The Geography of University-Industry Technology Transfer

A study assessing the role of regional context in TTO performance in the United States

Robbert van der Hert

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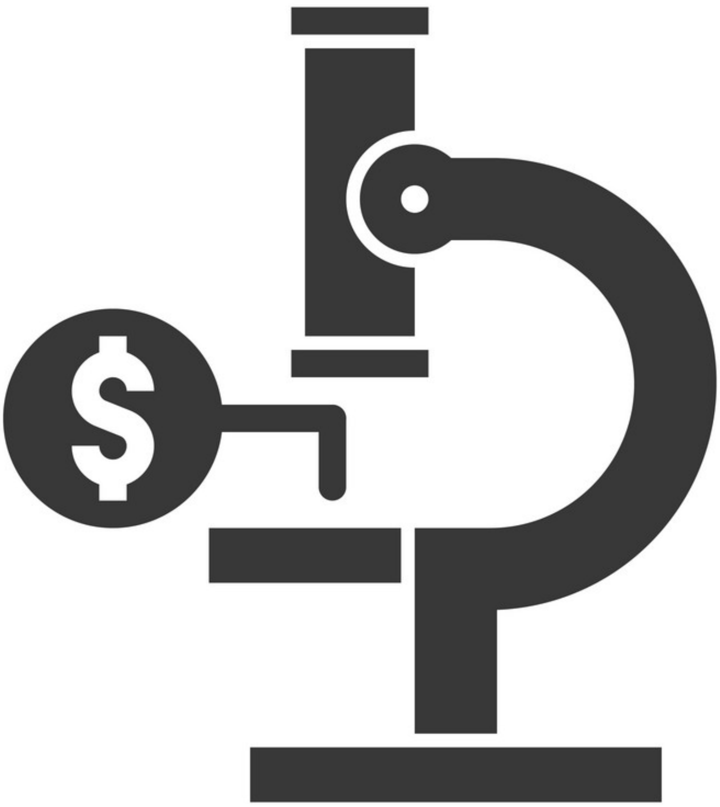

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Image on the front page by Emy Brook (n.d.)

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Acknowledgements

One of the first things I learned about doing research as a student, is that it is not a linear, but rather a circular process with moments for critical reflection at every single stage. This was also evident when writing this thesis. The specific topic changed three times, though every new topic was somewhat linked to the previous version. The final topic was based on the availability of a dataset that comprehensively captured the variables I was interested in. One could argue that being almost 9.000 kilometers from home would make little sense because of the use of a dataset. This can be easily refuted. Since I wrote my thesis at Arizona State University, I was able to meet with start-up entrepreneurs, incubator managers, TTO presidents, and dr. Donald Siegel, one of the most influential scientists in the field of University-Industry Tech Transfer. The face-to-face conversations provided me with new ideas and great help, especially because I was not familiar with the concept of University-Industry Tech Transfer before.

Writing my masters' thesis in an American context has been made possible by the efforts of the NEURUS organization. NEURUS allows for exchange of geography and planning students between three European and four American universities. My choice for ASU in the Phoenix metro area has been a choice that I will not regret. Other than the interesting insights for my thesis, I have had a truly great time in a beautiful area with plenty of exciting adventures to take.

Finally, I would like to thank my supervisor and first assessor of this thesis, dr. Sierdjan Koster, for his patience reviewing three different research proposals and his useful comments, pointing me to the right directions when needed.

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Summary

The concept of University-Industry Technology Transfer has become an important activity for universities over the past few decades. Commercialization of inventions, which can be seen as a third mission besides teaching and research, can be profitable for universities, leading to new sources for research expenditures. The key institution in the tech transfer process is the Tech Transfer Office. Indeed, practically every university with ambitions concerning commercialization of their research has one. TTO's are responsible for invention disclosures, patent application, licensing deals and spin-off creation. The outcomes are thus numerous and multi-dimensional.

Meanwhile, the cooperation between universities and the private market is believed to increase the innovative capacity of regions. Consequently, universities are now seen as vital institutions that could catalyze economic development by creating high tech companies and licensing technology to local companies. Conversely, there are numerous reasons to suspect certain regions could provide a more fertile ground for university tech transfer than other regions. The degree of absorption of university spillovers is argued to depend on the environmental characteristics. An important argument comes from the rather recent approach of the entrepreneurial ecosystem, where overall high development of key components, and interaction between these components, is believed to positively influence entrepreneurial activity.

This study assesses performance data from 137 universities in the United States over the course of three years, focusing on the performance of these universities in the Tech Transfer process. Following the main research question, this study will assess three different TTO performance indicators and will investigate the role environmental context have on the outcomes of TTO's. The indicators of interest are spin-off creation, licenses generating income and annual licensing income generated. The environmental characteristics of interest are workforce spillovers, R&D intensity of the state and startup activity in the metropolitan area. Subsequently, regression methods are applied, in which a number of control variables regarding the size and quality of the university and TTO are included.

Results indicate that regional variance is present. However, when control variables are included, no environmental variable has a significant influence on any of the TTO performance indicators. It is noted that performance is largely influenced by the size of universities and their respective research expenditures. Furthermore, private schools turn out to be more active in creating spin-offs and licensing income. Based on these results, new avenues for research are identified.

1. Introduction

1.1 Gatorade, a university invention

The invention of a sports drink may well be the best-known example of a commercialized university invention. It all started in 1965, when Robert Cade, a researcher at University of Florida specialized on kidney diseases, got a question from the coach of the UF football team. The coach was interested in why his players would sweat so much but urinate so little. Back in the day, drinking of water during sports was discouraged, as it was feared that players would get nausea and cramps. As a result, athletes would lose up to 8 kg during a three-hour practice in the hot and humid weather conditions of Florida and never feel the urge to visit a bathroom.
Cade quickly deduced that the football players did not feel the urge to urinate because they would lose their fluids in the form of sweating. This may seem obvious, but after the conversation with UF's coach, Cade began to give it more thought. He started taking urine samples and soon found out that the players were upsetting the chemical balance of their bodies as they were sweating. Especially the loss of electrolytes – sodium and potassium – seemed to negatively influence the player's strength, ability and endurance. Resulting, Cade came with a solution; he mixed water with salt to compensate for the loss of electrolytes and sugar to keep blood sugar up. As this substance was at first undrinkable, Cade's wife suggested adding lemon juice.
The results were striking. Not only did none of the players get hospitalized because of dehydration anymore, but the team would also perform significantly better during the rest of the season, often beating favored teams in the second half.
Cade knew his drink had commercial potential. Together with Stokely-van Camp, he began commercializing his drink, now called Gatorade (after the University of Florida mascot, an alligator) nationwide. The royalties would be as much as 5 cents per sold gallon, going directly to the Gatorade fund. To this day, UF receives around 20% of royalties received by the fund, which has translated into 283 million dollars in total royalties in 2017.

While the above may sound like a huge success story, the University of Florida may have wished they were not shortsighted earlier in the process. When Cade and the Gatorade Fund began making money out of Gatorade, the school wanted to receive all royalties as Cade made use of the university's labs and its mascot's name. Cade, who was funded by the federal government and somehow never signed any invention agreement, did not comply and a lawsuit started. At some point, both parties agreed to UF receiving only part of the royalties (Rovell, 2015; Rossen, 2018; Kay and Phillips, n.d.).

