129) Wallmark's Chair was responsible for teaching, and "also for leading university support to inventive activities in general" (1997, p. 129.) Spinoff rates grew to substantial numbers by the end of his tenure. First, however, it is important to recognize that inventive activity at Chalmers grew a rapid rate from the mid 1960s which largely explains the substantial increase in spinoffs. While the university grew by a factor of two in students and staff between 1960 and 1995, the number of patents increased by a factor of twelve during the same period, averaging about 15 per year after 1980. Wallmark attributes this increase to "…a change in the attitude to inventions and industrial interaction [at Chalmers]." (p. 131) Wallmark estimated that approximately 2/3 of all the patents were awarded to professors

[35] The closest is the survey by SCB which inquires university employees about their allocation of time. Please see a summary of findings at http://www.uka.se/arkiv/effektivitet/huranvanderlarareforskareochdoktorandersinarbetstid.5.23460b45143e7ded837b9e.html. Data from the matched employer-employee database based on official register data from various sources is available at Statistics Sweden to study the flow of university-employed to entrepreneurship, but only for those which switches employment to full-time entrepreneurship and leaves their university employer. Such analysis has been conducted by for example Åstebro et al (2013; 2015). Patent data are more complicated to systematically analyze as EPO data needs to be matched with Statistics Sweden data based on the name of the inventor.

and researchers while 1/3 to Ph.D. and undergraduate students. However, for spinoffs the opposite is the case: he estimated that 2/3 of all spinoffs were started by students and 1/3 by professors and researchers. At the end of this period Dr. Wallmark for several years had run Chalmers Innovation Centre (CIC), which had minimal office space; and Chalmers Innovation, a venture seed funding arm fully owned by Chalmers and funded from its balance sheet with approximately 4 million kronor per year (0.4 mill. US$.)

Recent history 1995-2008

Chalmers went through large changes in their innovation ecosystem during this period, precipitated by several events. First, in 1994 Chalmers became private. The newly ruling conservative party offered Chalmers a loan of approximately U.S. $166 million, to be repaid by 2009. This loan turned out to be useful for spinoff activities. The change in legal status allowed Chalmers to accumulate capital from its entrepreneurial activities, which became an important incentive (Jacob et al., 2003). Privatizing also allowed Chalmers more flexibility to locally determine educational programs (Jacobsson et al., 2001.) The loan also affected the culture of support for spinoff and commercialization activities and legitimized Chalmers' concurrent activities although other fundraising activities added new resources as well.

Chalmers appointed a new chair in Innovation in 1993; Sören Sjölander. As Dr. Wallmark he was an insider, formerly Associate Professor in Innovation at the Department of Industrial Organization. Sjölander's Professorship had as a third task to increase spinoff rates at Chalmers. Sjölander first started and capitalized "Chalmersinvest," a new seed financing fund at Chalmers, by appropriating 20 million SEK (approx. 2 mill. US $.) from the 1994 government loan, followed with an early-stage venture capital fund called "Innovationskapital" obtaining 30 million SEK from Bure, while Chalmers added 3.5 million SEK. Additional funds were subsequently obtained from for example Volvo, Ericsson and SEB. This was the first venture capital pool with university investment in Sweden. The pool eventually reached 300 million SEK before closing. Subsequent Innkap funds (II, III and IV) amounted to a total of more then 400 M€.

Offices of the incubator were too small. New offices for more significant incubation activities were sought. With the support of Chalmers President, Professor Sjölander negotiated a purchase of an old close-by hospital (Holtermanska). Its purchase was funded by a donation of 50 million SEK from the Sten A. Olsson foundation and a loan of 15 million SEK from Chalmers. It opened its door in 1999. A second incubator unit in Göteborg was established in 2000. These two locations house Chalmers Innovation, which in 2008 employed 12 people (8 business coaches) and as of March 2009 had incubated approximately 75 spin-offs since 1999. It is open to incubation for both Chalmers spin-offs (about 80 percent, of which approximately half arrive from the Entrepreneurship School; see below) and non-Chalmers spin-offs. Chalmers Innovation charges each spin-off 5% of shares for their services. The spin-off generally also obtains a negotiated investment from Chalmers Innovation which typically adds another 15% of ownership to Chalmers Innovation. Chalmers Innovation's operating expenses are financed by rental payments from the incubated, the Municipality of Göteborg, Vinnova and the Technology Bridge Foundation, Västra Götalands Regionen - Western Region.

Funding of spin-offs in Västra Götalands Regionen has increased drastically. Chalmers Innovation started a pre-seed and seed fund in 2008, primarily with 50 million SEK from Europe 1B and the Swedish state pension fund “7-e AP-fonden,” and had a pool of approximately 115 million SEK to invest. In 2008 it offers “pre-incubation,” administers soft loans from Vinnova, and provides some seed funding. Another partly owned VC fund was started in 2007 in partnership with the Royal School of Engineering in Stockholm; KTH-Chalmers Capital, which made its first investment in a Chalmers spinoff during that year. Maybe the plethora of funds is somewhat confusing, but with many alternative sources of risk capital, spinoffs from Chalmers are in a good position to obtain early stage financing.

However, the most radical impact on spinoffs from Chalmers was the foundation of the Entrepreneurship School in 1997, the first of its kind in Sweden. Started by professors Sjölander and Mats Lundqvist, the idea came out of the observation that Chalmers students could be paired with inventions from Chalmers laboratories to form spinoffs. Another pillar was the belief that entrepreneurship is best taught with a combination of formal theory and practise: action-based learning. In the two-year International Master Program students develop a business from an invention. The first intake comprised 12 students and in steady state the program admits 20 students each year from approximately 100 applicants. A dominating fraction of students have an undergraduate degree (Civilingenjör) from Chalmers. A contract is signed where the inventor is left with a third ownership rights, the students in the project obtains a third conditional on continuing on the project after graduation, and Chalmers obtains the remaining third. Each project’s expenses (approximately 200,000-300,000 SEK) for incorporation, patenting, legal and other expenses are paid by Chalmers. The inventor agrees in writing to provide reasonable efforts (typically two days a month.) After finishing E-School approximately half the students continue in the newly incorporated businesses in a leading position, and many projects take the next step to the incubator, Chalmers Innovation. Approximately 80 percent of the businesses remain in the region. The students often return to Chalmers as guest speakers, providing contract research (more in absolute terms than from the region’s larger firms) and their spin-offs provide many opportunities for undergraduate theses work. The school conducted seven projects in 2007, the majority expected to become businesses in 2008. An addition to the entrepreneurship school was made with GIBBS (Gothenburg International Biosciences Business School), which in 2007 graduated its second cohort of students with four projects.

Chalmers ecosystem of entrepreneurship was in 2008 already quite complex. Vigorous efforts are being made to further increase co-operation and interplay (Chalmers Annual Report, 2007.) Chalmers participates in “The Drivhuset [Greenhouse] Foundation” which works to stimulate entrepreneurship in general, and supplies free advice. Around 3,000 students have participated in events there since 1998 and Drivhuset was involved in advising 132 spin-offs in 2007. Chalmers also are involved in organizing a business plan competition (The Venture Cup), with 400 submissions to Venture Cup West during 2007, 74 which originated from Chalmers. Further, through voluntary input from around 1,500 mentors, Connect West supplies commercial expertise and experience.

As of 2007, the university's Chancellor was convinced that a Swedish version of the Bayh-Dole act would be advantageous and lamented that "Sweden and Italy are now the only countries in the European Union [which maintain] the 'teacher's exemption'" (Chalmers Annual Report, 2007, p. 40.). Indeed, following top-down pressure, Chalmers reached an agreement to replace the Professor's Privilege in favour of 'more professional, interactive innovation management' at two newly opened competence centres; the GigaHertz and CHASE Centres (ibid, p. 40.). Leading faculty members at Chalmers and key players in its innovation system however disagree with their Chancellor. They do not see a problem with the Professor's Privilege and point to the fact that in reality ownership is efficiently allocated through contract negotiations, and do not see any need for the government to change the current system.

In comparison to Chalmers, which clearly focused on commercialization through spin-offs, some universities have had more difficult times with technology commercialization. This is especially the case for those focusing more efforts on licensing patents to established firms. In fact, most Swedish TLOs with that focus have had to close down, including Forskarpatent Syd (Sellenthin, 2004). Even the Chalmers TLO (Chalmers Technology Licensing AB) has closed (Sellenthin, 2004, p. 48). To explain this, interviewees in Sellenthin (2004) argue that Sweden has too few large firms to buy large number of patents and licenses, that VC funding is amply available for spin-offs, and that many professors are used to go directly to industry to sell or barter their IP.

This section has shown that there are cases where the innovation ecosystem functions very well in Sweden. The Professor's Privilege is one of the basic building blocks of well-functioning systems where the ultimate allocation of IP ownership is efficiently determined through case-by-case negotiations. However, some university TLOs have been suffering from lack of competencies, lack of licensing income and lack of budget support and have either had to close or realign their services (see e.g. Braunerhjelm, 2007; Sellenthin, 2004). We cannot say in this report how prevalent effective innovation ecosystems are in Sweden. We can state that frequent and *direct* interaction between researchers and industry has for a very long time been part and parcel across Swedish universities (e.g. Klofsten and Jones-Evans, 2000; Lööf, 2005; Wigren and Wahlbin, 2007) and that new regulation should not be enacted that could jeopardize these interactions.

