The America Invents Act – do stronger patent systems encourage university innovation?

April 6th, 2020

Erasmus University Rotterdam, Erasmus School of Economics

Master thesis

Economics and Business, Policy Economics

Abstract:

Innovation has played a major role in the economic development in the United States in the last century, with universities producing more than half of the basic research. Patent systems are one of the governmental interventions used to incentivize innovation, but the literature remains inconclusive with regards to their efficiency especially when applied to higher education institutions. Few empirical resources have been devoted to investigating the relationship between patent laws and university innovation and this article is a pioneer in this aspect. It uses a recent development in American patent law, the Leahy-Smith America Invents Act, to investigate the central question: what is the impact of the AIA on university innovation? The Higher Education Research and Development survey provides numbers on research and development expenditures which I use as a proxy for innovation. Data retrieved from the US Patent and Trademark Office allows me to use the number of patents granted to each American university as a measure of exposure to the policy. The more patents an institution owns, the more it is affected by a patent reform. Combined with university and time fixed effects this methodology allows me to find that on average a 1% increase in exposure to the AIA has increased R&D expenditures of universities by 1.64%. I also find homogeneity in the effects implying that large universities benefit from this policy six times more than their smaller counterparts so that this policy increased inequality between universities. The US seems to be positioned on the left-hand side of the inverted U-shaped relationship between innovation and

patent strength, suggesting there are more opportunities for policy makers to increase innovation through patent reforms. Those findings imply patent reforms for universities have the benefit of increasing innovation at the expense of increased inequality in terms of R&D spending.

Author: Cedric Chambrillon

429064

Supervisor: Sacha Kapoor

1. Introduction

Innovation has played a major role in the American economic history. Around 50% of the economic growth between 1950 and 1993 was caused by the increase in global research intensity (Jones, 2002). However, research has become less productive in the last decades (Bloom, Jones, Van Reenen & Webb, 2017) compromising not only economic progress but also social and environmental advances. In order to boost innovation and consequently growth, President Barack Obama signed the Leahy-Smith America Invents Act on the 16th of September 2011. This act aimed at increasing the efficiency of the American patent system, making it easier for inventors to capitalize on their inventions and therefore increasing the incentives to find new ideas. This act is viewed as a “significant shift” (Ashworth, 2012), “the most significant change to the U.S. patent system since 1952” (Tseng & Raudensky, 2015), and a “historic reform” (Armitage, 2012). Amongst others, this policy has lowered the cost of patent application for micro-entities, favored transparency and initiated international harmonization. The main features went into effect in 2013.

In the past, economists have avoided studying patent systems empirically (Besen & Raskind, 1991), possibly due to the lack of a clear counterfactual that still prevails today. Today, the “economics of patent” and the “economics of innovation” illustrate the work that has been done in this area (Hall & Harhoff, 2012; Gallini, 2002; Langinier & Moschini, 2002; Rockett, 2010). Much of this research analyzed this specific policy and its impact on innovation of American firms, but the results remain inconclusive. The most striking is the lack of attention brought to universities’ response to this policy. Higher education institutions play a massive role in the economic development of countries. Not only through the education they provide but also through their contribution to research. In the United States, universities produce about 56% of basic research (NSF, 2008). Additionally, university patenting has increased recently (Tseng & Raudensky, 2015 and Ryan & Frye, 2017) while the few findings on this topic highlight that the use of patents at universities can be harmful. It increases the costs of future research and diverts researchers from relevant research that is non-patentable (Mowery & Sampat, 2004, Ryan & Frye, 2017).

The importance of universities for innovation and growth and the potential impact of patent policies on those actors highlight the relevance of studying them. Unintended effects on university innovation can prove highly detrimental to the American economy and society. This recent development in patent policy together with the newest data from the Higher Education Research and Development (HERD) survey provide a new opportunity to provide empiric evidence on the mechanisms involved with university innovation and incentives. I will try to answer the main question: what is the impact of the AIA on university innovation?

There have been very few empirical methods applied to the AIA and university innovation. Most research has been using correlations and descriptive analysis, working with theoretical or survey evidence. This paper is an attempt to provide empirical evidence to the discussion. The method used here is closest to the one used in Ryan and Frye (2017), who investigate both the impact of the Bayh-Dole act of 1980 and the AIA on patenting activities of universities using a differences-in-differences approach. The limitation of their methodology will be discussed and contributed to improve this paper.

The methodology from this paper uses patent data retrieved from the US Patent and Trademark Office (USPTO) which is the institution responsible for screening patent applications and granting patents in the United States. Their database provides an overview of the number of patents owned by each American university and has also been used by Ryan and Frye (2017). This analysis finds it novelty in using the number of patents owned by each university prior to the AIA as a measure of exposure to the policy. It is likely that universities being involved with the patent system are affected by a patent reform. I am therefore using universities that own no patent as a counterfactual to study the impact of the implementation of the policy on university innovation.

A primary descriptive analysis of the data reveals there is a high inequality of patent distribution at universities. About 50% of all patents are owned by 7% of universities. I find a similar inequality of R&D expenditures. This inequality in patent ownership has also been observed in Europe (Geuna & Nesta, 2006). Large entities tend to own more patents (Scellato, 2007) so that patent reform can contribute to increasing the gap between small and large universities. In order to observe whether the AIA has affected inequality of universities I split up the dataset in two, to analyze small and large universities separately. Inequality in patent ownership and R&D expenditures are harmful for research output and access to finance (Geuna & Nesta, 2006). It could also indicate an excessive patenting activity from several universities acting as patent trolls (Rai, Allison & Sampat, 2009). Considering the theoretical evidence and literature on this topic I expect that exposure to the AIA has decreased R&D expenditures of universities. I also hypothesize that large universities benefited more than small universities, so that the impact of exposure to the AIA is positive for large universities and negative for small universities.

Overall, I find that the AIA has managed to increase university innovation by 1.64% for every 1% increase in exposure to the policy. Both small and large universities have positive estimates, but those estimates are six times higher for large universities than for small universities. Those observed effects are however not causal in light of the limitations of the data and methodology. Those findings remain concerning as it seems the AIA has increased inequality of R&D spending across universities. Additionally, this paper finds descriptive evidence regarding the unequal distribution of American university patent ownership. The United States seem to be positioned on left hand side of the inverted U-shaped relationship between patent strength and innovation suggesting there is still room for increased innovation with stronger patent systems.

The next section discusses the main features of the AIA and their potential impact on university innovation and inequality. Section 3 provides an overview of the economic rationale behind patent systems and previous evidence surrounding the topic. Section 4 describes the data and variables used and provides a descriptive analysis. In section 5 I display the methodology and limitations. Section 6 provides results and links them to the theoretical findings. Section 7 verifies the robustness of the use of patents as a measure of exposure to the policy. Section 8 provides the main conclusions of this article.

2. The America Invents Act

Lerner (2005) indicates that there are four indicators of the strength of a patent system. He lists the duration of the patent, the patent fees, limitations on patent revenue (any barrier that reduces the gains of patentees ranging from strong antitrust laws preventing high prices, to compulsory licensing for example) and the industries protected by patents. The AIA has reduced patent fees for micro-entities and made it easier to appropriate gains by decreasing litigation costs. The AIA did however not affect the number of sectors encompassed by patent law nor the duration of a patent. Overall, this reform has led to a strengthening of the American patent system.

The most prominent contribution of the Act is the change from a first-to-invent (FTI) to a first-inventor-to-file (FITF) system. While previously patents were granted to inventors that could prove they were first in inventing the subject matter, today patents are granted to the first inventor filing a patent application at the USPTO. Most patent systems worldwide operate under a first-to-file system and the United States were one of the rare cases under which the

FTI scheme was applied. International harmonization of patent laws is therefore cited as one of the main motives for this switch and, as argued by Kappos (2010), is essential for technological progress in a globalized economy.

The law also implemented a reduction in patent fees for micro-entities, making patents more affordable. The AIA allows for third-party pre-issuance submissions. This implies that third parties can submit information to the patent authority that either helps or compromises the patent applicant during the application process. Competitors could for example submit documents that discredit the invention. This measure increases the information available for the examinations of the applications. The law also extended the prior commercial use defense. If an invention has been used or commercialized by a third party before an inventor submits a patent application, that third party can continue using or commercializing the subject matter without the risk of being accused of infringement. Those are only a couple of the modifications brought up by this reform. Other features reduce the costs of the litigation or increase the protection provided by patents. The AIA is very comprehensive as it is intended to impact the efficiency, transparency and accessibility of the patent system thus making it more attractive for inventors to file a patent application. These changes should therefore increase innovation, in theory.

3. Literature review

Economic theory background

The main rationale for patent systems comes from the fact that knowledge is a non-rival good. This implies that once produced this good can be used by an infinite number of users without incurring additional production costs. Knowledge is also non-excludable meaning that it isn’t possible to prevent anyone from using it. Such characteristics of a public good make it hard for inventors to perfectly appropriate gains of their invention. Innovators incur two types of costs, the first type relates to the costs of developing an invention, and the second type to the costs of bringing the invention to the market. As the innovation is made public, each competitor can easily use and imitate the invention, free riding on the developing costs. In addition to being a public good, knowledge also produces positive externalities. An invention created by an inventor may give him private benefits but the generated knowledge benefits society. In a free market, knowledge suffers from underproduction. This type of market failure calls for governmental intervention (Arrow, 1962) aiming at incentivizing production of the public good.

One of the interventions governments carried out is the subject matter of this paper, intellectual property. While intellectual property comprehends copyrights, trademarks and patents, I will focus the discussion on the latter. The US Patent and Trademark Office (USPTO) defines patents as the grant of a property right to the inventor for a period of 20 years from the filing date. This right excludes others from making, using, offering for sale, selling or importing the invention[1]. By being given control and appropriability of enough gains to cover the costs of the invention, an inventor is incentivized to innovate.

The grant period of 20 years may seem arbitrary at first. In the words of Nordhaus (1969), "If the sole concern is to encourage innovation, then intellectual property should last forever". But there are costs attached to patent systems. In traditional economics the deadweight loss represents the cost of society incurred by supply and demand being out of equilibrium due to the absence of a free market. Patents grant monopoly power to the inventor, and thus generate deadweight loss. In an attempt to balance between spurring innovation and containing the deadweight loss, the current patent length is finite.

Public goods are often subject to market failures and require market interventions. However, as for the production of new knowledge and ideas, Dodgson et al. (2011) qualify the market approach as too narrow a perspective to provide an adequate analytical or empirical basis. Martin and Scott (2000) assert that the forces leading to underinvestment in innovation differ across sectors, advising for a systemic approach for policy design instead. In practice, a systemic approach entails the study of the flows between and the interactions of all actors involved in innovation processes. Innovation systems, as defined by Lundvall (1992) are systems constituted by elements and relationships which interact in the production, diffusion and use of new and economically useful knowledge. In 1997, the OECD published a report on National Innovation Systems that highlighted the growing number of institutions involved in knowledge creation. Policies on innovation systems worldwide have progressively been shifting to systemic approaches (Bleda & Del Rio, 2013). In order to respond to underproduction of new knowledge, policy makers need therefore to consider other elements

[1] For a complete definition of patents, go to https://www.uspto.gov/patents-getting-started/general-information-concerning-patents#heading-2

than solely incentives and pricing. In the following literature I will highlight some of these elements using concepts and input from different disciplines.