1.2 Bayh-Dole and the TTO

Back in 1965, there were no legislative institutions that allowed or encouraged for invention disclosures. The phenomenon of the Tech Transfer Office (TTO) did not exist yet. If it did, the university of Florida would not have been shortsighted and have received even more royalties than it does nowadays from this globally sold sports drink.

The Bayh-Dole Act of 1980 was of great importance to the rise of university research commercialization. Back in the day, growing concerns regarding perceived deterioration of comparative advantage and increasing competition from Japanese firms arose, which prompted policy makers to re-conceptualize the role of public universities. The success of Silicon Valley and Route 128 influenced the idea that universities could uphold a response to the Japanese success. The United States would compete by introducing the newest technologies, which would be developed in research universities (Grimaldi et al, 2011). The resulting Act allowed inventions (made possible because of federal funding) to be commercialized by private organizations. Before this Act, most patents were left uncommercialized as they were owned by the federal government, which was the exclusive party allowed to commercialize them. Thus, the Bayh-Dole Act changed the ownership of patents from the federal government to the universities themselves. Universities were now allowed license inventions and patents to private organizations to earn returns on their research (Thursby and Thursby, 2002). Because of this, American universities have increasingly contributed to the innovative capacity of regions through the licensing and startup creating practices (Grimaldi et al., 2011). The government also benefited from this Act, as it was a new source of tax-money.

With the Bayh-Dole Act, Tech Transfer Offices (TTO's) have also emerged as the vital university institution that coordinates the commercialization process. TTO's are responsible for recording invention disclosures, patent applications, marketing to private organization and negotiating deals for options or (exclusive) licenses. They also play a crucial role in the development of spin-offs/startups based on a university invention.

1.3 Licensing process and outcomes

The licensing process starts with a researcher doing an invention that is expected to have market potential. This is then disclosed to the university's TTO, which will evaluate the invention on multiple levels, such as revenue potential and academic field of the invention. If the office decides to move forward, patent protection will be requested. This process usually takes up to 24 months and is costly in the sense that legal fees need to be paid. A large part of the tech transfer office budget is therefore reserved for legal and other patent related fees. When a patent protects the invention, the tech transfer office will start marketing activities for the invention in order to connect the right private organization to the invention. The right party being found, negotiations can start on royalties, based on the subjective added value. Afterwards, the private party can use the patent and develop a product, commonly known as a licensing deal (Arizona Board of Regents, n.d.). Figure 1 displays the growing relevance of licenses for US universities.
Variables like invention disclosures (Hülsbeck et al, 2013), patents (Thursby and Thursby, 2002; Shane, 2002), licenses (Chapple et al., 2005; Jensen, 2003; Siegel et al., 2003; Conti and Gaule, 2011) and spin-offs (Di Gregorio and Shane, 2003; O'Shea et al., 2005) are all used as examples of TTO output. Scholars have attempted to explain these phenomena with various components, consisting of elements related to the organizational, institutional and (to a lesser extent) environmental context of a TTO.

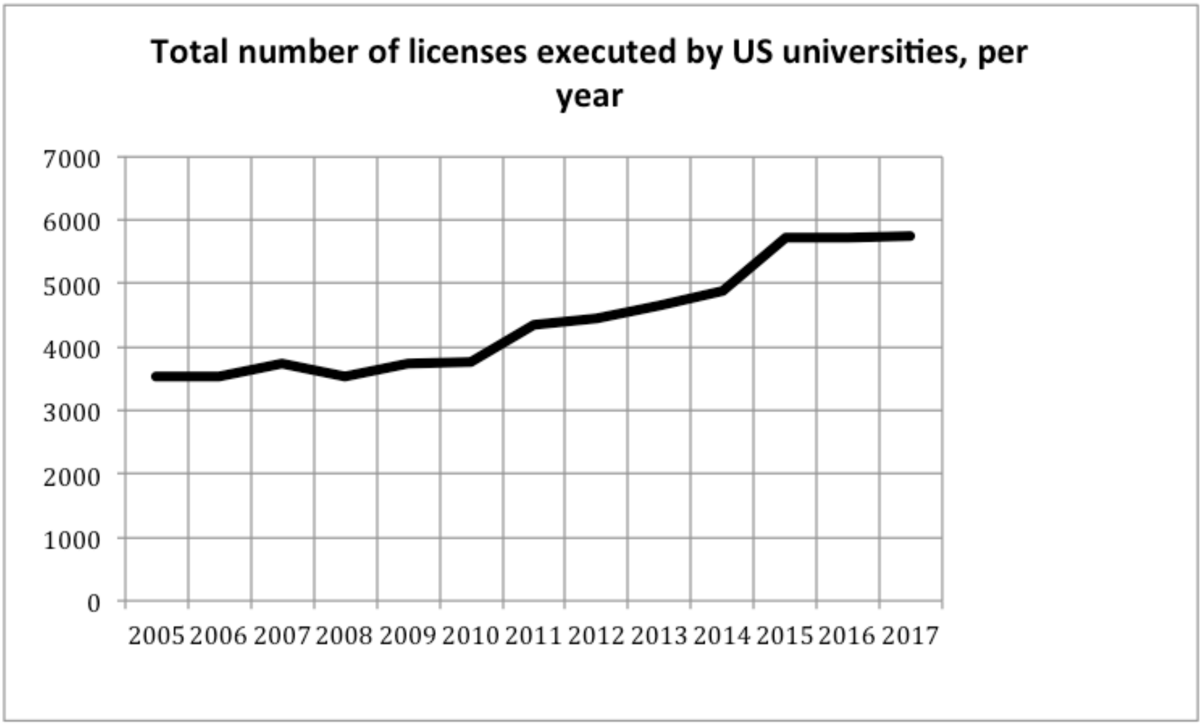

Figure 1: Licenses executed by US universities (AUTM, 2017)