Experimentation with innovation service offerings is a natural part of the learning process for any organization, and miracle solutions cannot be expected overnight. It would be useful if there was a Swedish clearinghouse established for sharing information about best TLO and innovation service practises. There is no data in our review of the Swedish situation which points to that revoking the Professor's Privilege would necessarily solve any of the observed inexperiences or inefficiencies in some universities or geographic locations.

German organization of university technology commercialization[36]

There is no systematic evidence on the organization or operations of German university technology commercialization efforts. What follows is a focus on one particular aspect which is particularly interesting: regional TLOs serving a larger group of universities. Such regional offices have been mentioned by several interviewees in Sellenthin (2004) as a possibility to generate a better funding structure for technology commercialization at Swedish universities.

Following the introduction of the German Bayh-Dole act, the federal government created 22 regional patent exploitation agencies (PVAs) in 2002. At that time, German universities had little experience undertaking technology transfer activities, and only a few universities maintained professionally managed TLOs. The intent of the Federal Ministry was to “patent all commercially-viable inventions and to promote their commercialization” (Deutscher Bundestag, 2011).

The PVAs were created outside of universities and ruled under private law in order to avoid the complications of the restrictive law governing universities. Universities were free to choose whether to use the PVAs’ services or not, but few universities initially opted not to use the PVAs because they had little other internal resources to manage the patenting and commercialization activities. Universities with an agreement to a PVA would report all disclosed inventions to the PVA, the PVA would screen the invention for suitability to patent, pay for patenting fees, execute the patent application, find industry partners, and determining fruitful commercialization paths. Inventions screened out by the PVA would return to the inventors with full ownership rights within 30 days of receipt.

As an example, the State of Bavaria in 2000 first settled on an arrangement with the Fraunhofer Institute’s patent department. But this arrangement was not suitable as the Fraunhofer Institute was not legally entitled to receive returns on investments. The Bayerische Patentallianz (BayPat) was therefore established in 2007. As a representative of the state, this entity takes 40% of university IP, the university takes 30% and the inventor is given 30% of equity. Under a standard contract BayPat funds the filing and marketing of patents while the universities and inventors bear no cost. University remains the owner of the rights. BayPat acts on commission basis.

These regionally operating PVAs were fully funded for a start-up period and given training and financial support. The federal government allocated a budget of 46.2 million EUR to be used between 2002 and the end of 2004. PVAs should after this transition period earn all necessary income from licensing revenues. However, because of uneven and low licensing income the PVAs have continued to receive federal and regional (Länder based) funding. In 2013 the accumulated funds provided by Federal and regional goverments were forecasted to approximately 87.4 million EUR. It is estimated that

[36] This section has been drafted from personal interviews and written correspondence with Dirk Czarnitzki, Professor at Department of Management and Innovation, KULeuven, Guido Buenstorf, Professor at University Kassel, Dr. Georg Licht, Head of the research department of Industrial Economics and International Management at the Centre for European Economic Research (ZEW), and Professor Dietmar Harhoff, Managing Director, Innovation and Entrepreneurship Research, Max Planch Institute and Honorary Professor at the University of Munich, with material from Deutscher Bundestag (2011), EFI (2012), Keck (1993), Kilger and Bartenbach (2002), Schmoch, Licht, and Reinhard (2000), and Sellenthin (2004).

universities paid approximately an equal amount to the the PVAs. An estimated cost of patent application were 23,200 euros, a fairly large amount. The results are 898 issued patents and 870 licensing agreements over the period 2002 to 2011, with a median total income of 15,000 euros per license. To date, 29 PVAs have served different regional "Länder" and some additional regional PVAs have been created.

Many PVAs, in particular those focussing only on licensing, have had large financial difficulties. The PVA of lower Saxony and of the Berlin region have been forced to close. Some PVAs have started to charge fixed fees to participating universities to balance their budgets, and this has created ire among by member universities. There are several problems with the new organization of university technology commercialization. First, the universities are reluctant to let the PVA representatives speak to their scientists. This makes it more difficult for the PVAs to accomplish good transfer of knowledge as such typically requires deep interaction between the scientist and industry. Second, the university and the PVA often starts haggling about licensing terms, sometimes leading industry to pull out. Third, universities have been shown to be inexperienced and "greedy" while at the same time poor at negotiating business deals, liable to insert clauses and conditions in contracts that are unacceptable to industry (refusing for example exclusive deals, restricting access to scientists, etc.) Fourth, the addition of the PVA in between the scientist and industry, as well as the implied lower retained share of proceeds by the scientist has reduced the willingness of the scientist to effectuate good knowledge transfer. Fifth, the presumption that the PVAs would find more deals or know better than the scientists about business deals has been put to shame. It transpires that the scientist often is acutely aware of the relevant business to transfer the technology to, and the PVA then simply causes unnecessary contracting difficulties. Sixth, there has in some cases developed an unhealthy competition between the local TLO and the regional PVA for "significant" patents, and a starving of resources to other patents. Seventh, the employees at the PVA were considerably underpaid compared to the expertise required (typically they have been paid 3,200 euros a month) and inexperienced at the task. This deficiency has taken a long time to correct.

As a consequence of all frictions and deficiencies mentioned above, several universities now do all panting and licensing work themselves and have broken agreements with their PVAs.

As a consequence of all frictions and deficiencies mentioned above, many universities now do all panting and licensing work themselves and have broken agreements with their PVAs. The best practise examples are the PVAs that offer a range of additional services to university inventors. Those who compete on a non-exclusive competitive basis for inventors offer the best services. An example mentioned is Rubitec (www.rubitec.de). This PVA started as a TLO dedicated to Bochum University, but as a separate legal entity, and it later expanded to provide additional innovation and commercialization support to Bochum University and then to neighbouring universities, always offering services under commercial criteria.

Effects on technology commercialization of introducing Bayh-Dole-type regulation in Europe

We start this most important section of this report with some data comparing the U.S. and Canada. We then move on to examine the effect on university patents, spin-offs, and university-industry collaboration of the introduction of Bayh-Dole type regulation in Germany, Denmark and Norway in the early part of the new millenium.[37]

Many Canadian universities operates in similar ways and conditions to U.S. schools. However, Canadian universities are free to choose whether the University retains control rights over inventions by their employees or whether the employees are granted these control right by default, making a comparison both within Canada and across the border with the U.S. very interesting.

In contrast to the U.S., spin-off activities are very concentrated in Canada -- four universities account for 57 of the 141 spin-off companies in a study by the National Science and Engineering Research Council (NSERC) (2005). In addition, compared to most countries, Canada has a long tradition of state involvement to promote the use of scientific research with a large number of programs at federal and provincial level.[38,39]

Similarly to several initiatives in Europe, a directed program was launched by NSERC in the 1990s to support universities' TLO activities. The rather small program (for Canadian measures) contributed to a small share of a TLO's budget, but was considered particularly important for some of the smaller TLOs. A total of CAD 19 million was awarded for the years 2005–2008. Group awards provided funding for groups of institutions to undertake cooperative activities and for broaden existing capabilities.

Almost all Canadian universities now have a TLO. According to a Statistics Canada's 2008 Survey, 88 percent were actively engaged in IP management through TLOs (Tantiyaswasdikul, 2013). The tasks, organization, and size of the TLOs differ and the number of technology transfer staff varies from one person up to 30 on some campuses; the national average was 3.8 in 2002 (AUCC, 2003).

While the Canadian universities overall underperform their U.S. counterparts in terms of technology licensing productivity, they create considerably more spin-off

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[37] Finland changed the law to an exact replica of the Bayh-Dole act in 2007. Only IP from research financed by public funds were applicable to be held *de jure* by the university. Germany, Denmark and Norway implemented much stricter versions, requiring control rights of IP from *all research*, irrespective of funding source, to be held by the employer.

[38] Federal investments in R&D were significantly reduced in the early to mid-1990s as the Government of Canada struggled with a growing deficit and public debt. The 1997-1998 fiscal year, however, marked the beginning of federal reinvestment in research and development. The federal government's role in financing R&D was clarified and given momentum in 2002 with the launch of Canada's Innovation Strategy. A part of this strategy was to double the university research funding and triple the commercialization performance by 2010. While these targets have not been achieved, this initiative has led to a significant increase in the public funding of university research and a strong commitment of funds to improve the commercialization of research.