The case against patents

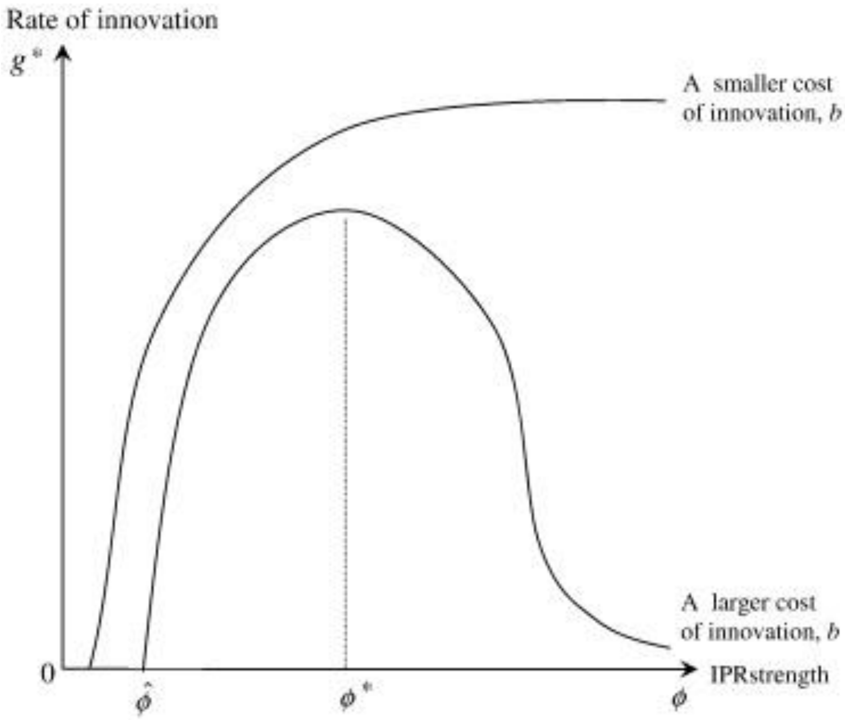
There are two major requirements for innovation to be impactful: the creation of new ideas, and their dissemination. Patent systems impact both. By granting ownership rights, patents incentivize creation of new ideas but hamper their dissemination and use by other inventors. Not only do patents restrict the use of the invention by outsiders, it also prevents them from building on the product or process. This increases the cost for subsequent innovators. Patents could however improve the disclosure of inventions as in exchange for property rights inventors are obliged to make their invention public.

a) Impact on innovation

A range of researchers have shown that intellectual property played a minor role in the increase of innovation although most of the evidence is not causal. Mansfield (1986) provides an informative table through which the pharmaceutical industry reported it would not have developed 60% of their innovations in the absence of patents, the chemicals industry comes second with 38%. These two industries are the only ones, out of the twelve surveyed, exceeding the 25% mark. Apart from these two sectors, patents are barely a source of innovation. It is interesting to note that Mansfield only surveyed companies with more than $25 million in sales and as we will discuss later, smaller companies may benefit much less from intellectual property. Another survey described in Cohen et al. (2000), showcases that in the manufacturing sector, patents are given as the last mean to protect profits of an innovation. It is secrecy and lead time that appear first in the ranking of how to best appropriate gains. Nobel prize winner Paul Romer (1990) argues that it is the non-rival characteristic of knowledge that makes it a large contributor to economic growth. By removing this non-rival aspect, patent systems reduce this potential (Jones, 2019). The empirical research on the subject remains inconclusive. On one hand, many caution that patents did not increase innovation (Bessen & Mankin, 2009; Sakakibara & Branstetter, 1999; Moser, 2005) but shifted innovation towards specific sectors (sectors for which secrecy was not effective in protecting an invention). On the other hand, evidence suggests that in France on average 15 to 20% of R&D expenditures are associated with the existence of patent laws (Schankerman, 1998). Nordhaus (1969) mentioned that patent systems applied to individual and isolated inventions do have a positive impact.

The relationship between innovation and patent strength seems to follow an “inverted U” shape (Qian, 2007; Horowitz & Lai, 1996; Gallini, 1992; Furukawa, 2010 & Lerner, 2005). Conform to this theory, increasing patent strength has beneficial effects on innovation when the system is weak, but negative effects when the property rights are already strong. Figure 1 retrieved from Furukawa (2010) illustrates this mechanism.

Figure 1: the “inverted U” shaped relationship between patent strength and innovation



Source: Furukawa (2010)

This theory could settle the dispute in the literature. The difference in the position of countries on this curve may be the explanation for the differences in observed effects. Horowitz and Lai (1996) remark that the current patent length in the US is larger than the social optimum. Longer patents tend to decrease the frequency and increase the size of innovations. A good balance between both makes a patent system optimal. The findings of this paper will shed light on the position of the US on this curve. Has the US reached the tipping point and gone too far?

b) Impact on dissemination

Much of today's research is interrelated and sequential. Sequential implies that current research uses and is based on previous findings. Bessen and Mankin (2009) indicate that in such setting, patents may worsen the innovation climate. Patents may stifle innovation as they hinder access to the invention and block improvements (Moore, 2002). This is also illustrated by Heller and Eisenberg (1998), who argue that patents constitute obstacles to future research in the biomedical sector. A common argument against this is that patentees have the right to license their inventions. Licensing implies that in return of claims on future profits (often a share of the revenues), an inventor gives the right to the licensee to adapt, produce and sell the invention. The authors however respond that licenses and patents stack up so that patent owners' rights remain present for all future developments. They call this the tragedy of the anticommons, in which one invention is owned by many agents. Additionally, licensing bargaining is a very expensive process (Gallini, 2002).

Cohen et al. (2002) find that patents can have a prevalent impact on knowledge flows. The design of the patent system is a major determinant of this. They note a clear distinction between the patent systems in the US and Japan that lead to big differences in the information flow. In Japan, patents are used for inclusion while in the US they are used for exclusion. In other words, the Japanese system has been implemented not to encourage domestic innovation but to disclose more inventions. The Japanese system has lower payoffs from infringement suits, greater technological interdependence (Japanese firms are better informed about R&D activities of their rivals), lower appropriability, pre-grant opposition opportunities and a lower grant rate. Like Hall and Ziedonis (2001), the authors argue that excessive patenting is harmful to society. The current configuration of the Japanese system allows to better cope with an excessive number of patents compared to the US.

The impact of patents on disclosure appears to be minimal too. In the US, 10 to 30% of all inventions were never disclosed (Cohen et al., 2002). This has again to do with the structure of patent laws. In the US inventors do not need to disclose their inventions before the grant of the patent. In Japan, they do. Furthermore, the risk of becoming the target of an infringement attack scares inventors away from using patent documents as source of information. This risk is lower in Japan as the payoff from infringement suits are lower. An in-depth discussion of those arguments and an overview of the literature regarding disclosure can be found in Hall and Harhoff (2012).

c) Other costs of patent laws

As patent grants create monopolies, they are also a concern for antitrust. Bittlingmayer (1988) quotes it as an "uneasy coexistence". As for antitrust laws, monopoly power should be granted very carefully and only if welfare is improved. Bessen and Hunt (2007) found, while analyzing the software industry in the 1990s, that firms that acquired most patents (read: firms with most market power) reduced their R&D expenditures. This goes in line with arguments from Acemoglu et al., (2006) Aghion et al. (2004), Aghion and Griffith (2008) and Marimon and Quadrini (2006) that barriers to entry curb innovation. Innovation is high in competitive markets as firms try to differentiate from their competitors and gain market power, and low in case of monopoly power, as there is no need to capture additional market power.

Patents marked the rise of so-called patent trolls or patent assertion entities (PAEs). Patent trolls are companies that do not manufacture the patented product but earn money from licensing or winning lawsuits when enforcing their rights. These companies try to acquire as many patents as possible, which blocks entry or use of certain innovations. Dealing with patent trolls and patent litigation is costing a lot of resources and time that could otherwise have been used for production or innovation (Chien, 2013).

Patents are often given the responsibility of unaffordable drug prices. As argued by Boldrin and Levine (2008), drugs for AIDS are sold with a large premium. Those drugs are unaffordable for many African nations but generate large profits for pharmaceutical companies in Western countries. The pharmaceutical sector gets a lot of media attention, especially due to cases such as the Belgian baby Pia, suffering from SMA type 1. The only drug capable of saving her life has been patented by Novartis and is currently sold at 2.1 million USD. The study of the advantages of patent systems is therefore crucial to answer the question whether the higher prices for certain drugs can be justified by increased innovation (and possibly better drugs being developed).

A fourth notable contribution of the literature to the patent idea is that external rewards tend to crowd-out intrinsic motivation (Deci, 1971; Bowles & Polania-Reyes, 2009). As the discussion revolves around incentives, many believe intrinsic motivation has played a major role in the evolution of technology and innovation in human history. The promise of profits is not the only motive behind innovation. The first inventions did not happen for personal profit but to improve lives of others too. Researchers have demonstrated that when a subject is intrinsically motivated, offering additional monetary rewards does reduce the extent to which the subject is inherently motivated to perform the task (Deci, 1971). As initially some inventors have high intrinsic motivation (we will discuss more about this in the following chapters), the introduction of a patent system providing monetary rewards has the potential to crowd out and reduce intrinsic motivation, resulting in a reduction in innovation. Similarly, strengthening the patent system and increasing external rewards will in theory reduce intrinsic motivation and innovation consequently.

The reform and its impact on small and medium enterprises

Small and medium enterprises (SMEs) are important contributors to innovation. In addition to quantitively affecting innovation themselves, small entities contribute to creating an innovative environment. Firm size is an important factor for R&D intensity (Foreman-Peck, 2013). But firm size also plays a role in the patent activity of firms. Figueroa and Serrano (2013) find that small businesses acquire more patents than their larger counterparts. This disagrees with a vast literature that claims the opposite. Breitzman and Hicks (2008) find that smaller firms obtain better patents in terms of growth and citation impact as well as originality. In Italy, large companies tend to obtain more patents than small firms. This is mainly caused by the difference in financial constraints (Scellato, 2007). Bigger companies have fewer financial constraints, making it faster and easier for them to acquire patents compared to small companies. This is a problem for antitrust as bigger companies can therefore more easily block entry through patents and quickly increase their market power. Difficulties for small and medium enterprises to acquire patents is also a problem as patents are an efficient instrument to attract venture capital. Patents provide security about the potential of the invention, by reducing information asymmetries between the business and the investor about the good or service produced (Lerner et al., 2015). A patent works as a proof that the product is legitimate. This reduction in information asymmetry reduces the risks of an investment (Morgan and Sandoval, 2013) for investors. Difficult access to patents creates a trap for SME’s requiring patents to attract capital but not being able to acquire them because of their financial constraints. One aim of patent reforms should therefore be to increase accessibility to patents for SME’s, through reduction in application fees and simplification of the application process. This would increase both the overall quality of patents as small companies produce better patents and increase competition through better access to finance for those small companies. As a step in the right direction, the AIA has decreased application fees for micro-entities and increased the transparency. Ashworth (2012) believes the new reduction in patent fees should enable SMEs to keep up with large companies.