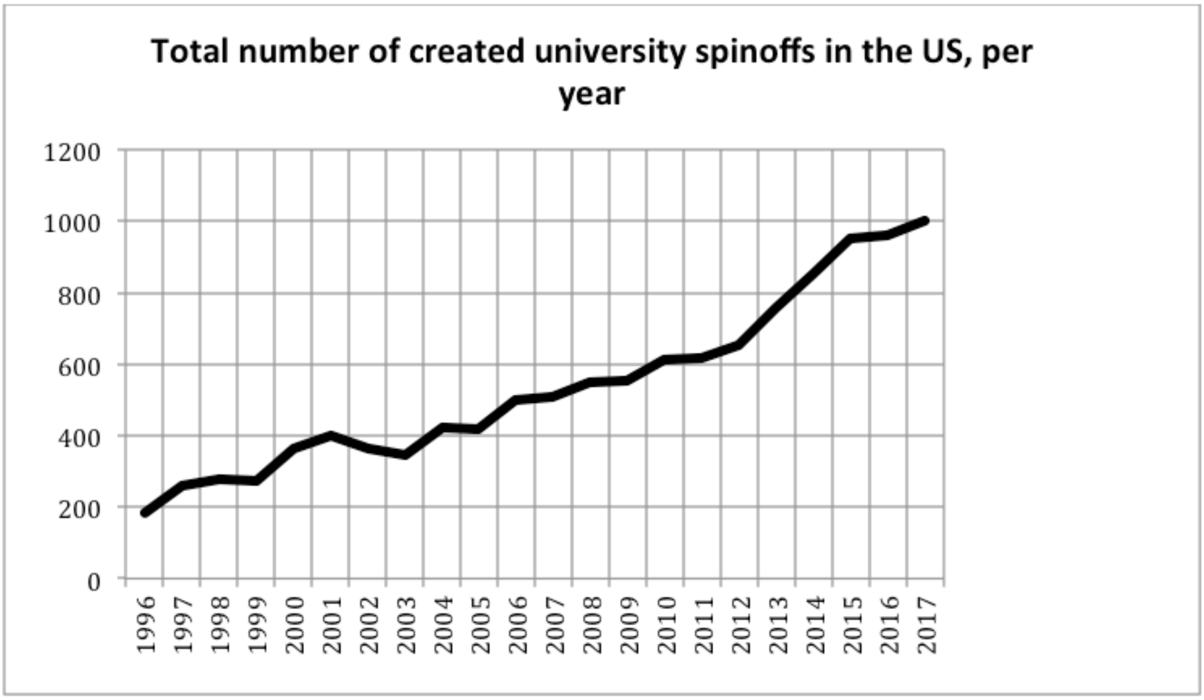

Figure 1: Spin-offs created by universities (AUTM, 2017)

Spin-off creation is an interesting activity for universities that care about the local economy. Similarly to startups, spin-offs are believed to make use of the indigenous potential of a region while also contributing to that potential. Contrary to companies commercializing ordinary licenses are spin-offs often based in the home state. Regional talent is therefore used to initiate a spin-off. However, not all inventions are likely to be commercialized by a spin-off. For instance, Shane (2002) has shown that the level of 'radicalness', importance and scope of a patent will all positively influence the probability of an invention to get commercialized through firm formation. As can be seen in figure 2, spin-offs too have become a much more prevalent activity in the US in the 1996-2017 period.

Box 1: University Spin-offs in the Netherlands
Over the past 25 years, around 1200 spin-offs have been created at Dutch universities, of which 600 were founded in the past 5 years. Most of these are founded at the technical universities. Compared to regular startups, these spin-offs are more likely to persist over time, as 80% stays in business (compared to 40-60% for startups). Well-known examples are Takeaway.com (Thuisbezorgd) and Booking.com, which are both spin-off companies from the university of Twente, created respectively in 1996 and 2000. However, few spin-offs turn into large companies. They employ in general 13 people. The most profitable Dutch university spin-off was Crucell, from the University of Utrecht. After the company's initial public offering in 2000, the university made 25 million euros (Steijaert, 2019).

1.4 Motivation and research questions

The national as well as international inequality of entrepreneurial activity and its subsequent wealth generation has spurred interest of both academics and regional policy makers. Indeed, numerous instances to mobilize indigenous potential or attract exogenous resources have been initiated in order to benefit region's economic development (Pike et al, 2017). Nevertheless, start-up rates have shown to be persistent over time, making it fairly difficult for regions with continuously low start-up rates to formulate policy aimed at raising the number of start-ups (Andersson and Koster, 2011). Thus, it may very well be possible that regions with a certain set of characteristics provide a fertile ground for this entrepreneurial activity, resulting in persistently high start-up numbers. Consequently, the 'entrepreneurial ecosystem' (EE) has recently gained attention. Presence of certain components and the interaction between them is believed to be beneficial to other innovative and entrepreneurial activity (Isenberg, 2010). Examples of this are supportive professions, financial and human capital and infrastructure. Focusing on university technology transfer, one would expect TTO performance to be higher in regions with a highly developed EE.
However, the alleged relationship between the regional context and its respective level of university technology transfer has received little attention from scholars. The majority of research has focused on the policy, managerial and business side of university entrepreneurship (as it can be evidenced by the journals that publish them, see Rothaermel et al. (2007) and Link et al. (2015)). For example, differences between European and American universities have been explained largely by the number of TTO employees and TTO experience (Conti and Gaule, 2011). Furthermore, absence of institutions like the Bayh-Dole Act in Europe has also been disadvantageous to their commercialization efforts (Chapple et al, 2005).

While Europe (as a homogenous entity) and the US may both be strong in creating academic research output, regions within the US or Europe may differ more substantially in terms of knowledge related activities. For instance, in the US, research and development (R&D) expenditures are highly concentrated in California, contributing half of the nation's total R&D expenditures in 2017 (NSF, 2017). High R&D intensity in the region is illustrative for its innovative capacity. What is more, as earlier mentioned, the start-up activity varies greatly per region and is persistent over time. Spillovers of R&D and start-ups are both indicators of the region's innovative capacity, yet their effect on university technology transfer is almost completely neglected.

On a small scale, Feldman (1994) suggested that the city of Baltimore could not optimally benefit from university spillovers due to disadvantageous characteristics of the labor force. Merely a few metropolitan regions in the US employ relatively high concentrations of professionals in so-called STEM-jobs (Science, Technology, Engineering and Mathematics)(US Census, 2017). Their presence in a region indicates an already established innovative spillover, as they work in professions that require a high degree of tacit knowledge. Furthermore, their input can be beneficial in the process of turning an invention into a successful spin-off. This can also be said about the number of entrepreneurs in the region that have obtained the specific skill set needed to develop a firm created with a university invention.

Following the analogy of Audretsch et al (2007), every entrepreneurial opportunity created by universities has to be recognized by individuals who will commercialize that invention through a spin-off. The individuals who determine the opportunity are often from outside the university. As new technology is inherently uncertain, these individuals take some amount of risk. Consequently, the individual that creates a spin-off typically has obtained a certain set of skills during his life, which limit the amount of risk. Indeed, knowledge about the market and the product reduces the presence of asymmetric information.

This study will therefore attempt to investigate whether regional differences in terms of TTO performance in the US exist and, if so, whether that can be attributed to the regional context of the respective TTO. Since TTO's are extensively involved in the commercialization process, there are various ways to measure the performance of TTO's. Whereas much of the existing literature on performance often chooses to address only one performance variable, this research will investigate three different performance variables. This reflects the multi-dimensional nature of TTO output. The three variables are the number of spin-off created, licenses generating income and gross licensing income received.

Spin-offs are created with the purpose of commercializing a patented invention. Spin-offs are believed to resonate strongly to the 'indigenous potential' of the region, since they are often located proximate to the university. The CEO of the spin-off may be the scientist itself or, more commonly, from outside the university. The fact that there is no available data on the performance of these spin-offs makes it difficult to claim anything about the success of this performance variable. However, although little is known about university spin-off performance, it is believed that spin-off income is only a small fraction of the universities' total income. For example, MIT, one the world's most successful institutions in creating spin-offs, only generates 5% of the universities' total income with spin-offs (Steijaert, 2019).

Licenses generating income are a result of TTO's structuring a deal between faculty and private parties. A patent is licensed to a big company, small enterprise or a spin-off. Indeed, a company from outside the university's' region or country may also use a

license, making it less geographically bound to the university. Even though the precise income per license is unknown, this variable is more illustrative for commercial success than spin-off creation, because only those licenses that generate income are included in the analysis.
Finally, the gross licensing income may have the most qualitative depth of the three performance variables. It comprises all potential sources that are derived from licensing activity. These include royalties, initial license payments and cashed-in equity. Assuming income is illustrative for TTO success, this variable thus captures it most effectively.
The main question of this research is as follows:

What is the role of regional context of universities on their respective tech transfer office performance in the United States?