[39] Using a very broad definition, one survey identified 178 initiatives that represented an expenditure of Canadian dollar (CAD) 3.2 billion a year (Gault and McDaniel, 2004). Among the more important for university spin-offs is the National Research Council (NRC) funded Industrial Research Assistance Program (IRAP) which has been in operation for over 60 years (Kolodny, Stymne, Shani, Figuera and Lillrank, et al., 2001). IRAP's mission is to stimulate innovation in Canadian small- and medium-sized enterprises (SMEs). In the year 2004/2005, 2615 projects were funded and the budget for 2005/2006 is CAD 167 million. Its singular most important feature is its 240 industrial technology advisors (ITAs) who are located in 100 communities across Canada. Not surprisingly then, about half the Canadian university spin-offs have received IRAP funds (Rasmussen, 2008). Full disclosure: the author of this report has been involved in one commercialization effort which obtained IRAP funding.

companies than their U.S. counterparts, when counting the number of companies created per dollar of research (Clayman, 2004). On the other hand the licensing income per dollar of research is lower in Canada than in the U.S. Clayman (2004) interprets the data as a Canadian deficiency. He states that Canada is well-known for not having enough established companies that can absorb technology from universities.

Possibly the most important point of comparison with the U.S. is that Canadian universities have a diversity of approaches to IP ownership.[40] From the Statistics Canada's 2008 Survey we learn that 22 percent of Canadian universities take control rights to IP while 42 percent grant the inventor ownership rights, 17 percent of Canadian universities have joint ownership allocation and there are 19 percent that have no policy on IPRs (Tantiyaswasdikul, 2013). A first and rather limited comparison of eight universities shows essentially no difference at all on the number of licenses, patents, license income, and spin-offs with the allocation of control rights (Clayman, 2004).[41] However, a reanalysis of the top ten most productive Canadian technology licensing universities with more recent (2004-2008) data reinforces the earlier assessment by Clayman (Tantiyaswasdikul, 2013). The author finds that Canadian universities which allocates ownership rights to the employer tend to produce greater number of new licenses and patents, while Canadian universities where the inventor is granted ownership of IP generate greater number of spin-offs.[42]

In another study Kenney and Patton (2011), conduct a comparative study of six universities whereof one operates under a Professor's Privilege regime (University of Waterloo, Canada) while the remaining five American universities are tied to the Bayh-Dole IPR system. Altogether the study comprises 515 university spin-offs between 1957 and 2009. The authors conclude that the Waterloo inventor ownership regime outperforms its U.S. counterpart in every dimension of academic entrepreneurship that is investigated (number of spin-offs, efficiency, rank, technology fields, etc.), with the possible exception of the largest U.S. university (University of Wisconsin, Madison) in one or two of these dimensions.

Moving on to Europe, three well-designed recent academic studies report a negative effect on technology commercialization through the implementation of Bayh-Dole-type acts in three European countries – Denmark, Germany and Norway. We report these results in the order by which the laws were enacted. But first, we note that Lissoni

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[40] The United Kingdom similarly allows its Universities to fully decide how to allocate ownership and control rights. Practises vary. For example, Oxford University takes control rights while Cambridge University does not.

[41] Clayman (2004) studied the following universities which take control rights; McMaster, Memorial, McGill, Université de Montréal, and the Universities of British Columbia, Guelph, Ottawa, and Saskatchewan. Universities which allocate control to the inventor were Queen's, Simon Fraser University, the Universities of Alberta, Calgary, Manitoba, Toronto, Waterloo and Western Ontario.

[42] The author, however, does not take the size of the various universities into account, and so caution is warranted in drawing conclusions from this report. The comparison is in absolute numbers between McMaster, McGill, Université de Montréal, Universities of British Columbia, and Ottawa which allocate control to the university and Queen's, Universities of Alberta, Toronto, Waterloo and Western Ontario which allocates control to the inventor. Full disclosure: the author of this report worked for University of Waterloo and University of Toronto and disclosed making an invention each at both universities.

et al. (2008), examine the share of academic patenting among domestic patenting for several European countries. Among the surveyed countries, the share of academic patenting in countries with the Professor's Privilege, when the policy is in place, appears quite high (Sweden 6%, Finland 8%, and in Norway 9%) while countries in Europe that did *not* feature the Professor's Privilege showed considerably less academic patenting over similar time periods (France 3%, Italy 4%, and in the Netherlands 4%). That is, in the Professor's Privilege countries academic patenting shares were approximately double those in the other European countries (and higher than likely estimates for the U.S.)

The Danish law providing the Professor's Privilege was erected in 1955 and it was directly influenced by the 6 year older Swedish legislation. The Danes subsequently enacted the Law on University Patenting (LUP) in January 2000, a Bayh-Dole inspired legislation. LUP transferred to universities ownership of patents on inventions made by Danish university scientists, be it as a result of individual effort or as an outcome of joint research with industry.[43] Valentin and Jensen (2007) evaluate the impact of this policy change on the contributions of university scientists to patent applications by dedicated biotech firms specialized in drug discovery comparing Denmark to Sweden where the industry shares a number of historical and structural features. That is, they evaluate the relative impact of this new law on cross-university-industry interaction and technology commercialization.

Difference-in-difference regressions show an increasing fraction of participation by university scientists in industry patenting in Denmark up to 2000, a temporary spike in the last quarter of 2000 as the law came into effect in Q1 of 2001, followed by a 13 percent reduction in the share of Danish domestic academic inventors on patent applications made by Danish biotech firms, relative to similar Swedish firms over the four years 2001-2004. The argument for this LUP-induced relative decline is that the previous bilateral agreements between university scientists and firms were made more complicated by the introduction of a third party at the table, as well the obviously reduced ownership incentive to the firms of engaging in these agreements (Valentin and Jensen, 2007).

A Bayh-Dole-type IP regime was also introduced in Germany in February 2002.[44] The German Professor's Privilege originated from Article 5 of the German constitution that protects the freedom of science and research. The new law repealed Clause 42 of the German employee invention law that had granted university employees the privilege to retain the ownership rights to their inventions. At the time of the law change, German

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[43] The act has the purpose of (§1) "...ensuring that research results produced by means of public funds shall be utilized for the Danish society through commercial exploitation." Its key instrument lies in allocating to universities ownership of an invention made as part of the work of employees (§7). That also pertains to inventions resulting from collaborative work with third parties (e.g. firms), but in these cases the university may (§9) "...upon prior agreement with the party concerned, renounce, in full or in part, the right to the inventions made by the project".

[44] In February 2002, the German Federal Government launched a comprehensive new program called "Knowledge Creates Markets" to stimulate technology transfer from universities to private industry for innovation and economic growth. At that time, policymakers believed that Germany had one of the world's leading scientific research enterprises, but was lagging the United States in terms of technology transfer and commercialization. The new program addressed a wide spectrum of science-industry interactions including processes and guidelines governing knowledge transfer, science-based spin-offs, collaboration, and the exploitation of scientific knowledge in the private sector. The abolishment of Professor's Privilege was one of the most significant changes from both a legal and cultural perspective.

universities had little experience undertaking technology transfer activities, and only a few universities maintained professionally managed TLOs (Schmoch et al., 2000). The government therefore decided to support universities' commercialization activities by establishing regional patent exploitation agencies (PVAs), as described in a previous section.

Czarnitzki et al. (2015) compare the effect on patenting before and after the introduction of this Bayh-Dole-type regime in Germany in 2002 by university researchers compared to a control group of public research organization employees not affected by the change in law (e.g. employees at the Max Planck and Fraunhofer Societies who had never had the Professor's Privilege as employees of these institiutions). They use a difference-in-difference approach and estimate an overall treatment effect from revoking the Professor's Privilege at universities reducing the overall volume of university citation-weighed patents by 27% (19% un-weighted). The difference between the weighted and unweighted patent counts indicates that patent quality declined. For professors who had existing industry connections, the policy decreased patenting, but for those relatively fewer without prior industry connections, it increased patenting, with the average effect between the two groups being sharply negative, as stated above.

In Norway, the Professor's Privilege (*laererunntaket*) was abolished by an unanimous Parliament decision in June 2002, and made effective for all public higher education institutions from January 1, 2003. The new law gave the university control rights to the commercialization of all IP, irrespective of funding source. Norwegian universities would share 1/3 of the net income with the researcher after the law change, so in effect the policy change reduced the inventor's pre-tax expected income by two thirds.[45] 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. In the case of patents, university bylaws gave the university the obligation to claim its property rights within six months after the researcher disclosed the invention. Should the university decide not to use its option, the rights were to be returned to the inventor.

There was an approximate 50% decline in the rate of new venture creation and patenting by university-based researchers after the implementation of the Bayh-Dole regime in Norway compared to the rate of venture creation by similar Ph.D.'s not employed at universities, and the quality of university spin-offs and patents also appears to have declined (Hvide and Jones, 2015). For example, the pre-reform period averaged 24.7 university spin-offs per year, while the post-reform period averaged 10.8 university spin-offs per year, for a drop of 56%. As a further data example, among university spin-offs founded prior to the reform, 12 percent were found to obtain a patent within five year of operations. Among university spin-offs founded after the reform, only 2.5 percent obtained a patent. This difference is significant at the 5% level using a simple t-test.

This section is remarkably simple to summarize. The empirical evidence consistently shows that in the European Professor's Privilege countries academic patenting shares were approximately double those in the other European countries and

[45] 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 university bylaws until later in the 2000s; it was also stated explicitly by the parliamentary committee chairman, at the time the law was passed, that a one third split with the researcher was expected.

that introducing Bayh-Dole regimes in three European countries has reduced patenting by academics, reduced research and collaborative interactions with industry, reduced the likelihood of forming spin-offs, and reduced the quality of the patents and number of spin-offs.