Some authors mentioned that the AIA would provoke a "race to the patent office" (Ashworth, 2012) because of the switch to the first-to-file system. In such system inventors want to file an invention as quickly as possible to secure the patent. Such a race could lead to inventors submitting inventions not yet optimized. According to the National Small Business Association, large corporations have better resources and ability to quickly develop an application (Morgan and Sandoval, 2013, Lerner et al., 2015), providing them a strong advantage to win the race. Lo and Sutthiphisal (2009) match these remarks with their findings. They illustrate how a switch from FTI to FTF in 1989 in Canada caused a decrease in patents owned by small entities relative to large companies. Identical results are found in Abrams and Wagner (2013). It therefore doesn't come as a surprise that Morgan and Sandoval (2013) maintain that it was mainly large corporations such as Microsoft, IBM, Caterpillar, PepsiCo or P&G that supported the AIA. This reveals that the policy could be biased towards favoring large companies relative to small companies. It could also mean that larger companies do value innovation more and are at the forefront of lobbying for more incentives for innovation. Microsoft owns over 129 000 patents ("Open Register of Patent Ownership", 2019) and commits to the creation of a healthy patent ecosystem as can be found on their website[2]. Even so, Microsoft founder Bill Gates (1991) admitted that "if people had understood how patents would be granted when most of today's ideas were invented, and had taken out patents, the industry would be at a complete standstill today". However, Ashworth (2012) noted that the official change to FTF may not have any impact as in practice inventors already operated under such a scheme. Making the official shift should not alter their operations.

In a preliminary investigation, Lerner et al. (2015) review the implication of this act for SME's. The AIA has also increased some of the fees for reexamination procedures, which has increased the share of patents of small entities being challenged post-grant relative to large entities. This has increased the barriers for small entities to be granted patents. The reform has also made it harder and more costly for patent assertion entities to collaborate in infringing patents. Patent trolls are a big problem for small businesses as dealing with litigation takes some of the scarce resources and time away from productive activity and often results in a "significant operational impact" (Chien, 2013). This is especially relevant as PAEs mainly

[2] For more information about Microsoft patents, go to https://www.microsoft.com/en-us/legal/intellectualproperty/patents/default.aspx

target SMEs (Bessen and Meurer, 2013). This feature of the AIA could have helped reduce interference for small entities. Through their own empirical research, Lerner et al., (2015) did not find a different impact of the act on small and large entities, however.

It is not the purpose of this study to investigate the impact of the AIA on small entities. Those insights remain valuable to help us understand the mechanisms involved in patent reforms. While some changes such as the reduction in the application fee to the USPTO does not apply to universities (they are not considered as micro-entities) other features could have a strong impact on smaller universities. The analysis will reveal whether there has been a differential impact of the AIA on small and large universities.

The reform and its impact on universities

The study of universities after the AIA finds its importance in several aspects. In the past decades, university patenting has increased, partly because technology has become more dependent on science (e.g the rise of biotechnology) and because universities suffered from heavier budgetary burdens and therefore sought alternative sources of revenue. Geuna and Nesta (2006) warned about heterogeneity in the patenting intensity of universities in Europe. As we will show, this trend is also observable in the US. Those differences in patent ownership are critical. Inequality in patent ownership can cause an increased inequality in financial resources and research output (Geuna & Nesta, 2006). Universities diverging causes problems not only for the diversity of scientific research but also for the equality of access to quality education. In addition, the rise in universities owning many patents nourished the fear that universities act as patent trolls (Rai et al., 2009).

Many of the arguments against patents are based on the idea that innovation does not need additional incentives. Competition is a natural force pushing for more innovation, and first-mover advantage plays an important role in appropriating gains of an invention. What is made clear from the Innovation Systems theory is that actors react differently to incentives and have different motivations for innovating. Higher education institutions are an example of inventors motivated differently. Research conducted by universities is not intended to be transformed into profitable products produced by the researchers themselves. Murdock (2002) and Stern (2004) find that academics value research itself regardless of monetary returns and argue for intrinsic motivation. Academia has other forms of rewards that include peer review, the impact of their publications or priority rules (Dasgupta & David, 1994). Geuna and Nesta

(2006) find no evidence that university licensing if profitable for most universities. Moreover, in some cases patent application were filed by the university itself rather than by the inventors himself (Geuna and Nesta, 2006). Such an observation suggests that without patents, university inventors would still do research. And as observed previously, the introduction of patents could even harm the intrinsic motivation of academic researchers.

The Bayh-Dole act of 1980 served as a natural experiment to test the impact of the availability of patents on innovation of universities. Afore the Bayh-Dole act it was not possible for federal agencies to license any invention officially owned by the federal government. As universities are not capable of bringing their inventions to market (Ryan and Frye, 2017), licensing is their only way to capitalize on their ideas. A patent system without the possibility to capitalize on the patent is worthless from the perspective of incentives. The Bayh-Dole act therefore marks the beginning of an incentive for universities to patent their inventions. While the act clearly had a strong impact on the amount of patent applications from university researchers (Tseng and Raudensky, 2015 and Ryan and Frye, 2017), the actual evidence that patenting and licensing are critical for university inventions is weak (Mowery and Sampat, 2004). An increase in patenting has not led to better technology transfer (Colyvas et al., 2002) and had only little effect on the content of university research (Mowery et al., 2001). If impactful, the Bayh-Dole act probably contributed more to slowing innovation through deteriorating open-access, increasing costs for future research and drifting away from relevant research (Mowery and Sampat, 2004, Ryan and Frye, 2017). The widespread incentive motive to justify patents does not apply to universities (Mowery et al., 2001) and the means through which information flows between universities and firms happen mainly relate to publications, informal interaction or consulting (Mowery and Sampat, 2004). Some worry that patents weaken universities' commitment to free access of information (Foray and Lissoni, 210).

All in all, universities have different incentives to perform research from private inventors. Patents possibly do not push them towards more invention and could even negatively impact the quality and quantity of the research as well as worsen the flow of information, the equal access to education or the intrinsic motivation of researchers. In consideration of the influence universities have on basic research and the economy this information is critical. In the remainder of this paper I will investigate whether on average higher education R&D has been increased after strengthening of the American patent system.

Summary of the literature

So far I have shown that the impact of patents has been different across sectors (Mansfield, 1986; Cohen et al., 2000; Schankerman, 1998), size (Ashworth, 2012; Morgan & Sandoval, 2013; Lerner et al., 2015; Lo & Sutthiphisal, 2009) and status (Geuna & Nesta, 2006; Dasgupta & David, 1994). This mainly relates to the complexity of innovation (Cohen et al., 2000) and the costs. Especially in sectors such as pharmaceuticals, biotechnology the costs are very high and some incentive system is needed (Martin & Scott, 2000; PhRMA, 2013; Grabowski, 2002), but the current system intellectual property system may not be the one (Aghion et al., 2008, Heller & Eisenberg, 1998).

The design of the patent laws is critical for success (Cohen et al., 2002). The strength of the patent system is one of the factors affecting innovation (Gallini, 1992; Qian, 2007; Furukawa, 2010). But, when referring to patent length, the distinction between statutory patent length and effective patent length needs to be made. Effective patent length is a much more accurate measure as it accounts for the breadth of the patents but also the costs of renewal of the patent (Encaoua et al., 2003). These characteristics certainly weight in the success of patent laws, as do many other criteria unrelated to patent strength. History and the context of the economy play a role in the determination of the costs and benefits of patents (Hall & Harhoff, 2012). Changes in competitiveness, innovativeness and health of the economy affect many of the mechanisms discussed previously. The complementarity with other laws and institutions such as antitrust also matters. Features such as post-grant reviews are mechanisms that can reduce the impact of the mistakes made by the patent authority during the patent examination period (de Rassenfosse & van Pottelsbergh de la Potterie, 2007) and their importance in the efficiency of patent laws should not be understated. The factors determining patents are thus numerous, making it difficult to design an optimal policy. In the words of Encaoua et al. (2003): "optimal patent protection differs across inventions".

Overall, the evidence portrayed above indicates that innovation could still be present without property rights and could even be spurred in some industries. It also shows that patents have potential negative impacts on productivity, equality, competition, innovation and overall welfare. Dealing with patent applications and litigation can even lead to a waste of resources. The net effect of patent systems for businesses on welfare is ambiguous. It seems, however, that the quantity and quality of research at universities is deteriorated by patent laws, which I will investigate in the following sections.

4. Data

The dataset has been put together by combining multiple sources. The USPTO (US Patent and Trademark Office) provides data on patents owned by each American university until 2012. This dataset has been used previously in Ryan and Frye (2017) for their analysis on the AIA. The HERD survey (Higher Education Research and Development) reports the R&D expenditures from each American university until 2018. Information regarding enrollment numbers has been retrieved from the Digest on Education Statistics of 2010 from the National Center for Education Statistics (NCES) and the university rankings have been obtained through the Times Higher Education World University rankings of 2012-2013.

One of the limitations of the dataset in this paper is that it only counts 280 American universities. With observations ranging from 2009 until 2018 it adds up to a total of 2800 entries on R&D expenditures. Many universities do not appear in the USPTO dataset possibly indicating that those universities have no patents. Therefore, universities with many patents will be overrepresented in this analysis, causing a threat to the external validity. With far above 1000 universities and colleges operating in the United States I only capture a small proportion of American universities in this research. A second limitation of the data is the absence of explanatory control variables. While there are in reality many variables that could affect R&D expenditures of an university, much of this data is not available publicly. Another factor is the complexity of the American universities. Many universities have many campuses more or less independent from each other. This results in some data being published by campus or school and some data being published at the institution level. The absence of explanatory covariates is a threat to the validity of this analysis.

Conceptual definitions

a. Innovation

In this paper innovation is described as the production of new knowledge and ideas. This definition has been inspired by the one described in Baregheh, Rowley and Sambrook (2009) as follows: "Innovation is the multi-stage process whereby organizations transform ideas into new/improved products, service or processes, in order to advance, compete and differentiate themselves successfully in their marketplace". Their definition is rather restrictive as it excludes research activity that does not lead to production by the researcher from being innovation. In this article the subjects of interest are universities and most universities do not use the new ideas they create to produce new products, services or machines.