This question will be answered following these sub-questions:

To what extent do regions within the United States differ based on TTO performance?

To what extent do regional R&D and start-up spillovers influence TTO performance?

To what extent do characteristics of the regional labor force influence the performance of TTO's?

The first sub question will attempt to answer whether or not there are notable regional differences between different US regions, while the other two questions will investigate the benefits of possible presence of spillovers in the region.
These questions will be answered with the help of the AUTM STATT database. AUTM (Association of University of Technology Managers) is a non-profit organization that annually collects data from TTO's in the US and Canada since 1991. The database consists of 60 variables and 160 universities. Local labor market characteristics can be found in census data. The method that will be used is regression, with performance as the dependent variable and environmental factors as the independent variable, along with a number of control variables.

2. Theoretical framework

As with almost all forms of economic activity, differences between and within regions exist. As universities are increasingly seen as engines of growth by university administrators and policymakers, the question on what explains variance in university transfer success has also been raised numerous times.

2.1 Tech transfer options

The ability of US universities in producing outputs to the economy has received considerable attention from scholars. Universities can transfer their research through more components than just tech transfer offices, i.e. through science parks, incubators, and venture funds. Science parks and incubators are both property-based organizations that are linked to the university environment. They both offer space and services to technology-based businesses in a developing phase. An incubator is a single building whereas a science park can host multiple buildings (Link and Scott, 2003; Bergek and Normann, 2008). In contrast, a TTO does not offer any property for potential spin-offs, and would often choose to license inventions to existing companies. For this research, only TTO's are investigated as they have clear, universal goals with multiple forms of measurable output readily available in the AUTM database.
The number of stakeholders in the basic tech transfer model is limited. Their actions and motives are clear and can be seen in table 1 (Siegel et al, 2003).

Stakeholder	Actions	Primary motive	Secondary motive
University scientist	Discovery of new knowledge	Recognition within the scientific community	Financial gain and a desire to secure additional research funding
TTO	Works with faculty and firms/entrepreneurs to structure deal	Protect and market the university's intellectual property	Facilitate technological diffusion and secure additional research funding
Firm/entrepreneur	Commercializes new knowledge	Financial gain	Maintain control of proprietary technologies

Table 1: Stakeholders in the classic TT model (Siegel et al., 2003)

This model can be extended with other stakeholders, like students who may be interested in becoming an entrepreneur by commercializing university inventions, federal agencies that support entrepreneurship programs and economic development officials at the university and in the region that may want to use TT for improving the innovative capacity and foster economic growth of the region (Siegel and Wright, 2015a).
While the university's efforts to protect and commercialize their research after Bayh-Dole has supported over 1,3 million jobs and has contributed 591 billion dollars to US gross domestic product, the approach used has received substantial criticism.
The Bayh-Dole Act requires faculty members to disclose technology or invention that has commercial potential to their institutions TTO (Friedman and Silberman, 2003). This means that faculty members may not commercialize their findings on their own

efforts, like Robert Cade did when he created and commercialized Gatorade. The perceived fear of potential bureaucratic inflexibility makes faculty members reluctant to disclose their inventions (Siegel et al., 2003). Furthermore, researchers often do not want to delay publication until the technology is patented or licensed.

2.2 Tech transfer performance input

The tech transfer process is complex, since it requires significant resources and involves high levels of uncertainty and risk. It is evident that certain regions perform better than others. Therefore, it makes sense to look into the determinants for successful tech transfer practices.

Siegel et al. (2003) conducted one of the first and one of the most influential studies on the determinants of TTO performance. The underlying question was why some universities are more effective in transferring technology (through licenses) than other universities. This study showed that environmental and institutional factors could not completely explain the variance in performance of TTO', which implied that organizational practices were also an important determinant. Through qualitative analysis, 3 key impediments to effective TT performance were found. Cultural and information barriers between universities and (small) enterprises seemed to exist, rewards for faculty involvement in TT were perceived as insufficient and there were problems with the staffing practices of TTO's. Finally, the number of license agreements were revealed to have constant returns while the total license revenue turned out have increasing returns of scale.

Contrarily, this could not be said about the situation in the UK. Chapple et al. (2005) found out that the growth in size of TTO's was not accompanied with corresponding growth in business skills and capabilities of TTO managers and licensing professionals. Similar to Siegel et al. (2013), this article underlined the importance of a balanced skill-set of managers, lawyers and scientist within the TTO.

Conti and Gaule (2011) investigated the so-called 'European Paradox'. In fact, European universities are good at producing academic results, yet they lack the ability to produce outputs to the economy. Results indeed showed clear differences between US and European universities in terms of licenses, but this difference was primarily explained by the age of TTO's and their staffing level. Similarly, US universities earned significantly more license income, but were again explained by age and staff. The importance of experience was also found by Hüllsbeck et al. (2013). A learning component was identified, as transfer experience on the university level had a positive effect on invention disclosures. One could thus argue that because universities in the US started earlier in taking efforts in commercializing their research, they are also more successful. These results indicate that the difference between the US and Europe can be explained by the level of inputs from universities itself. Furthermore, Messini Petruzelli (2011) found the existence of the so-called 'professors' privilege'[1] in three European countries is also a negative factor in the commercialization of inventions. Other findings were that publications, TTO size and experience positively influence the number of licenses concluded and tend to be more abundant in the US.

[1] The professors' privilege connotes the researcher's right to commercialize an invention rather than the university. The privilege exists in Sweden en Italy and is abolished in Denmark, Germany, Norway and most recently Finland. In countries with the privilege, researchers have no incentive to disclose inventions to a TTO. See also Färnstrand Darmgaard and Thursby (2013).

Meanwhile, Muscio (2010) investigated the determinants of universities use of TTO's in Italy and found that being located in the south significantly disadvantaged the likelihood of creating university-industry collaboration. However, this could not be explained by the proximity of science industry. Identified determinants that did have noticeable effects on the amount of U-I collaborations are the size of the department, cognitive distance and applicability of research.
Concluding, this section has shown that TTO output has primarily been assessed by looking at input variables that capture the characteristics of the TTO itself (size, funding, age), the university/faculty (size, quality, orientation), or even personal characteristics of faculty member themselves.