Theory and evidence on effective university technology commercialization

This section reviews theoretical models and empirical evidence on the role of university policies with respect to economic development objectives, the organization of technology licensing and transfer activities, and researcher incentives. The amount of research on this topic is probably the largest among all research topics reviewed in this report.[46] We focus our discussion on the possibilities for adverse unintended effects of university policies and designs, in particular as they reflect on the allocation of IP rights to their employees. Given the potential for goal conflict between maximizing total licensing revenue and local spin-off generation it is important to first understand how licensing revenues are affected by university policies and designs. When then move on to discuss the role of university policies and designs for affecting spin-off rates.

Most empirical research on the role of university policies and design for licensing and spin-offs has been focusing on the productivity of TLOs. Most research has also been based on aggregate data by each university, comparing inputs and outputs across universities in production-function models of licensing revenues. Many have used the same data, the annual survey by AUTM. A few brave have hand-collected similar data, and fewer yet have studied individual-level or project-level data (see Tables 1 and 2 in Siegel et al., 2007). Studies collecting individual-level data are the most interesting as they can investigate the role of university policies while controlling for individual and sometimes peer effects (e.g. Louis et al. 1989; Bercovitz and Feldman, 2008; Audretsch et al., 2005; Lowe and Gonzalez-Brambila, 2007; Zucker et al., 1998; 2000; Zucker and Darby, 2001). Articles focused on spin-offs will be given most space here. In reviewing the literature explaining licensing income, Siegel et al. (2007) conclude that the key impediments to effective patenting and licensing tend to be organizational in nature.

> "*These include problems with differences in organizational cultures between universities and (small) firms, incentive structures including both pecuniary and non-pecuniary rewards, such as credit towards tenure and promotion, and staffing and compensation practices of the TTO [TLO] itself.*" (Siegel, Veugelers, and Wright, 2007, p. 649).

Details on the estimated role of university policies, procedures, organization, and norms for licensing revenues are summarized in Table 2. However, simply listing associations often hides complex relationships, and ignores the potential for reverse causation. For example, Siegel et al. (2003) find that increasing TLO staff increase the number of licenses executed but has no effect on total licensing revenues. Apparently TLO staffs simply make themselves busy. Further, the same authors find that external legal

[46] Others have recently reviewed this material and so we will refer to their summaries whenever possible (Rothaermel, et al. 2007; Siegel et al. 2007; Djokovic and Soutaris, 2008).

expenditures increase total licensing revenues but decrease the number of licenses executed. In this case outside lawyers may be negotiating harder, focusing on bigger deals and getting more out of less for the university than university-employed lawyers. Other potential explanations for the latter finding are reverse causality – that universities hires outside advice on larger deals, or that it represents litigation expenses.

Table 2: Effects on university licensing revenue of various conditions.

Variable	*Positive and significant*	*Zero effect*	*Negative and significant*
INCENTIVE STRUCTURE			
Royalty shares to faculty	Link and Siegel (2005), Friedman and Silberman (2003), Lach and Schankerman (2008)		
Royalties to department	Markman, Gianiodis, and Phan (2009)		
TLO staff salary		Markman, Gianiodis, and Phan (2009)	
TLO staff bonuses	Belenzon and Schankerman (2009)		
INPUT METRICS			
Faculty quality	Rogers, Yin, and Hoffmann (2000), Foltz, Barham, Kwansoo (2000), Thursby and Kemp (2002), Markman, Gianiodis, and Phan (2009)	Lach and Schankerman (2008)	
Federal R&D spending	Foltz, Barham, Kwansoo (2000),		
Industry R&D spending		Siegel, Waldman, and Link (2003)	
Invention disclosures	Siegel, Waldman, and Link (2003), Belenzon and Schankerman (2009)		
Patents			
TLO DESIGN			
Age of TLO	Rogers, Yin, and Hoffmann (2000), Friedman and Silberman (2003), Siegel, Waldman, and Link (2003), Powers and McDougall(2005)	Chapple et al. (2005), Markman, Gianiodis, and Phan (2009)	
Number of TLO staff	Rogers, Yin, and Hoffmann (2000), Foltz, Barham, Kwansoo (2000), Thursby and Kemp (2002), Siegel, Waldman, and Link (2003), Lach and Schankerman (2008)[b], Chapple et al. (2005)	Siegel, Waldman, and Link (2003)	

	Markman, Gianiodis, and Phan (2009)		
External legal expenditures	Siegel, Waldman, and Link (2003), Chapple et al. (2005)		

Notes:

a) Federal R&D support becomes insignificant when environmental/institutional variables are excluded from the model.

b) Significant only at 10 percent.

c) Table only covers studies conducting multivariate analysis with university licensing revenues as the dependent variable.

Therefore, rather than detailing the empirical studies listed in Table 2 we move on to discuss the particular agency situation when there is a university and a researcher with a research project that potentially can be commercialized in various ways. We then introduce the TLO as an intermediary between the inventor and the market and discuss optimal organizational design. This will serve to highlight the potential agency problems and will give a useful framework to interpret the empirical literature.

We use the model developed by Lowe (2006) as a framework for analyzing the various parties' incentives. Lowe's base case is where the university-employed inventor starts out owning the invention fully.[47] The model has three stages and involves both the option that an invention is licensed to a third party[48] or is commercialized by the inventor.[49] In stage one the inventor discloses an invention[50] and offers a licensing contract to an outside firm. In the second stage, if the firm accepts the offer, the inventor chooses an effort level to transfer know-how. The effort level is not contractible. The firm chooses output and pays the inventor in the third period. If the firm rejects the offer, the inventor decides whether to do nothing, or to start a firm on his own. In the third stage the firm earns profits and pays royalties. A key feature of the model is that the inventor will improve the probability of successful development with increased effort and that the marginal value of the effort is scaled by the degree to which the effort is tacit.

There are five main findings. 1. When considerable effort is required it is always better for the inventor to found the firm himself rather than obtaining royalty from a licensee. 2. Inventions not requiring effort from the inventor for technology transfer are optimally licensed for a fixed fee. 3. There exists a separating equilibrium where some

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[47] The allocation of ownership does not matter in a world with no transaction costs (Coase, 1960) and so in this world it does not matter if the university or the inventor is initially assigned ownership of IP. But given the existence of transaction costs, the initial allocation of property rights matter. A normative conclusion drawn from the Coase theorem is that property rights should be assigned to the actors gaining the most utility from them. This is hard/impossible to distinguish *ex ante* and also means that the allocation may vary across projects. As will become clear, however, allocative efficiency is likely the highest with the inventor initially assigned control rights.

[48] Jensen and Thursby (2001) demonstrate that university licensing contracts should include a royalty or outcome-based component as a means to encourage the inventor to work with the licensee to transfer knowledge. If no further effort is required by the inventor, a fixed fee agreement is efficient.

[49] For recent contributions see Dechenaux et al., (2009; 2011), Färnstrand Darmsgaard and Thursby (2013), and Jensen and Showalter (2010).

[50] In this model disclosure to the university does not entail any change of ownership and so is costless for the inventor.

inventors with low opportunity cost of their time start firms, and others with high opportunity costs license their invention for a royalty rate. Given a distribution of inventor opportunity costs, this equilibrium is more efficient than all inventors licensing or all inventors starting firms. 4. when an inventor starts a firm based on a university license any positive royalty rates that remains in the contract between university and the inventor reduces the level of the final goods output (value of the inventor's firm) below the output under a simple contract between the inventor and the outside firm without the university as an intermediary. The university gains, but for society this gain is more than offset by a reduction in total output. The inventor is also worse off because of the decrease in output and sharing royalties with the university. However, a "pure fixed fee contract" does not distort output and provides a Pareto efficient solution. If the university TLO is able to bid up the selling price of the patent (through for example engaging in an auction) then inventors may be better off and the university no worse off.

The model predicts that introducing a TLO as an intermediary will have negative consequences on total economic efficiency, except if the TLO is able to find multiple buyers of the inventor's IP to sufficiently bid up the selling prize. Even the latter case does not guarantee overall system improvements, or improvements for all inventors, as competing bids must bring up the selling prize enough to compensate for efficiency losses introduced by the TLO tax reducing total output, and because some positive Net Present Value projects will not be actively marketed by the TLO.[51]

To support this model we reflect on some interview evidence from university inventors. While some TLOs are noted to be very helpful, it is questionable whether *all* TLOs provide useful services. For example, Audretsch et al. (2005) quote two scientists saying:

> "*I refuse to work with the TTO [TLO]. They have destroyed any of my commercial work. I have given up on any sort of commercial enterprises with my TTO. I don't think any of my colleagues have attempted to commercialize anything here the past six years.*" (ibid., p. 25)
>
> "*My commercial spirit stops at the TTO [TLO] door*" (ibid., p. 25)

Indeed, various researchers have found TLOs to have a high rate of staff turnover, and for TLO staff to have insufficient business and marketing experience (e.g. Siegel et al. 2003). Surveying firms, Hertzfeld et al. (2006) found that firms expressed great difficulties dealing with TLOs, citing the same problems as Siegel et al. (2003) discovered. As a result, in some cases firms decided to bypass the TLO and deal directly with the inventor, for example through consulting.