A patent system aims at incentivizing innovation. In other words, the goal is to positively impact the intentions to innovate which in turn affects innovation. Therefore, in this paper, I will investigate the impact of the AIA on innovation effort of universities as measured by their R&D expenditures. Innovation and intentions to innovate vary greatly in their definitions and the distinction is of uttermost importance. Much previous research considers innovation only and uses patents as a proxy for innovation. While this is not possible here as patents are our main variable of interest, there is anyway no consensus on the fact that patents do accurately reflect innovation. As indicated by Ahmed and Mahmud (2011), using patents as a proxy for innovation leads to an underestimation of the innovation effort as not all innovations are being patented. The most accurate variable for innovation is a variable similar to the one used in Foreman-Peck (2013), where companies were surveyed about the amount of innovation they implemented in the year. This would range from new products or processes to any small innovative improvement. The issue with this variable is that there is an unknown time lag between the investment and the return. This time lag could range from months for some invention to decennia for others. Using R&D expenditures tends to overestimate innovation, as not all R&D results in innovation (Flor and Oltra, 2004 and Kleindrecht et al., 2002).

All three variables described above intent to measure innovation output. A patent system aims at incentivizing innovation. In the case of the AIA, we want to observe the efficiency of the incentives, not the output of the inventors. We are therefore interested in the change in effort exerted by the inventors and researchers rather than a change in output. A difference in output can be determined by a difference in productivity for example. Patent systems have no impact on the productivity of inventors, rather they aim at increasing innovation effort. In this paper innovation will therefore be proxied by R&D expenditures.

b. Research and development

The HERD survey defines R&D expenditures as being any expenditure incurred with the aim to increase the stock of knowledge and devise new applications of knowledge. This does not include the costs involved with public service or outreach programs, curriculum development, non-research training grants nor capital projects. There are three main categories of R&D: basic research, applied research and experimental development. This research will cover R&D as the sum of those three categories as no data was available for each specific category.

c. Patents

There are three categories of patents: utility patents, design patents and plant patents. The university data obtained through USPTO only covers utility patents which are the most common form of patents applied for and are patents for any new or improved product or process that does not fall in the design or plant patent categories. Design patents protect new shapes or configurations of products and plant patents protect the creation of new living organisms having roots and using photosynthesis. In this dataset patents refer to the count of utility patents that have been granted in that year. Accordingly, we do not observe the total count of patents owned by a university but the number of patents granted to them by the USPTO in 2012.

d. University size

In the remainder of the analysis, I want to investigate whether there is a difference in effects by university size. I will classify universities in two groups, “large” and “small”. In order to do so, the first step is to understand which variable represents the best fit as a proxy for university size. Enrollment and ranking are two available variables that theoretically could explain differences in size of universities. Enrollment correlates to the teaching and administrative effort required from the university, as well as the revenues it makes. Ranking in on the other hand does not indicate about the academic staff but provides a good projection of the quality of the teaching and research performed, as well as the quantity of research grants received. I run a simple regression of enrollment and ranking on the natural logarithm of R&D in 2018 to see which variable predicts best R&D and therefore which variable I will use as a proxy for university size in the next steps. Enrollment barely predicts R&D in 2018 as the estimate is very close to 0 (0.59E-6). Ranking does predict R&D better as an increase of 1 in the ranking (meaning being ranked one university lower) reduces R&D expenditures by approximatively 0.43%. In the following steps I will therefore use ranking as a proxy for university size. This proxy is needed in order to carry forward the analysis of a differential impact of the AIA on different university sizes, which could potentially indicate an increase or decrease in university equality.

The university rankings have been retrieved from the Times Higher Education World University Rankings. This ranking bases its judgement on the scores of the universities across all core missions. This includes teaching, research, knowledge transfer and international outlook. With the focus of this paper lying on innovation, the scores on research and knowledge transfer are most relevant. The top 94 universities are considered as the large universities and the remaining 186 universities as small.

Descriptive Statistics

Table 1 provides a description of all the variables used for the analysis. A first glance at the descriptive statistics already suggests high inequality of patent but also R&D distribution. As seen from table 2 the disparity between the mean and the maximum patents is much larger than between the mean and the minimum. This distribution shows a strong skew and suggests big outliers. The same holds for R&D expenditures. The data also allows to investigate the evolution and we see that total R&D expenditures have increased by 34,66% between 2009 and 2018. This dataset contains many universities with null patents and a few with null R&D expenditures in certain years. The fact that there are more universities without patents than without R&D spendings implies that some universities own no patents but still have positive R&D expenditures. This suggests that owning patents is not a prerequisite for undertaking innovative activities (there are multiple reasons why a university owns no patent which are detailed in section 5). This questions again the efficiency and necessity of patent systems. In the following sections I will use the log transformation of the R&D and patent variables as I am interested in growth rates. Having observations with 0 as value is a problem for log transformations as the natural logarithm of 0 is undefined. I therefore use ln(1+x) instead.

Table 1: Variable description

Dependent variable	
rd	R&D expenditures of the university expressed in thousands USD
Independent variables	
l.rd	First lag of the *rd* variable
i.id	University fixed effects
i.year	Time fixed effects
patent	The number of patents held by the university in 2012. In the baseline specification this variable is used as the measure of exposure to the policy.
treat	= 1 if treated (years 2013 and after), 0 if otherwise. The AIA was implemented in 2013. A university in considered as treated after the implementation of the policy.
year	Year, from 2009 to 2018
*log(patent)*treat*	Interaction variable of log(patent) and time. In the baseline specification this variable captures the effect of a marginal increase in exposure (increase in patents owned in 2012) on the marginal change in R&D expenditures after the introduction of the policy.
nopatent	= 1 if the university owns no patents in 2012, 0 if otherwise
topdistribution	= 1 if the university is part of the top 7% of the patent distribution in 2012, 0 if otherwise

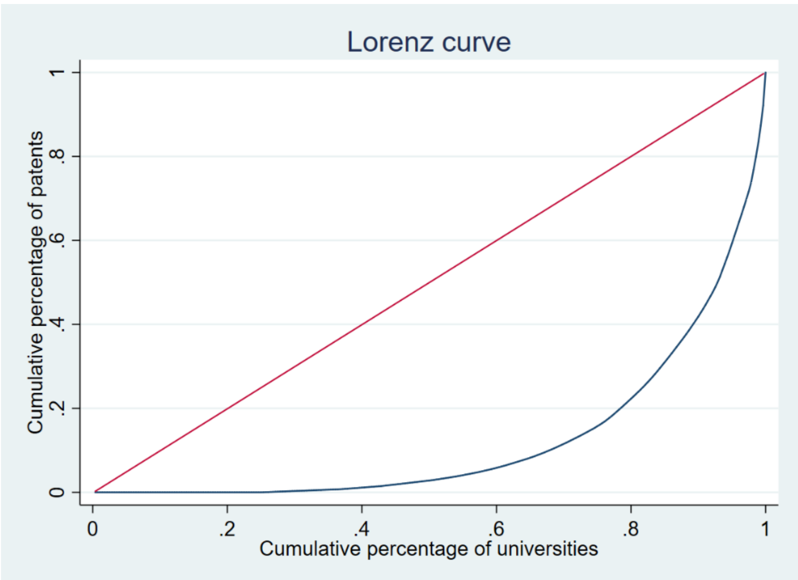
Table 2: Descriptive Statistics
Standard deviations for the mean can be found in parenthesis below

	All universities			Public universities only			Private universities only		
	Mean	*Min*	*Max*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
Patents	16.19 (34.85)	0	357	16.66 (36.46)	0	357	15.54 (32.61)	0	216
R&D in 2009	184,358.5 (408,814.2)	877	5,104,208	209,204 (491,846.9)	1045	5,104,208	151,735.1 (261,349)	877	1,866,243
R&D in 2018	273,723.2 (560,874.3)	416	6,816,402	320,223 (651,765.6)	416	6,816,402	222,872.9 (398,605.2)	941	2,661,033
Observations	280			163			117		

Note: Variable definitions are given in table 1
Source: USPTO 2019 and HERD 2019

Figure 2 portrays the Lorenz curve of the ownership of patents by universities. The red line indicates the 45-degree line of perfect equality. The further away our Lorenz curve from this 45-degree line, the higher the inequality. In our dataset patents seem to be highly unequally distributed as we can read from the figure that about 20% of the patents is owned by 80% of the universities. As a point of reference, de Nardi, Ren and Wei (2000) find that in the US, 80% of the population owns around 50% of the income. In the US, patents are thus even more unequally distributed than income.

Figure 2: Lorenz curve of patent ownership of US universities



I observe that 7,29% of universities own 50,81% of all patents in this merged dataset. The R&D expenditures are also unequally distributed but to a smaller extend than patents. 8,68% of the universities spend 50,27% of all R&D expenditures in 2009, against 9,72% for 51,21% in 2018. Even though smaller, the inequality of R&D expenditure remains very high. Over the 10-year period, R&D expenditures have become slightly more equally distributed. This finding of heterogeneity in patent ownership at universities in the US is in line with the similar finding in Europe from Geuna and Nesta (2006). As discussed in the literature review, this high inequality for both patent ownership and R&D expenditures does raise concerns as it may engender an increased inequality in financial resources and research output. With knowledge comes power, especially in the case of higher education institutions. In terms of research, independence comes under threat if a couple of entities produce most of the output. The more equal and even the knowledge production across institutions the better independence can be guaranteed.

The differences between private and public universities are not big in terms of patents. However, we see that R&D expenditures do vary and that public universities tend to spend more on R&D than private universities. This is however in absolute terms implying it does not take size nor budget into account (table 2). More insights about differentials across private and public universities are provided in table 3. Public universities spent on average 25,599,000 in 2012 R&D spending per patent they held. This number is only of 16,055,000 for private universities. This could imply that private universities are much more efficient at allocating their resources for research or that private universities patent their inventions more often, or both. While R&D expenditures increased over the period 2009 to 2018, they increased by around 39,09% while only by 28,07% for private universities. An increase of R&D by about 40% in 9 years is a significant change. This illustrates the shift our economy is making towards a knowledge-based economy.