2.2.1 Environmental context

Factors that have received relatively little attention are the external or geographic factors that the TTO has to deal with. This is surprising, as there are of reasons to believe that the environment plays a significant role in the success of TTO's, as the knowledge they transfer is often tacit and requires face-to-face contact and spillovers of talent. For example, Saxenian (1994) found that start-ups are more likely to occur in regions with high technology clusters. Meanwhile, Audretsch and Feldman (1996) showed that innovations are spatially concentrated, as they found that industries where knowledge plays an important role tend to have a high propensity to cluster together. Furthermore, Feldman and Desrochers (2003) and Feldman (1994) noted that degree of absorption of university spillovers was dependent attributes of the region, among which industry composition, characteristics of the labor force and social capital.
An approach that has recently gained interest is that of the 'entrepreneurial ecosystem' (EE), first coined by Isenberg (2010). This concept comprises an approach that investigates the interacting components in a region that make a certain area favorable for entrepreneurs. Examples of these components are the presence of Human Capital and Support infrastructure. Other components can be seen in figure 3. Indeed, universities and TTO's play a vital role in the ecosystem, but in order to be successful, other components need to be developed as well. Hence, a region's EE is potentially an important contextual factor for explaining TTO performance variation, as they are believed to regulate the direction and quality of entrepreneurial innovation (Autio et al., 2014). This may be especially true for university spin-offs, since these are reliant on entrepreneurial capacities and culture. However, the concept has various issues that make it difficult to conceptualize (Stam, 2015). Nevertheless, it is still interesting to look at the presence of certain components that form the entrepreneurial ecosystem.

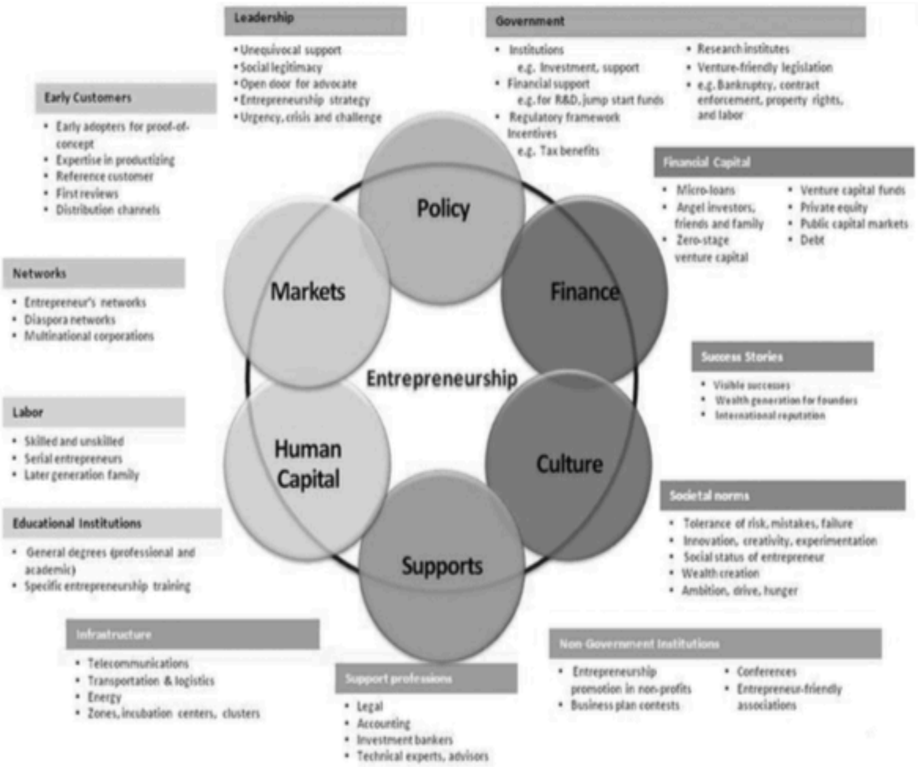

Figure 3: Components of the EE (Isenberg, 2011)

Possibly due to the aforementioned conceptual problems with Entrepreneurial Ecosystems, no known research has investigated the role of EE's in TTO performance. However, the presence of regional spillovers did receive some attention.

Knowledge intensive industries have shown a tendency to cluster in space, creating spillovers. These spillovers are then beneficial to universities as they provide local demand for licenses (Conti and Gaule, 2010).

Siegel et al. (2003) did indeed find strong positive relations between R&D spending in a region and licensing activity of universities in those respective regions in the US, while Chapple et al. (2005) found similar results in the UK. The same was also true for regional GDP. This too implies regional spillover effects exist and explains why universities in region with low GDP and R&D spending struggle to be efficient in the commercialization of technology.

Friedman and Silberman (2003) found a positive significant relationship between TTO performance and the location quotient on technology industry in the Tech-pole index of the 1999 report from the Milken Institute. Nevertheless, this regression experienced endogeneity problems, as metropolitan areas with high technology industry LQ's are also the areas with the best universities in the US[2].

Somewhat contradictory to the above are Hülsbeck et al. (2013)'s finding that complementary economies are better able to transfer knowledge from universities to industry[3]. This article implemented a variable regarding the level of regional

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[2] E.g. Stanford University is located in the San Jose metro area (LQ: 23,7) and Boston (LQ: 6,3) houses MIT and Harvard.

[3] Industries characterized with high levels of specialization have Marshallian spillovers. They occur between firms in the same sector through imitation. They produce economies of scale. Contrarily, industries with low levels of specialization in a certain industry have Jacobian spillovers, which occur between firms in different sectors through learning.

specialization in their regression and found that TTO's located in regions with a high concentration of a particular industry tend to produce less invention disclosures. TTO's in regions with low concentrations of a particular industry tend to be more successful in producing invention disclosures. However, this article did not look at specialized spillovers that are ought to be relevant to technology transfer, but rather at specialization of any industry.
In conclusion, previous has shown that environmental factors are fairly relevant in the form of spillovers to technology transfer. Presence of relevant spillovers in terms of R&D seem to positively influence the various forms of TTO output. However, it is important to keep the possibility of endogeneity issues in mind as universities are also the partially the cause of R&D spillovers (Anselin et al., 1997).

2.3 Performance

Following the chronological process of TT, the first form of output is an invention disclosure made by a university employee to the TTO. In reality, not all inventions become disclosed with the TTO due to the aforementioned impediments perceived by scientists. Thus, TTO's must play an active role in convincing scientist to disclose their inventions. The amount of invention disclosures are basically the pool of inventions that can be commercialized and can therefore also be seen as tech transfer input, as shown in Friedman and Silberman (2003), while Hüllsbeck et al. (2013) used disclosures as the only dependent variable to measure TTO performance.

After an invention gets disclosed, the TTO will evaluate and attempt to issue a patent. The latter is not necessarily the next step, as a TTO can also attempt to license the disclosure without patent protection readily available. Most of the times, a disclosure will eventually lead up to patent protection.

Patents can be seen as an example of TTO output. It is a form of intellectual property protection that provides the exclusive right to commercialize an invention to one or a number of individuals. To be more precise, it actually does not give the right to commercialize, but it excludes others from doing so. This exclusivity generally lasts 20 years and can be extended under certain circumstances. Not all disclosures get patented, as TTO's evaluate the potential of the disclosures first. Furthermore, not all filed patents get issued as such, as the United States Patent and Trademark Office also evaluates the innovativeness and utility of the invention. Patenting activity as a dependent variable has been used by Thursby and Thursby (2002), who investigated the origins of the increase of university's commercial output. Meanwhile, Shane (2002) used the characteristics of patents itself to determine the factors why patents become licensed and commercialized.

Licenses can be seen as an output of higher quality from TTO's than patents, since their added value is recognized by a private organization. A license is often exclusive, and endows the company with a unique resource. It can be seen as valuable as it allows firms to exploit technological opportunity, it is rare because the license is exclusive and it is imperfectly imitable as a patent protects it. A university license can thus be seen as a true competitive advantage (Barney, 1991; Rothaermel and Thursby, 2005). An 'option' can be seen as a predecessor of a license, in which a company can 'test' an invention for a lower price before actually obtaining a license. In exchange for the gained competitive advantage, a company typically pays a fee for the license, based on the subjective added value. Furthermore, the amount revenue can be negotiated through royalties and license fees. In the case of a university spin-off, equity is often also part of the deal.