Audretsch et al. (2005) found in multivariate analysis that scientists that self-identified their TLO as being helpful had a higher probability of licensing their invention but a lower probability of starting up a firm based on their invention. Further, those that

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[51] Other theoretical models similarly propose that the TLO has an advantage over the inventor as an information aggregator (Hoppe and Ozdenoren, 2005; Macho-Stadler et al. 2007). The rationale is that the TLO sees more projects than the individual inventor and thus may have lower search costs for potential partners, a benefit which will be passed on to the inventor. In practise, the evidence from Germany and Sweden suggests that simply aggregating patents into a pool does not generate informational advantages. In-depth knowledge of the IP seems to be key to finding a willing licensor.

transferred ownership rights to their TLO had a higher probability of licensing their invention but a lower probability of starting up a firm based on their invention, compared to those that did not transfer rights to their TLO. Finally, they uncovered that TLOs that were more efficient in terms of converting patent applications to patents positively impacted on the probability of licensing inventions, but did not affect spin-off rates. The authors interpret these results as indicating a bifurcation in TLO skills – TLOs appear to know how to sell licenses but do not know how to help inventors that want to commercialize their research on their own. We interpret these results as indicating differences in incentives. TLO employees typically have greater and more immediate personal benefit from selling a license than from helping an inventor to start a business.[52]

While there might be potentially superior benefits to using a TLO in some cases, Kenney and Patton (2009) argues that such services in no way motivates a *de jure* allocation of ownership to the TLO. Their arguments are as follows. Suppose that the inventor knows best how to commercialize his invention. Then there is no need for the inventor to pay for the TLO service and since *de jure* TLO ownership implies extracting royalty from the spin-off, taxing the project this way leads to lower social welfare (Lowe, 2006). Suppose instead that the TLO has superior knowledge. The inventor will realize this after contacting the TLO and will contract for the services at fair market value, or sell the rights to the TLO. Gains from trade will emerge. Suppose instead that the TLO is initially allocated the rights but the inventor is the most effective commercialization agent, a not unlikely case when key technical information is highly tacit and in-alienable (Thursby and Thursby, 2007).[53] The TLO will either have to negotiate an effort agreement with the inventor or allocate royalties as incentive. However, an effort agreement is un-enforceable when tasks are tacit. And in the latter case the incentive is always less than if the inventor owned the firm and the inventor will thus underperform, partly due to the tax extracted by the TLO, but also due to the loss in output (Lowe, 2006). The only remaining solution which turns out Pareto-superior is if the TLO charges a fixed fee for their service which in itself does not require *de jure* TLO ownership.

An additional complication from introducing a TLO with *de jure* ownership is that industry negotiates with the TLO but the TLO does not credibly represent the inventor as the TLO cannot enforce compliance by the inventor for successful technology transfer. Industry would thus prefer directly negotiating with the inventor in order to provide stronger assurances of adequate technology transfer, be it in a licensing or other form of

[52] These results can be interpreted in several ways. It is possible that there is self-selection such that scientists with inventions with high commercial prospects are not disclosed to the university TLO, rather than the TLO handling negatively affecting the commercialization probability. The negative effect of the "TLO helpful" variable on commercialization probability is more difficult to explain by a self-selection argument. Other TLO descriptors, including TLO age, size, and licensing focus, were not significant.

[53] The authors found that 82 percent (74 percent when asking industry) of all licensed inventions are in proof of concept or lab-scale prototype stage when licensed and Jensen and Thursby (2001) document that faculty involvement in commercialization increases the likelihood of commercialization of a licensed invention.

contract, and the rationale for the existence of a TLO is on this account thus also questioned.[54]

In sum, if the inventor is the default owner, superior allocation of rights will always occur. Conversely, *de jure* TLO ownership is only economically efficient when, a) the TLO performs valuable service, and b) the TLO charges the inventor a fixed fee for its services. But if a TLO is providing valuable services, these can be contracted at will and *de jure* allocation is inefficient (Kenney and Patton, 2009). Either way, allocation of rights should rest most efficiently with the inventor.

It has been argued that an open market for commercialization services will guarantee the provision of superior skills (Litan et al. 2007; Kenney and Patton, 2009). Indeed, there are many privately operated invention evaluation and marketing services available, some with considerable experience and reputation and the numbers of intermediaries and their menu of services is growing.[55] It is important to understand that a market for commercialization services does not suffer nearly the same difficulties as the market for inventions. It is comparatively much simpler to price an invention marketing service than it is to price an invention (as the TLO-centric model implicitly does.) This is an additional argument for why control rights should initially rest with the inventor – offers of marketing and patenting services should be fairly easy to evaluate by the inventor and services are likely to be provided at close to marginal costs, while default decisions on equity-sharing by the TLO does not likely lead to efficient allocations and appropriate incentives.

Introducing a TLO as a mandated technology transfer agent may have additional negative effects on technological change. The starting point of interaction between an inventor and the TLO at most universities is the disclosure by a researcher of an invention to the university. Post Bayh-Dole all U.S. universities now require such disclosures, although in countries such as Sweden which maintains the *Professor's Privilege* there are no such requirement.[56] A researcher loses some and gains some by disclosing the invention. As discussed above, he may potentially gain help in commercializing the invention. Since disclosure is mandated he also avoids potential censure or prosecution. He loses the guarantee of keeping all returns to himself, reducing his incentive to commercialize. In most U.S. universities the researcher retains about 30 percent ownership rights, which means he loses 70 percent directly on disclosure. If the benefits of using the TLO are small and the potential penalties small the inventor has a large incentive not to disclose.[57] A fair number of spin-offs indeed go unregistered by

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[54] Ironically, one of the motivations for the introduction of *de jure* TLO ownership of IP was that industry complained that IP ownership rights were difficult to ascertain and contracts thus difficult to negotiate directly with academic inventors. It appears the Bayh-Dole legislation thus replaced one agency problem with another.

[55] See e.g. Åstebro and Gerchak, (2001), for a description of one such service that has operated since 1976 and performed over 14,000 invention evaluations.

[56] It is clear that disclosures have increased in the U.S. post Bayh-Dole. Thursby and Thursby (2007) report that the percent of disclosures at six selected universities have risen from 2.7 percent of faculty in 1983 to around 10-11 percent in the mid-1990s, where it appears to have levelled off.

[57] Needless to say, inventions go undisclosed for many other reasons; they have zero value, the researcher cannot be bothered, or the process of disclosing is perceived to be cumbersome or unfamiliar, or all of those combined.

universities. According to Markman et al. (2008) 42 percent of Professors who patented bypassed the TLO, while Audretsch et al. (2005) put this number at 30 percent for their sample of university researchers obtaining NIH Cancer Institute grants. Further, in direct contravention with the Bayh-Dole act, 26 percent of all faculty patents in US under the Bayh-Dole act were directly assigned to firms (Thursby et al. 2009). However, not all of these non-employer assignments are sinister. Many could be due to research consulting engagements, where assignment to the client is legal and the faculty inventor's contribution is properly acknowledged on the patent. It is not clear what useful recourse a university has if it uncovers that a faculty member has commercialized IP without its disclosure and the university also has some legal rights to the IP. Forcefully extracting rents from the spin-off or imposing penalties on the non-reporting employee may have negative repercussions on university reputation, contributions to endowments, and future entrepreneurship. Kenney and Patton (2009) illustrate this with the cases of Marc Andreessen[58] and Jim Clark.[59]

As a case in point, in our interviews at a European university which recently came under Bayh-Dole type regulation, the TLO administrators found the following effects upon implementing *de jure* ownership with mandatory disclosure:

- Faculty disclose but are uncooperative in further interactions with the TLO;
- Faculty with established industry collaborations started to withhold information about their activities, or simply stopped claiming IP;
- Faculty state invention as having zero commercial opportunity, thus leading to immediate release of university ownership claims.

Examining this negative incentive to disclose, Siegel et al. (2007, p. 643), recommends that "the university needs to have proper incentive schemes in place, specifying an adequate share for the inventors in royalties or equity." Indeed Thursby et al. (2009) find that the greater the inventor royalty share the greater the probability that the IP is assigned to the university employer.[60] However, any share less than 100 percent reduces the incentive to disclose. One might ask why universities have attached *de jure* ownership to the requirement by faculty to disclose. If universities want to maximize disclosures it would seem more reasonable *not* to claim ownership by default upon disclosure. Further, it appears from Bercovitz and Feldman (2008) that disclosure is a

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[58] When Marc Andreessen joined James Clark to form Netscape in 1994, they attempted to negotiate a license with the University of Illinois but found the process so frustrating that they ultimately rewrote the browser code entirely. By 1999, the University of Illinois had successfully collected $7 million from the Mosaic copyrights, but the ill feelings of the Netscape founders almost certainly cost the university a far greater amount in lost donations (Reid, 1997, p. 37; Kenney and Patton, 2009, p. 1413).