Table 3: R&D expenditures per patent

R&D expenditures per patent	*Mean*	*Std. Dev.*	*Min*	*Max*
Public universities	26,200.09	30,958.28	522	182,560
Private universities	16,438.02	25,598.53	640	209,040

Note: R&D is expressed in thousands USD
Source: USPTO 2019 and HERD 2019

5. Methodology

a. Empirical specification

The AIA as mentioned has been a very comprehensive reform. Except from the fact that micro-entities benefit from a fee reduction, there is no heterogeneity in the reform. As no university qualifies for the micro-entity status, I conclude that the changes of the AIA applied to all subjects to the same extent. This causes problems for causality as we clearly lack a counterfactual. The baseline specification of this research has been inspired by the work of Ryan and Frye (2017). They empirically analyze the impact of the Bayh Dole act and the AIA on patent activity of universities. A significant difference between both studies is that I use R&D expenditures instead. I believe patent activity is a bad measure of innovation. Patent data is however very relevant for the analysis. I use the number of patents owned prior to the AIA as a source of exogenous variation which will serve as a measure of exposure to the policy. I interact this variable with time to create the treatment variable. The methodology used here is relatively similar as it uses both time and university effects and uses an interaction variable. However, Ryan and Frye use spline regression as their main tool of analysis.

The baseline specification to answer the central question is as follows:

$$(4) \qquad \ln(1+RD_{it}) = \beta_0 + \mu_i + \lambda_t + \beta_1(\ln(1+patents_i)\times treat_t) + e_{it}$$

I am interested in the growth rates of R&D expenditures and therefore log-transform the dependent variable. As some universities have no R&D expenditures or patents, taking the natural logarithm of (1+x) is necessary. The interpretation is made difficult by the fact that many universities have no patents. In the case of R&D only few universities do which should not affect the interpretation of the results (Woolridge, 2012). As discussed in the data section, the data lacks good explanatory control variables. In order to deal with this I include university fixed effects μ_i which allows to control for many unobservables fixed over time. For instance the university management, the size, the location or revenue of the university could all play a role in the determination of R&D expenditures and are captured by this variable. It also covers the number of patents, and the type of the university (private or public) which has shown to be an important factor of R&D growth in section 3. The variable λ_t takes care of the time fixed effects. There are for example many macro variables such as unemployment rate, inflation rate or federal budget imbalance that influence the innovation climate. Time fixed effects allow to control for these factors and other unobservables that affect all universities identically.

It is very likely that universities follow certain strategies and aim to increase their R&D expenditures by a constant amount over time. Or on the other hand that some universities decide to never increase their R&D expenditures. Also, the amortization of big projects may result in R&D expenditures may result the growth in R&D expenditures being flattened. This implies there are possible trends in R&D expenditures. Including one lag of the dependent variable allows to account for those trends. The issue with including the first lag of the dependent variable in a model with fixed effects is that the estimates may suffer from the Nickell bias (Nickell, 1981). This bias is the result from the lagged dependent variable being dependent from the error term. It is important to recall this possibility before taking any conclusions regarding the interpretation of the results.

In the event of anticipation of the AIA by universities, our estimates would be biased. The AIA has been announced in the third quarter of 2011 and the main changes occurred in 2013, not leaving room for anticipation. As yearly budgets are set at the end of the calendar year, universities could only have set new R&D budgets by 2012. The fact that this law was phased-in over two years makes the analysis more difficult. To account for possible anticipation, I will run a separate specification including time dummies ranging from 2009 to 2018 instead of a treatment dummy. This specification will allow to obtain estimates for each specific year which will also indicate if the effect persisted over time. The estimates from before 2013 show whether there was an anticipation of the policy. If the estimates of the pre-AIA years have statistically different from 0 values, we can conclude there are anticipatory effects. Similarly, if the estimates of the years following the AIA are statistically different from 0 we conclude that there was a long-term effect of the policy. Sometimes policies only have a short-term impact on an outcome variable and the values go back to normal in the years following the policy. With this specification I can see whether the impact of the AIA on R&D expenditures persisted over time or was only a short-term effect. As policies such a patent reforms aim to increase innovation in the long-term, knowing the persistence is necessary to determine the success of the intervention.

b. Assumptions

In order to use the AIA (time) as a treatment variable it needs to satisfy several conditions. The treatment should not be correlated with any other independent variable, which isn’t the case here. The first lag of the R&D expenditures is the only other variable correlated with time, but it is related to t-1 and not t. Another assumption, conditional independence, implies no correlation between the treatment variable and the error term. In other words, there should be nothing affected by time that also affects the growth of R&D through another variable absent from the model. An example of this is if another reform happening at a specific point in time impacted the productivity of researchers, implying a university needs to spend more or less on R&D for the same return. Bloom, Jones, Van Reenen and Webb, (2017) find that research has become less productive. It is quite likely that other events had an impact on R&D too as it is volatile and pro-cyclical. There are both macro and micro variables that impact the private sector R&D: unemployment rate, inflation rate, government budget imbalance, firm size, competition intensity, R&D subsidies, spillover effects… (Wang, 2010 and Becker, 2013). We are interested in only a couple of those, that seem to have especially a big impact on universities. As universities are partly government funded, government budget imbalance plays a prevalent role. The fiscal cliff of 2012 occurred amid the implementation of the AIA. The US federal budget deficit has been decreased from 8.3% of GDP in 2011 to 2.7% in 2014. This could have both positive and negative impacts on R&D expenditures. On one hand, a lower budget deficit being good for the economy, universities may gain confidence in the future and increase their investments in R&D. On the other hand, a lower budget deficit may imply a cut in expenditures in education. With reduced funding, universities could reduce R&D expenditures. R&D subsidies and changes in the tax base play a minor role as most universities and colleges are exempt from income taxation. They qualify as tax-exempt charitable organizations as they have scientific and educational purposes. Institution size can also be disregarded as we observe growth rates. The major problem we face are spillover effects. Universities often share information and benefit from each other's research. However, I assume spillover effects are relatively stable over time and have not increased significantly in 2013. When having a look at national unemployment and inflation rates, 2013 did not present strong fluctuations. We can still however not exclude the consideration that there may have been other events that impacted R&D in this period. This has been mentioned previously as one of the limitations of the data. The impossibility to control for additional explanatory variables reduces the validity of the future results.

This model may suffer from heteroskedasticity. The latter implies that the variance in the error terms is not constant. It could be dependent on one of the independent variables of the model. Here, it is likely that the variance in the error terms becomes higher as time increases. Differences in R&D expenditures becomes more pronounced over time if some universities do not change their expenditures while other universities increase them every year. Also, I suspect the error terms to be correlated. This implies that the error term of year t is correlated to the error term of year t+1. If an event occurred in year t and persisted in t+1 we have serial correlation. For example, a shock such as a change in university management could affect the R&D expenditures in that year but also in the next years. To account for both heteroskedasticity and serial correlation I cluster my standard errors at the university level. I choose to cluster at the university level rather than clustering using time because this variable has 280 clusters compared to 10 for time. Angrist and Pischke (2008) maintain that a minimum of 42 clusters is necessary.

c. Robustness of the measure of exposure

Another assumption of this paper is that patents is an accurate measure of exposure to the policy. This variable has several advantages and disadvantages. The number of patents owned reflects the degree of involvement of a university with the current patent system. Therefore, I expect universities owning many patents to be more affected by a patent reform such as the AIA. However, there is heterogeneity in the reason why a university owns no or few patents. First, the university could have nothing to patent because of low or no innovation. In theory this would be solved with a patent system. By providing incentives to innovate patent systems should care of such institutions that do not innovate. As a patent system is already operational in the US, this first reason for no patents would indicate that it fails to encourage innovation. Second, the university could have nothing to patent because of luck. Research and development are unpredictable, and some years inventors do not invent anything. Or if a university loses the "patent race" (if the university has been working on a new product for years, but just before they could finish the product another inventor, who was unknowingly also working on the same invention, finished the invention and patented it first). Third, the university could have applied for a patent and not have been granted it. This could be caused by problems with the product or process itself. This could also be related to litigations with other inventors. A big gap between the number of patent applications and patent grants is evidence for efficiency problems in the patent system. Divergence of expectations between inventors and patent authorities, asymmetric information, miscommunication could all be causes. Either way, this indicates that the patent system fails. Fourth, an innovative university could prefer not patenting. This could be caused by other and stronger motives for innovating such as intrinsic motivation or simply the desire to openly share their inventions to the world and allow for contributions of other inventors. To summarize: some universities own no patents. This could be due to luck, unsuccessful or inefficient patent systems, or preferences of inventors. Understanding this is key for the continuation of this research. If the patent count differs across universities because of luck or preferences of inventors, patents will not be an accurate measure of exposure. However, with luck being by definition random and the number of researchers at universities being quite large, I do not expect a university to have much better luck or very different preferences from others.

There are two other possible variables to generate cross-sectional variation that both use patents but for which the definition changes slightly. Instead of using the patent count I can use a dummy variable for the universities owning no patents against universities owning at least one patent. Another possibility is a dummy for universities at the top 7% of the patent distribution against the other 93%. Both being dummies allow to simplify the interpretation of the results as a log transformation is not necessary. The first dummy makes a distinction between universities not making use of the patent system and universities making use. One limitation, as discussed before, concerns the fact that not owning patents does not necessary imply that the university is not interested in patents (consider a patent application being rejected). The second dummy would consider strong inequality in patent distribution amongst universities. One of the disadvantages with this dummy is that the two universities right below and above the cutoff of 7% only differ by 1 patent held. There is no evident distinction between those two universities. In both cases we lose precision. The patent variable in the baseline is continuous allowing for better disaggregation. I will test both dummies in the robustness section.

6. Results

a. Baseline specification

We first observe the estimates from our baseline specification. Table 4 reports estimates of regressions with and without the first lag and fixed effects. While the fixed effects seem to have little impact on the size of the estimates of the interaction variable, the first lag significantly reduces them. Adding lags to regression (4) brings the estimate down from 0.0371 to 0.0164. A 1% increase in exposure to the AIA (increase in patents owned) increases R&D expenditures at universities by 1.64% on average. The coefficients are significant at a 1% level. It is difficult to interpret this as a causal effect. From this primary result it seems the AIA had a considerable positive impact on R&D expenditures for universities making use of the patent system. A 1.64% increase in expenditure corresponds to an increase around 2.5 million USD per university on average (using 2009 numbers). This finding suggests that a stronger patent system does incentivize innovation. This does not correspond to my first hypothesis but nor does it coincide with the literature. A similar policy shift made in Japan in 1988 has not increase R&D expenditures (Sakakibara and Branstetter, 1999). While their study did not focus on universities contrary to this one, the Japanese reform was also a case of strengthening the patent system. As the results diverge, the context in which the policy shift occurs seems to play an important role in R&D determination. One explanation relates to the "inverted U" shape of the relationship between patent strength and innovation. The US and Japan have very distinct patent laws and therefore are located on different areas on this curve. It seems like Japan was positioned near the tipping point of the curve, while the US are positioned under it. Following such reasoning, the patent system in Japan in 1988 was stronger than the US patent system in 2013. The coefficient of the first lag of R&D is equal to 0.6029. This implies that the R&D growth of the preceding year determines roughly 60% of the current year's R&D growth. In other words, the persistence of R&D growth from one year to the next is around 60%.