A somewhat special example of TTO output is the formation of university startups/spin-offs, hereafter called spin-offs. A license can be commercialized in a spin-off when the university deems it unfit for an existing company. For example, Shane (2002) found evidence for a relationship between the radicalness, importance and scope of a patent and the likelihood that the patents were commercialized through venture creation. This suggests that universities critically look at inventions and could earn more revenue through venture creation than by licensing the invention to an existing company.
Indeed, spin-offs are often based in the home state (AUTM, 2017). Some universities use the aforementioned incubators and science parks to locate their spin-offs. Thus, spin-offs are beneficial to the local economy as they make use of the indigenous economic potential in the state or even city (Pike et al., 2017). This is also acknowledged by Feldman and Desrochers (2003) who found that Johns Hopkins University had little impact on its local economy as measured by a low number of spin-offs. However, the creation of spin-offs as a proxy for TTO performance is rarely used. This was especially evident in the early days of university technology transfer research, as spin-offs were regarded as a distraction to the potentially much more lucrative deals with patent licenses (Siegel et al., 2015). Even after spin-offs became more common in commercializing inventions, it still did not receive much attention. This happens mainly because the datasets (including the AUTM STATT database) on TT's do not incorporate the performance of spin-offs themselves. Issues with confidentiality make universities reluctant to share data on the amount of revenue these spin-offs create. It is therefore difficult to say anything about the quality of spin-offs or the success of TTO's in terms of spin-offs.
Nevertheless, some studies have investigated the question why some universities are more successful in the creation of spin-offs than others. Di Gregorio and Shane (2003) investigate four arguments for cross-university variation in the absolute number of venture creation in the US: university policies, local venture capital activity, intellectual eminence and commercial orientation of university research. Consequently, it was found that the intellectual eminence, illustrated by a score in the Gourman report, significantly predicted the number of spin-offs. This may be explained by the assumption that universities with high eminence employ high quality researchers and are thus more capable to create firm that successfully capture the rents of their innovative abilities. Secondly, the reputation of a high eminence university may help attract more commercial capital, which may be used to create new ventures. Furthermore, university policies can also have an effect on the spin-off rate. Universities that show willingness to obtain equity in exchange for upfront payments for patenting costs are more successful in producing spin-offs, while universities that provide high shares of royalties to the inventor produce *less* spin-offs. However, the other variables, including the amount of venture capital, did not significantly predict the amount of spin-offs.
O'Shea et al. (2005) adopts a resource based perspective to the explanation of the university variation on the number of spin-offs. One of the findings is that spin-off rates are largely explained by history, as previous spin-off rates seem to explain subsequent spin-off rates, suggesting persistence. Furthermore, it is noted that, similar to Di

Gregorio and Shane (2003), faculty quality positively influences the number of spin-offs. Both O'Shea et al. (2005) and Di Greorgio and Shane (2003) did not find evidence that presence of a university owned incubator increased the amount of spin-offs.

2.4 Conceptual model and hypotheses

Figure 4 presents the conceptual model based on sources used in this theoretical framework. Three different components are identified, which are believed to influence the TT process and performance. R&D, GDP and the local industry spillovers are all beneficial to, for example, the creation of licenses, spin-offs and revenue. Furthermore, the amount of revenue is believed to be highly dependent on the number of spin-offs and licenses, although this income can come from a wide variety of sources. Spin-offs and licenses are in turn dependent on the number of invention disclosures.

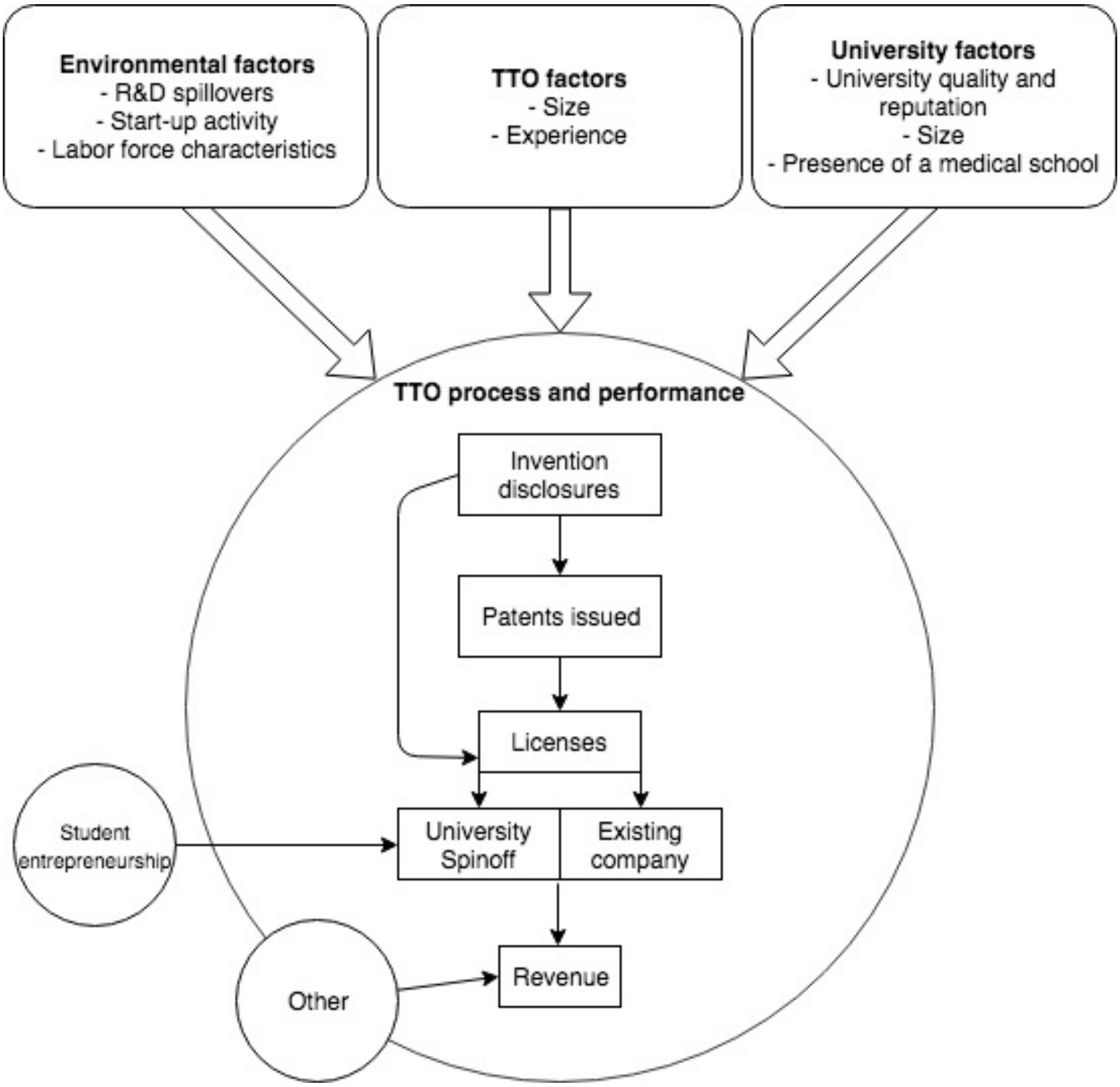


Figure 4: Conceptual model on the factors influencing the TTO process and outcomes

Note that student entrepreneurship may also lead to university spin-offs, but these kinds of spin-offs are not assessed in this study, as these often do not make use of highly innovative patents created by faculty. Furthermore, revenue is related to more factors that may or may not be located within the realm of the TTO process and performance. Examples can be derived from the other forms of tech transfer possibilities, described in paragraph 2.1.