[59] Conversely, the positive experience of James Clark –the same person investing in Netscape and a professor at Stanford University until he left in 1982 to form Silicon Graphics to exploit the fruits of his university research – was explicitly mentioned in his 1999 decision to donate $150 million to Stanford (Kenney and Patton, 2009, p. 1413).

[60] It is not clear what the mechanism is that produces this effect. It might be that increased royalties increases the chance that the IP is disclosed to the university because the inventor loses less. And/or it might be that the economic incentive to assign the IP to an external firm is reduced because the external firm pays more for the IP to the inventor, all else equal. And/or it might be that the inventor prefers to do less consulting with higher inventor royalties, as suggested by Thursby, Fuller, and Thursby et al. (2009).

function of department norms, university norms, as well scientific norms. That is, there are other ways of raising disclosure rates.

After disclosure follows patenting. The TLOs decision on what to patent may diverge from what is in the inventor's best interest. For example, where TLOs have a reputation of presenting high quality inventions to industry, the TLO may have an incentive to not to pursue some projects with positive expected net present value because losing the reputation by not delivering a certain quality level may be very costly for the TLO (Macho-Stadler et al. 2007). Further, even in the absence of reputational effects, since the returns functions of the TLO is different from the inventors' the TLO may not pursue some projects with positive expected net present value.[61]

Finally, as already alluded to, the TLO may be biased towards executing a license with an established company because: a) licenses generates royalty income sooner than spin-offs and many TLO officers are incentivized to maximize royalty income especially in the U.S. and Germany; b) TLOs have a budget to manage and so may be more likely to take cash now than a risky option; c) spin-offs often require exclusive licenses which makes it a more risky proposition for the TLO;[62] and d) a licensing contract is likely easier to execute for TLO personnel than an equity deal (Debackere and Veugelers, 2005; Thursby and Thursby, 2007; Belenzon and Schankerman, 2009; 2013). These incentives may not always be in the interest of the inventor and are not likely in the interest of society.

In fact, there is good evidence that TLO officers have incentives that are not aligned with inventors' incentives. Approximately 70 percent of university central administrators report that "royalties/license fees" is extremely important as a measure of success for their TLO, while only 36 percent of them mention "number of inventions commercialized" as extremely important (Jensen and Thursby, 2001). The survey also asked TLO officers what they think faculty considers most important. Incongruously, the TLO officers know that their goals are different than that of faculty. Approximately 75 percent of TLO officers state that "obtaining sponsored research funds" is extremely important for faculty, while 36 percent report that they believe "number of inventions commercialized" is extremely important for faculty.

Nevertheless, if a TLO adopts incentive pay for their staff (in particular merit pay and bonus) it increases university licensing income per license with between 30-40 percent, a substantial amount given that the mean licensing income per active license was $38,900 and yearly number of executed licenses per university were 29 in the data (Belenzon and Schankerman, 2009). This benefits universities but also inventors. Private universities are significantly more likely to adopt these incentives than public universities. However, incentive pay does not affect the fraction of spin-offs to licenses that are created. That is, the university seems only able to incentivize staff for generating licensing income, not for generating spin-offs.

Moving on to discuss inventors' incentives, it is likely that allocating greater royalty shares to inventors increases their efforts. Indeed, U.S. universities that allocate greater ownership shares to inventors have larger licensing income (Link and Siegel, 2005; Friedman and Silberman, 2003; Lach and Schankerman, 2008). The impact is much larger

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[61] For details on this argument, please see the prior discussion on Lowe (2006).

[62] Thursby and Thursby (2007) report that approximately 90 percent of all university start-ups are based on exclusive licenses, while licenses to established firms are approximately 60 percent non-exclusive.

at private universities than publicly operated universities (Lach and Schankerman, 2008). This differential effect is probably due to the TLOs at the private universities being more effective at finding firms willing to purchase/license the IP, in part because private universities impose less constraints and rules on their TLOs. In such places, a percentage point increase in royalty share means proportionally more in the inventor's pocket. In most private universities allocating a dollar more licensing income to the inventor raises total royalty income by more than a dollar. However, if universities expect competing universities to match changes in their royalty share, this net gain is only present in a small set of universities. Importantly, the incentive effect is twofold, it raises faculty effort at the margin, and it sorts scientists across universities. The second effect implies that more commercially oriented researchers would tend to join universities that allocate greater royalty shares to inventors.

Faculty effort affects both the number of inventions and their quality, and both should be increasing functions of effort incentives. Lach and Schankerman, (2008) find that the primary incentive effect of raising the royalty share is to raise the quality rather than the quantity of inventions. Importantly, raising the royalty share at private universities by *one percentage point* will generate *4.3 percent more* licensing income, given the same number of licenses. The effect of a percentage increase in the royalty share on the number of executed licenses is about half of that. Interestingly, the authors reject the idea that the inventors are *only* motivated by cash considerations – when they decompose the incentive into private cash and laboratory funding, the effect for laboratory funding is about *twice* the size of private cash, and both effects are statistically significantly different from zero. In public universities it appears that incentive effects are much weaker; many of the reported incentive effects turn out to be insignificant. These results illustrate that university central administrators and TLO officers alike currently may not fully understand how to most efficiently increase licensing income using university policies as a lever. If they knew, they would allocate as much effort as possible to maximize lab funding to their researchers since this produces the greatest licensing income per dollar unit cost. But instead, according to Jensen and Thursby (2001), increasing lab funding is only a secondary goal for university central administrators and a distant fourth ranked goal for TLO officers, but a top ranked goal for researchers. The latter is of course consistent with the estimates of Lach and Schankerman, (2008).[63]

While licensing revenues increases with inventors' royalty rates, two publications (Di Gregorio and Shane, 2003; Markman et al. 2009), show that the number of spin-offs is reduced by an increase in the royalty rate granted to inventors. However, the negative effect of inventor royalties on spin-off rates is not consistent – Lockett and Wright (2005) find a positive effect and two additional studies find null effects (see Table 3).

Table 3: Effects on number/probability of spin-offs of various conditions.

Variable	*Positive and significant*	*Zero effect*	*Negative and significant*
INCENTIVE STRUCTURE			

[63] The authors are concerned that their cross-university estimates are driven by unobservables, such as the "commercial orientation" of the university, and try to control for pre-existing university conditions by its cumulative number of patents issued (and their citations). For the validity of this approach, please see Blundell, Griffith and van Reenen (1999.) Lach and Schankerman also perform a large number of robustness checks.

Royalty shares to faculty	Lockett and Wright (2005)	Friedman and Silberman (2003) Louis et al. (1989)	Di Gregorio and Shane (2003), Markman, Gianiodis, and Phan (2009)
Royalties to department		Markman, Gianiodis, and Phan (2009), Friedman and Silberman (2003)	
Taking equity in spin-off by university	Di Gregorio and Shane (2003)	Louis et al. (1989)	
University venture capital fund		Di Gregorio and Shane (2003) Louis et al. (1989)	
Licensing for cash		Markman, Gianiodis, and Phan (2009)	
Sponsored research agreements		Markman, Gianiodis, and Phan (2009)	
Equity agreements		Markman, Gianiodis, and Phan (2009)	
Local development objective		Belenzon and Schankerman(2009; 2013)	
INPUT METRICS			
Faculty quality	Di Gregorio and Shane (2003), O'Shea et al. (2005), Markman, Gianiodis, and Phan (2009), Zucker, Darby, and Brewer (1998) Powers and McDougall (2005)		
Federal R&D spending	O'Shea et al. (2005)		
Industry R&D spending	O'Shea et al. (2005), Powers and McDougall (2005)	Di Gregorio and Shane (2003), Louis et al. (1989)	
Invention disclosures	Di Gregorio and Shane (2003), Belenzon and Schankerman (2009), O'Shea et al.(2005)	Friedman and Silberman (2003)	
Patents		Di Gregorio and Shane (2003), Louis et al. (1989)	
TLO DESIGN			
Age of TLO	Powers and McDougall (2005)	Friedman and Silberman (2003) Lockett and Wright(2005)	Markman, Gianiodis, and Phan (2009)
Number of TLO staff	O'Shea et al. (2005), Markman, Gianiodis, and Phan (2009)	Di Gregorio and Shane (2003), Lockett and Wright(2005), Louis et al. (1989)	
Expenditure on IP protection	Lockett and Wright (2005)		

TLO staff salary	Markman, Gianiodis, and Phan (2009)		
TLO staff bonuses		Belenzon and Schankerman(2009; 2013)	

This section has reviewed models and evidence concerning licensing and start-ups based on research at universities. TLOs are in most empirical work considered having a positive effect. However, whether this is due to causation, reverse causation, or common determination has not been shown. The theoretical work is much more skeptical as to the potential benefits of introducing or enlarging TLOs. Further, there are dissenting empirical data as to the value of TLOs, and in particular to the value of assigning control rights over IP to the TLO by default. Further, the research clearly shows that incentives matters, both for TLO officers and for researchers. A consensus seems to be forming that TLO officers are strongly incentivized to license IP, but much less interested in helping inventors to start businesses. By awarding the inventor greater royalty shares, researchers bring in more licensing income to the university than the university loses. The greatest effect on commercialization revenues may be when productive researchers are simply awarded more laboratory funding – this is what most researchers cares the most about.