De value of the overall r-squared reaches 99.27% in regression (5). This high value could indicate issues with the specification. First of all there could be a trend in one of the dependent or independent variables. As mentioned, I believe there is a trend in R&D expenditures which is the reason the first lag had been added as a dependent variable. Second, it could be that the amount of patents owned predict R&D expenditures too well. If a variation in patents explains almost all of the variation in R&D expenditures the r-squared is very high. However as R&D expenditures do vary over time and the amount of patents variable is fixed (it represents the amount of patents held in 2012) I do not think the patent variable is a very good predictor of R&D expenditures. I perform a check by regressing patents on R&D expenditures and find an estimate of 0.79. This implies that a 1% increase in R&D expenditures leads to a 0.79% in patents owned. This is a high correlation between R&D expenditures and patents owned but does not justify the high r-squared value. Another reason for this high value could be that our model has many independent variables due to the fixed effects. A better option is therefore to use the adjusted r-squared. As we see from table 4, the adjusted r-squared is lower and equals 0.9869. The value is still very high and the possible causes being numerous, I decide to not take any conclusions based of the r-squared values in this article.

Table 4: Baseline specification estimates

	(1)	(2)	(3)	(4)	(5)
log(1+patent)	1.0643*** (0.0418)	-	1.0635*** (0.0419)	-	-
treat	0.0096 (0.0348)	0.0107 (0.0358)	-	-	-
l.log(1+rd)	-	-	-	-	0.6029*** (0.1051)
*log(1+patent)*treat*	0.0374*** (0.0115)	0.0363*** (0.0119)	0.0382*** (0.0115)	0.0371*** (0.0119)	0.0164*** (0.0059)
University fixed effects	No	Yes	No	Yes	Yes
Time fixed effects	No	No	Yes	Yes	Yes
Observations	2800	2800	2800	2800	2500
Overall R-squared	0.6671	0.9849	0.6676	0.9854	0.9927
Adjusted R-squared					0.9869

All panel data regressions are including the intercept.
The quantities in parenthesis below the estimates are the robust standard errors clustered at the university level.
***, **, * denote statistically significant effects at a 1%, 5% and 10% level respectively.

In the next step I replace the treatment variable with a categorical variable for years to see how persistent the effect was and whether some of it was anticipated. The results displayed in table 5 showcase the persistence of the effects. There are positive effects starting from 2013, indicating there was some anticipation although the results are insignificant. Only in 2018 the estimate is significant at a 5% level. We read that during the period 2010 until 2018, the total effect on R&D expenditures increased was 2.71% on average. This estimate is much higher than the 1.64% obtained previously. Figure 3 illustrates how the increase only happened around 2016. This is a primary indication that the AIA had long-term effects on R&D. This could be caused by different factors. First, the budgets of universities are rigid, causing universities being unable to quickly change their budgets. Since the beginning of the 21st century universities have started becoming more financially constrained. Especially after 2008, federal budgetary cuts and austerity measures became popular, causing universities to reorganize their budgets. Also, budgeting periods may vary across institutions, causing some delay in the reaction to the policy. However, the more years we look at, the higher the chances that other events occurring in this time period have impacted R&D expenditures, making it more difficult to interpret these estimates as causal.

The estimates indicate an initial negative impact in 2011 and 2012. Ryan and Frye (2017) find a similar pattern with their study of patent reforms of patent acquisition of academic institutions. They demonstrate how universities anticipated the policies and reduced their patent activity prior to the implementation and increased it immediately after. By acting strategically and holding up to their patents, universities expect to appropriate more gains on their inventions after the policies have been implemented. Following the authors this rent-seeking behavior is problematic for innovation. In figure 3 however we see that the increase in R&D did not really happen immediately after the policy. This could be because research and development expenditures are more rigid than patents meaning it is more difficult to delay R&D expenditures than it is to delay patent applications. Furthermore, considering the time needed to translate research expenditures into innovative output it makes little sense to reduce the expenses one or two years before the policy is implemented. Ideas can still be created and kept private until the implementation.

Figure 3: Baseline estimates

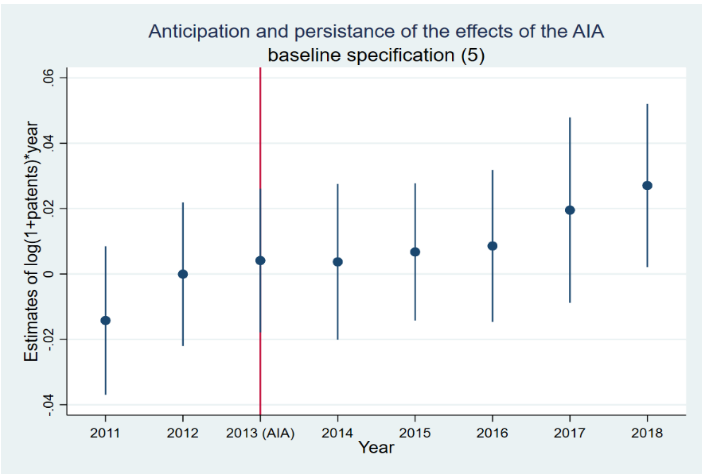


Table 5: Anticipation and persistence of the effects

	(5)	(6)	(7)	(8)	(9)
l.log(1+rd)	0.6029***	-	-	-	0.6001***
	(0.1051)				(0.1040)
log(1+patent)	-	1.0507***	1.0506***	-	-
		(0.0439)	(0.0439)		
*log(1+patent)*treat*	0.0164***	-	-	-	-
	(0.0059)				
*log(1+patent)*year*					
2010	-	0.0164	0.0164	0.0109	-
		(0.0140)	(0.0140)	(0.0137)	
2011	-	0.0118	0.0118	0.0046	-0.0142
		(0.0140)	(0.0139)	(0.0133)	(0.0115)
2012	-	0.0223	0.0222	0.0151	-0.0001
		(0.0148)	(0.1476)	(0.0144)	(0.0111)
2013	-	0.0327**	0.0327**	0.0255	0.0041
		(0.0159)	(0.0159)	(0.0155)	(0.111)
2014	-	0.0386**	0.0386**	0.0314*	0.0037
		(0.0168)	(0.0168)	(0.0166)	(0.0121)
2015	-	0.0379**	0.0379**	0.0374**	0.0067
		(0.0182)	(0.0182)	(0.0175)	(0.107)
2016	-	0.0506***	0.0505***	0.0434**	0.0086
		(0.0188)	(0.0188)	(0.0188)	(0.0117)
2017	-	0.0651***	0.0651***	0.0579**	0.0195
		(0.0226)	(0.0225)	(0.0230)	(0.0144)
2018	-	0.0814***	0.0814***	0.0741***	0.0271**
		(0.0239)	(0.0239)	(0.0245)	(0.0127)
University fixed effects	Yes	No	No	Yes	Yes
Time fixed effects	Yes	No	Yes	Yes	Yes
Observations	2800	2800	2800	2800	2500
R-squared	0.9927	0.6678	0.6678	0.9855	0.9927

All panel data regressions are including the intercept.
The quantities in parenthesis below the estimates are the robust standard errors clustered at the university level.
***, **, * denote statistically significant effects at a 1%, 5% and 10% level respectively

b. University size

Universities are now classified in two different groups. The "large" universities count the 94 universities being ranked highest. The "small" universities include the remaining 186 ones. As discussed in section 2, it is believed that the AIA does favor the big universities compared to the small universities. The second hypothesis therefore states that small universities reduce their R&D while large universities increase them. This section will investigate this hypothesis. From table 6 we see the differences in estimates obtained across both groups. While all coefficients are highly insignificant, the magnitude of the effects still provide an interesting image. Figures 4 and 5 plot those estimates for an overview of their evolution.

Table 6: Effects by university size

	Small universities (10)	**(11)**	**Large universities (12)**	**(13)**
l.log(1+rd)	0.4975***	0.4981***	0.9454***	0.9422***
	(0.0739)	(0.0724)	(0.101)	(0.1004)
*log(1+patent)*treat*	0.0029	-	0.0309	-
	(0.0138)		(0.0196)	
*log(1+patent)*year*				
2011	-	-0.0375	-	0.0193
		(0.0227)		(0.0216)
2012	-	-0.0292	-	0.0161
		(0.0232)		(0.0177)
2013	-	-0.0339	-	0.0361*
		(0.0236)		(0.0189)
2014	-	-0.0283	-	0.0153
		(0.0276)		(0.0162)
2015	-	-0.0171	-	0.0216
		(0.0262)		(0.0166)
2016	-	-0.0261	-	0.0509
		(0.0251)		(0.0615)
2017	-	-0.0180	-	0.1041
		(0.0276)		(0.0766)
2018	-	0.0057	-	0.0307**
		(0.0284)		(0.0137)
University fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Observations	1860	1860	940	940
Overall R-squared	0.9884	0.9885	0.9774	0.9891

All panel data regressions are including the intercept.
The quantities in parenthesis below the estimates are the robust standard errors clustered at the university level.
***, **, * denote statistically significant effects at a 1%, 5% and 10% level respectively

Figure 4: Small universities estimates

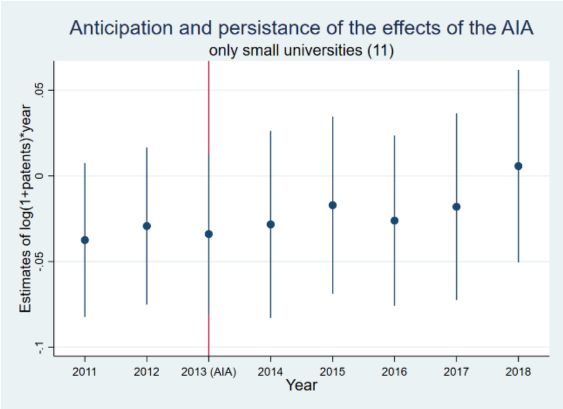
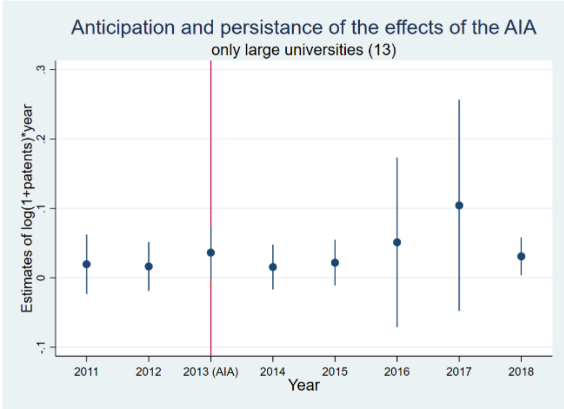


Figure 5: Large universities estimates



A first glance at the estimates shows us the magnitude of the effect is remarkably different. The estimates for the top 94 ranked universities are positive throughout the whole period, reaching 10% in 2017. In 2018 this decreases back to 3%. This implies that between 2009 and 2017, R&D expenditures of the universities being part of the largest 94 universities have increased by 10.41% on average for every 1% increase in exposure to the policy. Very interestingly, universities not part of the top 94 universities have been negatively impacted by the policy until 2018 where the estimate equals 0.57%. In 2017 the difference in estimates between small and large universities was more than 12 percentage points. This is a significant difference. In 2018 this difference drops back to 2.5 percentage point approximatively. While considerably lower than 12 percentage points, this difference remains large. Even though the estimates are insignificant, the largest universities had their R&D expenditures increased more than the smaller universities. This corresponds both to my hypothesis and to the theoretical arguments formulated in the literature that argues that large entities benefit more from patent system than small entities.