Following the model, a number of hypotheses are derived. Firstly, it is evident that the universities' efforts to be innovative are of vital importance to TTO performance. In fact, universities of high quality and with high research expenditures are most probable to make pioneering inventions with market potential. As a result, more spin-offs are and licenses are created and thus income generated. Secondly, the number of employees and experience of the TTO should translate in higher performance, as experienced and staffed TTO's are more effective in commercializing inventions.

Among the performance indicators, university spin-off creation is expected to be most dependent on the environmental context. This is evident as the spin-off development is often located in the region of the university, thereby making use of the region's indigenous potential. Furthermore, spin-offs may also benefit the region's ingenious potential, although no endogenous relationship should be expected, due to an only modest impact on the area. Contrarily, revenues are expected to be less dependent on environmental context, because of other potential sources of income. Accordingly, this income may well be derived from outside the region and even the country. Similarly, the number of licenses generating income are often utilized by entities from outside the region.

3. Methodology

This study will assess around 137 universities and their respective characteristics. Some of these are aggregated at a CBSA or state level; others are at the level of the university or TTO. This section will assess the variables used and discuss potential bias. Finally, the modeling approach is revealed.

3.1 Sample

The data used for this study is from the American University Technology Manager (AUTM) organization. AUTM is a professional agency governed by and for TTO's. The institution controls that the data is only accessible by members of the organization.
AUTM annually collects data from over 160 universities and other research institutions to obtain information pertaining to patents, licenses, spin-offs, licensing revenue and funding. The database consists of a total of 60 different variables. The universities included are located in 48 different states, leaving out only Wyoming and Maine. Ohio is represented with the most universities, namely 10. Some universities are included as a system of universities. For example, the state of California has a system of public universities in place, comprising of 10 campuses located all over the state. Similarly, other states with such systems in the database are Louisiana, Maryland, Texas Pennsylvania, Oklahoma and Missouri. Because of the fact that these system universities are influenced by multiple regional contexts and the impossibility to distinguish between the different universities in those systems, they are excluded from the analysis.

Rank	University	Total # of spin-offs in three years
1	Stanford University	71
2	Purdue University	57
3	Massachusetts Inst. of Technology	52
4	Johns Hopkins University[4]	49
5	Brigham Young University	47
		Total # number of licenses generating income (2017)
1	University of Florida	998
2	Stanford University	805
3	University of Washington	615
4	Rutgers University	569
5	University of Minnesota	545
		Average annual gross licensing income in $
1	Northwestern University	235.000.000
2	New York University	184.000.000
3	Carnegie Mellon University	159.000.000
4	Columbia University	142.000.000
5	Stanford University	124.000.000

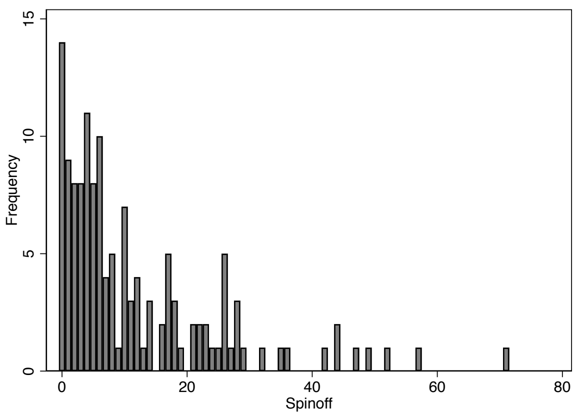
Table 2: Best performing universities in terms of TTO output

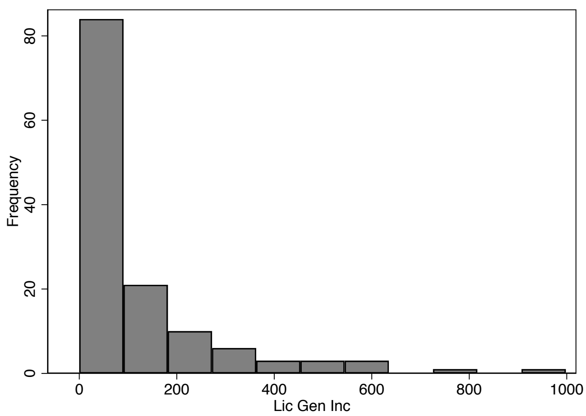
[4] Johns Hopkins University position on this list may be regarded as a small suprise, as Feldman (1994) found that this university did little to generate direct entrepreneurial activity from their research base. Apparently, a lot can happen in 20 years.

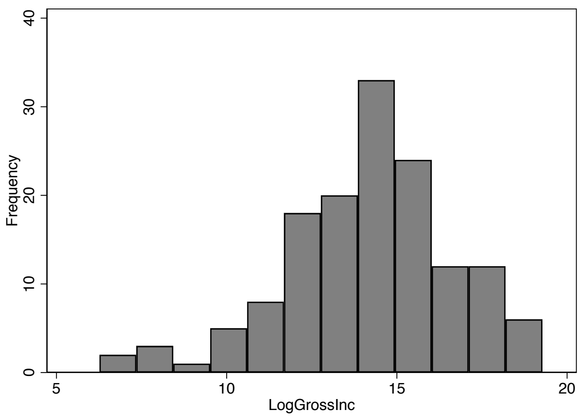
The coverage of the AUTM data is excellent, as it covers more than 80% of the universities in the US with over 200 publications in the fields of Science and Engineering (Conti and Gaule, 2010).
To give a sense of the sample, table 1 displays the five best performing universities in terms of the number of spin-offs created, licenses generating income and the average gross licensing income.

3.2 Dependent variables

The dependent variables are all regarded as measurements of TTO performance. The first one is the total number of spin-offs located in the home state per year, formed during a three-year period before 2017. The chosen method limits the possibility that a university randomly performs significantly higher or lower in one year because of coincidence, leading the data to be accurate. Since many universities report 0 spin-offs in a certain year, three-year totals also limit the amount of 0's in the regression. However, the modus in this dataset is still 0, resulting in distribution of the data that is not normal (figure 5). The variable can be regarded as a count variable. Therefore, the regression used to estimate the effects is a negative binomial regression. This is also true for the second dependent variable, the number of licenses generating income (figure 6), which is also a count variable. The third variable, gross licensing income received is transformed to a log to deal with outliers and make it fitting for an OLS regression (figure 7). Details on the chosen statistical method are described in section 3.5. All performance indicators are from the AUTM database.