The case for an intermediate allocation of IP rights[64]

Consider a policymaker that seeks to encourage the flow of 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. Presume that the policymaker’s lever is, by 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 can be 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 TLO) 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 come from a researcher be $(s,)$, which is increasing and concave in both arguments and assume the inputs are complements. The policy parameter is the portion α that accrues to the individual researcher, leaving a portion $1-\alpha$ for the university. As Aghion and Triole (1994) and Scotchmer (2004) have emphasized, there are deep challenges in achieving first-best outcomes via the rent-sharing parameter α, where the parties bear private, non-contractible costs.

In particular, given a researcher investing s in commercialization activities, the university solves the problem $\hat{x}=arg[(1-\alpha)v(s,x)-rx]$ so that the university's investment level is sensitive to their expected share of income, $1-\alpha$. Meanwhile, let the individual

[64] This section mostly contains language taken *verbatim* from Hvide and Jones (2015).

researcher have quasi-linear preferences in income and for given x solves the problem $\hat{s}=arg[\alpha v(s,x)+G-\theta h(s)]$. The researcher earns $(s,)+G$, where G represents the individual's academic salary or other non-commercialization income. The disutility of commercialization effort (i.e. the loss of time for basic research, leisure, or other activities) is given by $\theta h(s)$.

One key observation from this simple model is that, with complementarities between university and researcher investments, innovative output may not be maximized at α=1, i.e. with a Professor's Privilege. 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.

In the absence of complementarities, researcher investment only increases in the researcher's rent share and the optimal allocation of ownership to the researcher is α=1. However, in the presence of complementarities, and over the part of the distribution where the university's investment is increasing in the university's rent share, researcher effort may decline in the researcher's rent share. Indeed, starting with a Professor's Privilege where the researcher has all rights to an innovation (α=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. Consider a constant elasticity of substitution production function. Equilibrium investment levels and innovative income are shown in Figure 1 as a function of the policy α for illustrative parameters. 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 $\alpha\approx1/3$. Thus, emphasizing complementarities in investment may provide a natural logic for reforming the Professor's Privilege in the vein of several European countries – and the similar balance between researcher and university rent shares in the United States today.

It must be emphasized that it is currently not known whether investments between the inventor and her university are complementary. Complementarity means that a one unit investment by for example the inventor increases commercialization revenues more the higher the level of investment by the university. A more standard argument would be that investments by both parties are additive – that is that both increases commercialization revenues independently of each other.

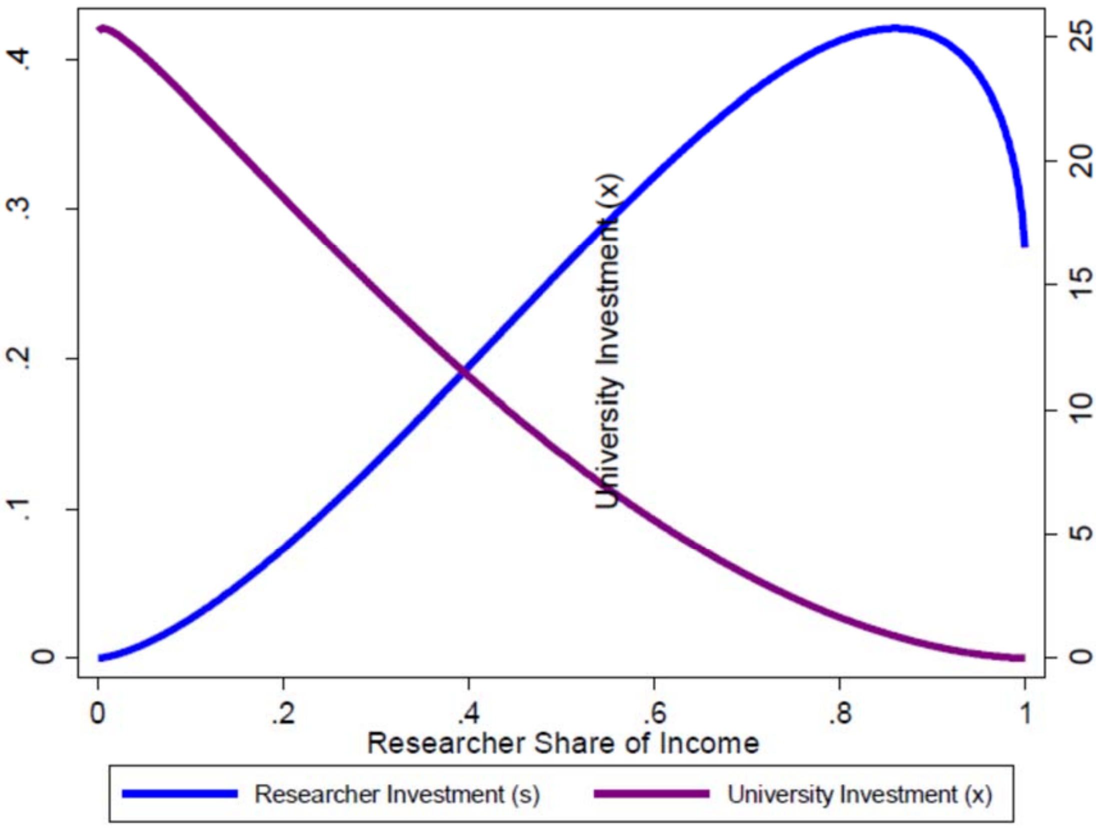

Figure 1. Investment and Innovation as a Function of the Rent Share (α) – example.

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 practice, this approach might mean giving all the rights to 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, while the researcher might feasibly control and internalize the spin-off, patenting or licensing costs that the university might otherwise choose. To some extent, the problem may approximate what university researchers already did under the Professor's Privilege, 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 can in fact lower the cost of x (e.g., through scale) compared to the price a researcher faces or whether there are other kinds of investments representing unique university capabilities, such as investing in infrastructure. Some analyses of commercialization practices, emphasizing incentive conflicts between the parties and low value in university capabilities, have argued for sharply curtailing the role of TLOs and increasing researcher's property or control rights (Litan et al. 2007, Kenney and Patton 2009). The empirical analysis of Norway, Denmark and Germany appears broadly consistent with this perspective. That said, the empirical setting only considers two policy regimes (α=1 and α=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 in Norway, Denmark and Germany 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 university onerous, and it is also plausible that external funders or licensors are dissuaded when multiple university-based parties become involved (Merrill and Mazza, 2011). 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.

Policy conclusions

There has been an increased trend in the number licenses to established firms and the number of spin-offs generated by universities. This has been driven by, or associated with, an increase in university research activities, increased funding from industry, an increase in privately protected ownership of research at universities, and an increase in disclosures and patents. The trend accelerated through the 1970s in association with the biomedical revolution, with implementation of legislation and court decisions conferring stronger private property rights on intellectual work, and with legislation in the U.S. allowing universities to take *de jure* ownership of intellectual work by their researchers funded by the public. This trend has not been limited to the U.S. but a widespread phenomenom across the industrialized world. In particular, several European countries have lately copied the U.S. legislation shifting control rights of intellectual property from the creator to the university employer.

It is not clear that these trends have been good for society. There can be several negative effects and system efficiency may be higher when research is made public rather than private. However, it is difficult to prove the counterfactual and pundits certainly have applauded the apparent rise in innovative output by U.S. universities over the past forty years. There has also been a rising acceptance by the public that universities engage in commerce and the public debate over whether privatization of research is good for society has abated.

Against this backdrop universities are being pressured to aid in "improving" the commercialization of research. University chancellors and presidents are being asked "What role does your university play in stimulating local economic development through entrepreneurship?" and they ask themselves "What can we as a university do to encourage entrepreneurship to increase local economic development?" Given these questions, universities are increasingly being "managed" to increase three performance metrics; number of patents, number of licenses and number of spin-offs. Early evidence of successful technology licensing offices (TLOs) such as those at Stanford and MIT are used as examples to follow. [65] To abide by legislative changes and to increase commercialization of research, universities create TLOs and appoint ever increasing numbers of administrators and lawyers to manage the commercialization of intellectual

[65] It should be re-noted that both Stanford and MIT practice extremely 'soft' versions of the Bayh-Dole act, not asking any questions if their employees decide to bypass the formal process and the TLO.

property. But it is not clear that such strategies will increase the overall efficiency of research commercialization. Research so far has not been able to identify causation in this direction. And the creation of TLOs may be as much a response to legislative changes and changes in scientific norms as a cause of increased commercialization.[66]

From a theoretical perspective we have reviewed articles showing that introducing TLOs, the most popular method to stimulate commercialization of research, may likely introduce economic inefficiencies, hold-ups and decision biases that deviate from what is optimal.

There is clear evidence that the top 100 U.S. research universities, Canadian universities as well German patent commercialization agencies do not more than break even on their commercialization efforts. Typically, licensing and spin-off revenues to the university or patent commercialization agencies amount to less than operating costs. If universities are asked to conduct commercialization efforts the budget of these efforts need external support by those asking.