In terms of anticipation of the policy, small universities have an estimate of -3.75 in 2011 implying a considerable negative anticipation. Large universities have a positive estimate of 1.93%. This difference of anticipation is hard to interpret. As argued previously there are few reasons for universities to reduce their R&D spendings before the policy and increase them right after. We do not make this observation. Instead, it seems that universities anticipated the impact the policy would have on their R&D spendings and adjusted them immediately. Small universities kept the R&D growth negative for seven years while large universities kept it positive. Although none of the estimates are statistically signficant, they point towards high heterogeneity in effects with respect to university size.

Larger universities seem to take more advantage from stronger patent systems than smaller universities. This could be caused by difficulties for smaller universities to access patents or by increased value of patents for large universities. The AIA has increased the average cost for several activities of the patent process such as the fees for reexamination procedures. Challenging someone else's patent has become more expensive. This implies that smaller and more financially constrained universities are less able to engage in a reexamination procedure against other inventors. The probability of ever losing a patent due to reexamination procedures is the product between the probability to lose the case once the procedure initiated and the frequency a patent is subjected to a reexamination procedure. Lerner et al. (2015) observed the AIA has led to small universities being more targeted by reexaminations than their larger counterparts. Ceteris paribus, the likelihood of losing a patent because of a reexamination procedure has increased for small universities relative to large universities. The profitability of patents has therefore increased for large universities relative to small universities. In response to those changes, large universities have increased their demand for patents, by increasing their R&D, more than small universities.

Next, the switch to a first-to-file system grants the patent to the first inventor to file the application at the USPTO. Large universities have better legal and administrative resources to file an application, while small universities need more time to gather the resources to pay the application fees. The switch in system caused inventors to become more competitive. It is therefore realistic to expect small universities to lose against the larger universities because of their endowment differences. and win the race. Again, aware of their new comparative advantage, large universities increase their R&D spendings relative to small universities.

While in this analysis nothing can be proven regarding SME's, I suspect this observed difference in effect between small and large universities to be larger for universities than for private inventors. Private inventors have other means of appropriating gains (Cohen et al., 2000) such as secrecy and lead time, that universities don't have as they don't produce themselves. A major implication of this distinction is that universities rely more on patents to appropriate gains and make R&D activities profitable. SME's could turn towards such activities instead of patents once patent systems are strengthened. Because of the lack of alternatives for universities, the ability of a university to obtain a patent is more correlated to its R&D expenditures than it is for private inventors.

7. Robustness checks

The whole previous analysis is based on the expectation that patents are a good indicator of exposure to the AIA. Two other alternatives could have been used, one being a variable regarding whether a university owned a patent or not. This variable splits the universities in two categories. Universities that did not have any patent in 2012 against the universities that did have at least one. The advantage of this measure is that it compares universities being totally absent from the patent system to universities using it. However, some universities could not have patents in 2012 while being granted many in 2011 and 2013 because of the randomness of the timing of inventions. The second alternative is distinguishing between universities at the top of the distribution and those below. The top distribution here refers to the top 22 universities that own over 50% of all university patents. As shown in the data section, patents are highly unequally distributed. This variable allows to make a clear distinction between the big patent users and the moderate users. Table 7 displays the results of the baseline regression ran with all three sources of exogenous variation.

Table 7: Robustness check

	(5)	**(14)**	**(15)**
l.log(1+rd)	0.6029***	0.6076***	0.6064***
	(0.1051)	(0.1049)	(0.1051)
*log(1+patent)*treat*	0.0164***	-	-
	(0.0059)		
*Nopatent*treat*	-	-0.0093	-
		(0.0303)	
*Topdist*treat*	-	-	0.0537**
			(0.0211)
University fixed effects	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes
Observations	2800	2800	2800
Overall R-squared	0.9927	0.9926	0.9927

All panel data regressions are including the intercept.
The quantities in parenthesis below the estimates are the robust standard errors clustered at the university level.
***, **, * denote statistically significant effects at a 1%, 5% and 10% level respectively

We note that using top distribution leads to a much larger effect of the AIA on R&D expenditures, around 3.6 times higher. This number already hints towards the idea that the biggest universities in terms of patents benefit most from a strengthening of the system. Using the "no patents" variables provides estimates with a lower magnitude. The interpretation of this variable is as follows: the AIA decreased R&D expenditures by 1.8% on average for universities owning no patents relative to universities owning at least one. This percentage is 1.64% for our baseline specification and 5.37% when using the top of the distribution. The estimate using the no patent dummy is statistically significant. I therefore all previous regressions again using the top of the distribution to see whether the estimates are significantly altered. Table 8 reports the new estimates.

Table 8: Robustness of the effects by university size

	Small universities (16)	**(17)**	**Large universities (18)**	**(19)**
l.log(1+rd)	0.4956***	0.4959***	0.9560***	0.9560***
	(0.0738)	(0.0743)	(0.1056)	(0.1055)
*topdist*treat*	0.3435***	-	0.0174	-
	(0.0261)		(0.0167)	
*topdist*year*	-		-	
2011	-	0.0051	-	0.0287
		(0.859)		(0.0315)
2012	-	0.1719***	-	0.0203
		(0.0350)		(0.0355)
2013	-	0.2257***	-	0.0369
		(0.0341)		(0.0355)
2014	-	0.5687***	-	0.0061
		(0.0303)		(0.029)
2015	-	0.5167***	-	0.0308
		(0.0293)		(0.0309)
2016	-	0.3237***	-	0.0162
		(0.0368)		(0.0598)
2017	-	0.3546***	-	0.0663
		(0.032)		(0.0573)
2018	-	0.4252***	-	0.052*
		(0.0321)		(0.0312)
University fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Observations	1860	1860	940	940
Overall R-squared	0.9885	0.9885	0.9883	0.9884

All panel data regressions are including the intercept.
The quantities in parenthesis below the estimates are the robust standard errors, clustered at the university level.
***, **, * denote statistically significant effects at a 1%, 5% and 10% level respectively

The estimates for small universities are much larger now, reaching 56.87% in 2014. Those results are statistically significant at a 1% level but do not seem very realistic. The estimates for large universities on the other hand appear to be more plausible but are all again highly insignificant. The magnitude has decreased compared to the baseline estimates.

8. Conclusion

This paper has tried to answer the following question: what impact did the AIA have on R&D expenditures of universities? I hypothesized that overall R&D would be negatively impacted while after decomposing the effects by university size I would observe a negative impact on small university R&D and a positive impact on large university R&D.

From this research several conclusions emerge. First, I find that in the United States, patents owned by universities follow an unequal distribution. In 2012, about 7% of the universities own 50% of all patents. This finding relates to what has been found previously in European countries and could have negative impacts on research output and access to finance. Second, the AIA is associated with an increase in university innovation by about 1.64% for every 1% increase in exposure to the policy (increase in patents held in 2012) on average. This result is highly significant. I therefore reject my first hypothesis. Third, over the period 2010 until 2018 the AIA has increased R&D at small universities by about 0.57% against 3.07% for large universities for every 1% increase in exposure. This is close to 6 times the size of the effect implying big heterogeneity in the effects. Both results are insignificant, but I reject my second hypothesis as R&D at small universities has not been decreased. Fourth, this analysis has additionally revealed that the effect of the AIA was persistent and even increasing over time, with the possibility that it is still having a positive effect as of today. Fifth, those results can be related to previous findings of an “inverted U” shaped relationship between patent strength and innovation. If such relationship were to be true, we can conclude the United States finds itself on the left of the tipping point after which further strengthening would decrease innovation. It is not possible to derivate from these results the exact position on the curve and what the optimal strength of the American patent system is. It is therefore impossible to state whether further strengthening is beneficial to innovation or harmful.

Limitations with the data and methodology prevent us from interpreting any of those estimates as causal. The methodology presented some flaws. First, some universities reported zero expenditures in R&D in certain years. I highly doubt those universities did indeed not incur any cost related to research. If my doubts were to be correct, the presented estimates from this paper would have been overestimated. Second, the AIA has happened between 2012 and 2013. The main features went into motion only in 2013 but some changes did already happen in 2012. Additionally, I strongly believe other events than the AIA have occurred in 2013 which had a significant impact on R&D expenditures of universities. Third, there is a positive correlation between the number of patents owned and the R&D expenditures of a university. I did my best at tackling this by using the number of patents owned by a university prior to the intervention. However, R&D in 2012 is highly correlated with both R&D in 2018 and with the number of patents owned in 2012. As such, patents are not a perfect measure of exogenous variation.

This study leaves a lot of questions unanswered. The literature has illustrated that the reaction to patent policies is not only dependent on size but also very sector specific. In the future one could build on this research by tracing back the areas of research of each university and comparing those fields. Once more recent available data will become available the same regressions can be run including more years, as we see that the effect has been increasing over time and that it could keep on following this trend for additional years. This paper has looked at the impact of patent policy on domestic R&D. As Kappos (2010) has argued, benefits may be very large internationally. Investigating the impact of national policies on foreign R&D expenditures could reveal important mechanisms.

The findings of this paper should be handled with care when it comes to patent policy making. First of all, we do not know where the US is positioned on the "inverted U" shape curve. Second, this analysis has some limitations in terms of internal validity but especially external validity. The American university system is distinct from any other country meaning that internationally mechanisms could be very different. Also, only 280 universities are part of this analysis which is only a small share of American universities and colleges. In addition, universities only represent a small share of total R&D expenditures and other actors may have very different responses to patent reforms. Third, the literature has discussed that not only does the patent strength matter for innovation, other legal provisions that are not covered by the definition of patent strength do still play a big role in determining innovation and its dissemination. Discussed features such as pre-grant review third party review have the potential to make a big difference. Last, patent systems have much more impact on society than solely through innovation or R&D expenditures. While the focus in the patent discussion has been innovation, this paper discussed a couple of other important aspects: prices, antitrust, patent trolls and intrinsic motivation. Policymaking needs to be based on all those concepts as they all have important implications for overall welfare.

References

Abrams, D. S., & Wagner, R. P. (2013). Poisoning the Next Apple-The America Invents Act and Individual Inventors. Stan. L. Rev., 65, 517.

Acemoglu, D., Aghion, P., & Zilibotti, F. (2006). Distance to frontier, selection, and economic growth. Journal of the European Economic association, 4(1), 37-74.

Aghion, P., Blundell, R., Griffith, R., Howitt, P., & Prantl, S. (2004). Firm entry, innovation and growth: theory and micro evidence. Unpublished manuscript. Institute for Fiscal Studies & Harvard University.

Aghion, P., & Griffith, R. (2008). Competition and growth: reconciling theory and evidence. MIT press, Cambridge, Massachusetts.

Aghion, P., Dewatripont, M., & Stein, J. C. (2008). Academic freedom, private-sector focus, and the process of innovation. The RAND Journal of Economics, 39(3), 617-635.

Angrist, J. D., & Pischke, J. S. (2008). Mostly harmless econometrics: An empiricist's companion. Princeton university press.

Armitage, R. A. (2012). Understanding the America Invents Act and Its Implications for Patenting. AIPLA QJ, 40, 1.

Arrow, K. (1962). Economic welfare and the allocation of resources for invention. The rate and direction of inventive activity: economic and social factors. N. Bureau.

Ashworth, A. L. (2012). Race You to the Patent Office: How the New Patent Reform Act Will Affect Technology Transfer at Universities. Alb. LJ Sci. & Tech., 23, 383.

Besen, S. M., & Raskind, L. J. (1991). An introduction to the law and economics of intellectual property. Journal of economic perspectives, 5(1), 3-27.

Bessen, J., & Hunt, R. M. (2007). An empirical look at software patents. Journal of Economics & Management Strategy, 16(1), 157-189

Bessen, J., & Maskin, E. (2009). Sequential innovation, patents, and imitation. The RAND Journal of Economics, 40(4), 611-635.

Bessen, J., & Meurer, M. J. (2013). The direct costs from NPE disputes. Cornell L. Rev., 99, 387.

Bittlingmayer, G. (1988). Property rights, progress, and the aircraft patent agreement. Journal of Law Economics, 31(1), 227-248.

Bleda, M., & Del Rio, P. (2013). The market failure and the systemic failure rationales in technological innovation systems. Research policy, 42(5), 1039-1052.

Bloom, N., Jones, C. I., Van Reenen, J., & Webb, M. (2017). Are ideas getting harder to find? (No. w23782). National Bureau of Economic Research.

Boldrin, M., & Levine, D. K. (2008). Against intellectual monopoly.

Bowles, S., & Polania-Reyes, S. (2009). Economic incentives and social preferences: A preference-based lucas critique of public policy.

Chien, C. (2013). Startups and patent trolls. Stan. Tech. L. Rev., 17, 461.

Cohen, W. M., Goto, A., Nagata, A., Nelson, R. R., & Walsh, J. P. (2002). R&D spillovers, patents and the incentives to innovate in Japan and the United States. Research policy, 31(8-9), 1349-1367.

Cohen, W. M., Nelson, R. R., & Walsh, J. P. (2000). Protecting their intellectual assets: Appropriability conditions and why US manufacturing firms patent (or not) (No. w7552). National Bureau of Economic Research.

Colyvas, J., Crow, M., Gelijns, A., Mazzoleni, R., Nelson, R. R., Rosenberg, N., & Sampat, B. N. (2002). How do university inventions get into practice?. Management science, 48(1), 61-72.

Dasgupta, P., & David, P. A. (1994). Toward a new economics of science. Research policy, 23(5), 487-521.

Deci, E. L. (1971). Effects of externally mediated rewards on intrinsic motivation. Journal of personality and Social Psychology, 18(1), 105

de Nardi, M., Ren, L., & Wei, C. (2000). Income inequality and redistribution in five countries. Ceps/Instead-Centre D'etudes de Populations, de Pauvrete Et de Politiques Socio-Economiques/International Networks for Studies in Technology, Environment, Alternatives, Development.

Dodgson, M., Hughes, A., Foster, J., & Metcalfe, S. (2011). Systems thinking, market failure, and the development of innovation policy: The case of Australia. Research Policy, 40(9), 1145-1156.

Encaoua, D., Guellec, D., & Martinez, C. (2003). The economics of patents: from natural rights to policy instruments. Cahiers de la MSE.

Flor, M. L., & Oltra, M. J. (2004). Identification of innovating firms through technological innovation indicators: an application to the Spanish ceramic tile industry. Research Policy, 33(2), 323-336.

Figueroa, N., & Serrano, C. J. (2013). Patent trading flows of small and large firms (No. w18982). National Bureau of Economic Research.

Fisher, W. W. (1999). The growth of intellectual property: A history of the ownership of ideas in the United States. Eigentum im internationalen Vergleich (Vandenhoeck & Ruprecht, 1999), 265-291.

Foray, D., & Lissoni, F. (2010). University research and public–private interaction. In Handbook of the Economics of Innovation (Vol. 1, pp. 275-314). North-Holland.

Furukawa, Y. (2010). Intellectual property protection and innovation: An inverted-U relationship. Economics Letters, 109(2), 99-101.

Gallini, N. T. (1992). Patent policy and costly imitation. The RAND Journal of Economics, 52-63.

Gallini, N. T. (2002). The economics of patents: Lessons from recent US patent reform. Journal of Economic Perspectives, 16(2), 131-154.

Gallini, N., & Scotchmer, S. (2002). Intellectual property: when is it the best incentive system?. Innovation policy and the economy, 2, 51-77.

Geuna, A., & Nesta, L. J. (2006). University patenting and its effects on academic research: The emerging European evidence. Research policy, 35(6), 790-807.

Grabowski, H. (2002). Patents, innovation and access to new pharmaceuticals. Journal of International Economic Law, 5(4), 849-860.

Hall, B. H., & Harhoff, D. (2012). Recent research on the economics of patents. Annu. Rev. Econ., 4(1), 541-565.

Hall, B. H., & Ziedonis, R. H. (2001). The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979-1995. rand Journal of Economics, 101-128.

Heller, M. A., & Eisenberg, R. S. (1998). Can patents deter innovation? The anticommons in biomedical research. Science, 280(5364), 698-701.

Horowitz, A. W., & Lai, E. L. C. (1996). Patent length and the rate of innovation. International Economic Review, 785-801.

Jones, C. I. (2002). Sources of US economic growth in a world of ideas. American Economic Review, 92(1), 220-239.

Jones, C. I. (2019). Paul Romer: Ideas, nonrivalry, and endogenous growth. The Scandinavian Journal of Economics, 121(3), 859-883.

Kappos, D. J. (2010). Patent Law Harmonization: The Time is Now. Landslide, 3, 16

Kleinknecht, A., Van Montfort, K., & Brouwer, E. (2002). The non-trivial choice between innovation indicators. Economics of Innovation and new technology, 11(2), 109-121.

Lerner, J. (2005). 150 years of patent office practice. American Law and Economics Review, 7(1), 112-143.

Lerner, J., Speen, A., & Leamon, A. (2015). The Leahy-Smith America Invents Act: a preliminary examination of its impact on small business. Bella Research Group.

Levin, R. C., Klevorick, A. K., Nelson, R. R., Winter, S. G., Gilbert, R., & Griliches, Z. (1987). Appropriating the returns from industrial research and development. Brookings papers on economic activity, 1987(3), 783-831.

Lo, Shih-Tse and Sutthiphisal, Dhanoos, Does it Matter Who Has the Right to Patent: First-to-Invent or First-to-File? Lessons from Canada (April 2009). NBER Working Paper No. w14926.

Lundvall, B. (1992). Å (ed)(1992) National systems of innovation: towards a theory of innovation and interactive learning. Pinter, London.

Mansfield, E. (1986). Patents and innovation: an empirical study. Management science, 32(2), 173-181.

Marimon, R., & Quadrini, V. (2006). Competition, innovation and growth with limited commitment (No. w12474). National Bureau of Economic Research:

Martin, S., & Scott, J. T. (2000). The nature of innovation market failure and the design of public support for private innovation. Research policy, 29(4-5), 437-447.

Moore, A. D. (2002). Intellectual property, innovation, and social progress: The case against incentive based arguments. Hamline L. Rev., 26, 601.

Morgan, J., & Sandoval, V. (2013). Pacific Northwest Perspective: The Impact of the America Invents Act on Nonprofit Global Health Organizations. Wash. JL Tech. & Arts, 9, 177.

Moser, P. (2005). How do patent laws influence innovation? Evidence from nineteenth-century world's fairs. American economic review, 95(4), 1214-1236

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

Mowery, D. C., & Sampat, B. N. (2004). The Bayh-Dole Act of 1980 and university–industry technology transfer: a model for other OECD governments?. The Journal of Technology Transfer, 30(1-2), 115-127.

Murdock, K. (2002). Intrinsic motivation and optimal incentive contracts. RAND Journal of Economics, 33(4), 650-672.

Nickell, S. (1981). Biases in dynamic models with fixed effects. Econometrica: Journal of the Econometric Society, 1417-1426.

Nordhaus, W. 1969. Invention, Growth and Welfare: A Theoretical Treatment of Technological Change. Cambridge, MA: MIT Press

Open Register of Patent Ownership. (2019). In Open Register of Patent Ownership. Retrieved from http://oropo.net/

Pharmaceutical Research and Manufacturers of America. (2013). 2013 Biopharmaceutical Research Industry Profile. PhRMA.

Qian, Y. (2007). Do national patent laws stimulate domestic innovation in a global patenting environment? A cross-country analysis of pharmaceutical patent protection, 1978–2002. The Review of Economics and Statistics, 89(3), 436-453.Ryan Jr, C. J., & Frye, B. L. (2017). An Empirical Study of University Patent Activity. NYU J. Intell. Prop. & Ent. L., 7, 51.

Rai, A. K., Allison, J. R., & Sampat, B. N. (2009). University Software Ownership and Litigation: A First Examination. North Carolina law review, 87(5), 1519.

de Rassenfosse, G., & van Pottelsberghe de la Potterie, B. (2007). Per un pugno di dollari: A first look at the price elasticity of patents. Oxford Review of Economic Policy, 23(4), 588-604.

Sakakibara, M., & Branstetter, L. (1999). Do stronger patents induce more innovation? Evidence from the 1988 Japanese patent law reforms (No. w7066). National bureau of economic research.

Schankerman, M. (1998). How valuable is patent protection? Estimates by technology field. the RAND Journal of Economics, 77-107. Stern, S. (2004. Do scientists pay to be scientists? Management Science, 50 (6), 835-853.

Romer, P. M. (1990). Endogenous technological change. Journal of political Economy, 98(5, Part 2), S71-S102.

Tseng, A. A., & Raudensky, M. (2015). Performances of technology transfer activities of US universities after Bayh-Dole Act. J. Economics, Business & Management, 3(6), 661-667

Wooldridge, J. M. (2012). Introductory econometrics: A modern approach.