Recent and remarkably consistent evidence from Denmark, Germany and Norway indicates that implementing strong versions of the Bayh-Dole act in Europe (which transfers control rights over IP from university employees to universities) appears to have been significantly detrimental to technology commercialization. In hindsight these results could have been expected. Europe is not starting from the agency problem that the US had pre-Bayh-Dole. European professors patent as much as or more than U.S. professors and interact as much or more with industry than U.S. professors and in European countries with the Professor's Privilege these "3rd mission" activities seem more intense than in European countries without the Professor's Privilege. So the argument that there is something broken that needs to be fixed in Sweden seems fallacious.

More importantly, the policy experiment we have observed in Denmark, Norway and Germany all indicate that 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, there is at least a subset of university researchers – those on the margin of important technology transfer avenues – who respond immediately and strongly to having their control and ownership rights taken away. In hindsight this could also have been expected. Removing about 2/3rd of ownership and as well control rights works like a heavy tax on inventors. If universities can only offer support from inexperienced and underpaid lawyers and administrators that in addition have little or no practical business start-up experience in exchange for this heavy penalty it seems obvious that academics would reduce their commercialization activities.

In closing this section, asking Swedish universities to shoulder economic development objectives is to ask universities to do something they historically have not been very good at (although their employees might still have been good at it). Are the universities learning to do so? – slowly but surely. Are Swedish TLOs and their personnel becoming better at technology transfer? – certainly. But neither the deficiencies nor

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[66] For a guide on how to set up a TLO from an experienced head of a well-known TLO, please see Nelsen (2007b).

improvement mean that Swedish universities should take control rights over IP produced by its researchers.

Summary of Findings and Policy Recommendations

We start by summarizing findings drawn from the empirical as well as theoretical literature reviewed in this report. We then list policy recommendations stemming from these findings.

Finding 1. The first goal of university technology transfer involving IP is the expeditious and wide dissemination of university-generated technology for the public good.[67]

Finding 2. The transition of knowledge into practice takes place through a variety of mechanisms. These include, but are not limited to 1. movement of highly skilled students from training to private and public employment; 2. publication of research results in the open academic literature; 3. personal interaction between creators and users of new knowledge (e.g., through professional meetings, conferences, seminars, industrial liaison programs, and other venues); 4. firm-sponsored (contract) research projects involving firm-institution agreements; 5. Multi-firm arrangements such as university-industry cooperative research centers; 6. personal individual faculty and student consulting arrangements with individual private firms; 7. entrepreneurial activity of faculty and students occurring outside the university without involving university-owned intellectual property; 8. entrepreneurial activity of faculty and students occurring outside the university involving university-owned intellectual property; and 9. licensing of IP to established firms or to spin-offs.

While policy makers have recently focussed attention on commercialization of IP, the other eight mechanisms of knowledge transfer might be as important to consider for effective transfer of university-generated technology for the public good. The rest of this section will nevertheless focus on licensing of patents and university spin-offs.

Finding 3. The increased focus on claiming private IP rights by universities and their employees have led to greater secrecy and restrictions on information flow, leading to a decrease in the wider diffusion of knowledge generated by its employees. This decrease has been most visible in the biotechnology and medicine-related fields but has also been observed more generally.

Finding 4. Royalty and IP sales income cannot typically support the operating costs of most university TLO and Innovation Offices and will never be a relevant source of income for universities. Many local Swedish TLOs and other similar types of organizations have during the last 15 years had to close or change their funding model from relying exclusively on licensing income to a mixed source of income to survive.

Finding 5. The three European countries which have switched from the Professor's Privilege to a system where control rights to all IP are retained by universities have all experienced reduced patenting by academics, reduced research and collaborative interactions with industry, reduced likelihood of forming spin-offs, and reduced the quality of patents.

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[67] This and the next finding does not deviate from the two primary findings of the National Research Council of the National Academies report "Managing University Intellectual Property in the Public Interest" by Merrill and Mazza (2011, p. 60).

Finding 6. Swedish university researchers have been and still are particularly active among European countries in claiming patents, and in engaging actively with industry in various other ways, such as conducting consulting and collaborative research projects.

Finding 7. An increase in inputs, in terms of funding of research and personnel, represents the largest source of increase in university technology commercialization. Other variables such as the creation of TLOs matter much less.

Finding 8. University researchers, and possibly in particular Swedish researchers, respond more positively, in terms of producing more and more valuable IP, to obtaining funds for their laboratories, rather than to obtaining greater royalty shares to the IP produced.

Finding 9. TLOs in the United States and Germany are, through the Bayh-Dole legal framework, the design of TLO worker's incentives, the hiring of personnel, and the implementation of operating procedures, generally more interested in and better able at promoting the licensing of IP to established firms than they are helping academic inventors commercialize university spin-offs.

Finding 10. There is no systematic source of information on the operating practises and operating efficiencies of Swedish TLOs.

Finding 11. Low-quality statistical information and anecdotal evidence may suggest that TLOs in Sweden are more oriented towards supporting spin-off generation, and that licensing of IP to established firms through TLOs is relatively less practised in Sweden.

Finding 12. Systematic and easily compiled data on university patents, licenses and spin-offs do not exist in Sweden.

Full-time academic entrepreneurship rates are observable trough the Swedish matched employer-employee register called LISA. It has so far not been possible to observe those practising part-time academic entrepreneurship using these data, but such efforts should be possible with current data from Statistics Sweden. Patenting by Swedish academics can only be observed through one-off matching effort, through a painstaking process of using name matching algorithms matching records of named inventors extracted from European Patent Office records with employment data through freedom of information act requests (see e.g. Ejermo and Källström, *forthcoming*).

Finding 13. Case studies suggest that some Innovation Offices in Sweden do very well and contribute significant value to local economic development. In other cases, their contribution may be smaller and less impactful.

Recommendation 1. The Swedish government should not revoke the Professor's Privilege.

Recommendation 2. The Swedish government should act to facilitate a national clearinghouse for knowledge sharing between TLOs and Innovation offices in Sweden and abroad.[68] Sister organizations are available to interact with and learn from, for example in the U.S. (AUTM) and in Germany (Technologieallianz).

Recommendation 3. The efforts of university TLOs and regional Innovation Offices need to have about half of their operating costs supported from other than licensing revenues and sales of spin-off equity in-the-money. Such funding can be a mix of fixed-price fees for services rendered, and base operating funding from local, university, regional and other public sources.

Recommendation 4. There is no need for Swedish universities to themselves operate TLOs or Innovation Offices, especially if a specific university does not have a large research budget. Resources for commercialization can be shared across regionally co-located universities and other organizations. Services offered from specific organizations should *not* be mandated to be used by university researchers. The choice to use these services, or services from other organizations should be kept free to the inventor. There should be competition for services provided by regional offices, no local monopolies should be granted as this will introduce inefficiencies and a greater need to control and monitor operations by the state, more administration oriented management and less business orientation at the TLO.

Recommendation 5. Should recommendation 1 be ignored, there must be a budget set aside by legislators for an independent evaluation of any change in law, regulation or otherwise intended act to affect university technology commercialization. A difference-in-difference regression methodology should preferably be employed where the effect on a target population is contrasted to the effect on a control group.

Recommendation 6. There should be an opportunity by researchers and officials to evaluate the performance of TLOs and innovation offices. The ability to do so using current official statistics is limited since patent records are not earmarked by TLOs unless patents are voluntarily assigned by the inventor to the university of her employment. Further, inventors can and should be able to use TLOs other than that at her university. At the same time, the separate reporting of data by TLOs and innovation offices for purposes of performance evaluation should be curtailed to a minimum to allow them to operate efficiently. It is therefore recommended that each TLO and innovation office report on an annual basis only the exact patent number for each patent which they have started to process in that year to a central statistical office, such as Statistics Sweden, and that these data become public. This abolishes the need to report invention disclosures. Further data on TLO operations on funding, licensing deals, licensing revenues, costs of operations, etc. may be voluntarily shared through a national clearinghouse as in recommendation 2.

[68] Maybe this role could be filled by the Swedish Network for Innovation and and Technology Transfer Support (http://www.snitts.se/om-snitts/), or by the Swedish Incubators and Science Parks (http://sisp.se/) or by Vetenskap och Allmänhet (http://v-a.se/) which all service various aspects of TLO and Innovation Center activities, but which to the author's knowledge do not seem to systematically collect and share comparable data on costs, cost structures, inputs and outcomes such as patents, start-ups, licenses and licensing income the way AUTM does.

Recommendation 7. It is important that there exists a variety of modern and competitive service alternatives for university researchers interested in commercializing their ideas in order to stimulate overall system efficiency in Sweden.

Research has shown that local access to funding and skilled business people historically has been extremely important for university technology commercialization. It is crucial for Sweden that the development of modern innovative versions of these resource provisions are developed. For example, Chalmers offer inventors in Västra Götalands Regionen to work with "surrogate" entrepreneurs from its Entrepreneurship School for quick and efficient commercialization. However, for some industries, in particular internet-based, such local access requirements are quickly diminishing. Crowdfunding is revolutionizing start-up funding, and accelerators offer bootcamp-quick skill building.

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