Figures 5, 6 and 7: Histograms regarding the frequencies of spin-off creation, licenses generating income and the log of gross license income

3.3 Independent variables

Following the conceptual model in figure 4, the independent variables used in this study are roughly distinguishable into three groups: environmental factors, university factors and TTO factors. Subsequently, the level of measurement also differs, as environmental factors are derived from the state and CBSA level. Resulting, multiple schools may have the same environmental context, as they may be located in the same state or CBSA.

3.3.1 Environmental factors

Workforce spillovers

Presence of certain professions could be seen as supportive to the regions entrepreneurial ecosystem and, thus, the formation of spin-offs. To measure the presence of workforce spillovers, census data is used. Consequently, each university's respective metropolitan/micropolitan[5] area is used as the level of interest. Metropolitan areas refer to functional urban statistical areas in the US. Each university in the dataset gets assigned to the metropolitan area it is located in. This geographic scale is useful, as it captures the area of the effective workforce better than the county level, as the county is generally smaller and not based on the functional area. Accordingly, one could argue that because the dependent variable makes use of the state-wide scale of creating spin-offs, the independent variable should also capture the state-wide division of workers. This analogy makes sense because of consistency, but as US states are rather big and the creation of spin-offs may benefit from place-based face-to-face contact, the metropolitan workforce division is more relevant to, for example, the creation of university spin-offs. The sectors that are of interest are management, science and technical occupations.

Managers are not necessarily entrepreneurial or innovative, though, a high proportion of them might indicate the presence of an entrepreneurial culture. Furthermore, since the researchers themselves often do not lead spin-offs, universities seek for outside CEOs, which is potentially easier in regions with a high concentration of managers.

Managers of companies and enterprises are quite rare. In a working population of over 150 million, the total number of individuals employed as a manager of an enterprise or company is approximately only 144,719 (US Census Bureau, 2017), making it the smallest industry category.

Meanwhile, workers in employed in so-called STEM-jobs (science, technology, engineering and mathematics) are believed to drive innovation and competitiveness of nations by generating ideas, enterprises and industries (Langdon et al, 2011). The data used in this study maintains a slightly different definition than STEM-jobs, namely the sector for professional, scientific and technical services. The population employed in these services is much more substantial. Here, a number of over 10 million civilians are active. Presence of these occupations provides a labor pool that could be useful to spin-offs, as they need these workers to start and maintain a business.

Thus, the result is two different variables that describe the percentage of workers employed in both the sector for managers of enterprises/companies and the sector for

[5] Metro- and micropolitan areas are both Core Based Statistical Areas (CBSA's). Micropolitan areas are clustered around an urban area of at least 10.000 but fewer than 50.000 inhabitants. Metropolitan areas consist of at least 50.000 inhabitants.

professional, scientific and technical services, based on the total number of workers in that metropolitan area. US census data for the year 2016 is used, based on the four digit industry of the North American Industry Classification 2012.

R&D intensity

Previous research has shown that industrial R&D expenditures in a region positively related to TTO output. This suggests that R&D spillovers exist and thus need to be assessed. In order to do this, the statewide R&D expenditures per capita is investigated. Following the argument of the section above, the metropolitan scale may be more relevant, though, unfortunately, there is no accessible data on industrial R&D at the metropolitan scale. This approach is similar to Siegel et al. (2003)'s in which the state was used as a level of scale when assessing TTO output. The variable controls for the size of each state and is thus a measure of the level of expenditures by industry per capita on R&D.

Start up activity

Regions with high number concentrations of startups may well be the regions with more fertile ground for university spin-offs, as their ranking indicates presence of a developed entrepreneurial culture. The Kauffman index ranks metropolitan statistical areas based on their startup activity. The area's startup activity is in turn based on the rate of new entrepreneurs, share of opportunity-based entrepreneurs (as opposed to entrepreneurs who were previously unemployed) and the startup concentration. Unfortunately, only the 40 largest metropolitan areas are included. Certainly, these do not sufficiently comprise all metropolitan areas in the sample. As a compromise, the variable is used as a dummy with the top 15 highest ranked metropolitan areas operationalized as 1 and all the other areas as 0. It is assumed that small metropolitan areas would not reach the top 15 in startup activity if they were included. This assumption can be considered as a valid one, as startup activity generally benefits from economies of scale and is thus higher in bigger cities.

3.3.2 University factors

University quality/reputation

The Academic Ranking of World Universities (ARWU) from the Shanghai Ranking Consultancy is assessed to control for the universities eminence. The ARWU measures a score of over 1500 universities based mainly on their faculty quality and research output. For example, publishing in Nature and Science, winning Nobel prizes and other field medals and employing highly cited researcher all positively influence this score. Following Messini Petruzelli (2011), the variable is a dummy with a 1 for universities ranked in the top 15 best American Universities and a 0 for universities ranked below 15. Of the 15 best universities, 14 are present in this sample, although 2 (University of California, Berkeley and Los Angeles locations) are omitted due to the fact that they are included as part of the University of California system.

University size

Bigger universities may have a greater possibility to create more spin-offs. In fact, they employ more researchers and could offer economies of scale that result in higher spin-off creation. Furthermore, they are better known in the region and thus of interest to entrepreneurs who want their organization to be linked to a well-known university. To control for university size, the total number of students (graduate and undergraduate) for the fall 2017 are taken into account.

Research expenditures
Similarly to university size, the amount of research expenditures is expected to have a relationship to the amount of subsequent commercialized research. Research expenditures, which consist of both federal and industrial expenditures, are provided in the AUTM database.

Presence of a medical school
Patents and licenses are most frequently provided in the medical and life science sectors. It is therefore important to control for presence of a medical school. It can be expected that schools that have a medical school are much more active in transferring knowledge. Data on presence of medical school is provided in the AUTM database and is used as a dummy variable.

Public or private
Some scholars have suggested differences between private and public universities in willingness to commercialize inventions. Private universities are typically not as engaged in their regional community as their public counterpart (Wright et al., 2017), resulting in less incentive to commercializing through a local spin-off. However, Siegel et al. (2003) note that public universities may have less flexible policies regarding commercialization through spin-offs or licenses compared to private universities. Furthermore, this article argues that public universities may have less incentive to obtain revenues through TT, as they already receive their funds from governmental institutions. Thus, the nature of the effect of public/private universities on TTO performance is unclear.

3.3.3 TTO factors

TTO size
According to O'Shea et al. (2005), the amount of full time employees in a tech transfer office significantly influences the number of produced spin-offs in a positive way. It is therefore important to control this variable in the analysis. Data on the amount of full time employees is provided by the AUTM database and does not include support staff employees.

TTO Experience
As acknowledged by various scholars, TTO experience appears to be important in determining the performance of TTO's (Conti and Gaule, 2010; Friedman and Silberman; 2003). Experience may be beneficial in negotiating deals with the private sector, and thus result in better performance. In this research, age of the TTO is used as an indication of experience. To be more precise: the year in which the TTO employed 0,5 full time employees is used as the year in which TTO started operations.

Number of invention disclosures
The amount of invention disclosures is another way to measure the TTO size. Invention disclosures are the raw material and can be seen as the pool of possible inventions firms and entrepreneurs can commercialize (Friedman and Silberman, 2003). Meanwhile,

invention disclosures can also be seen as a proxy for the level of innovativeness of the university. However, as not all inventions become disclosed at the TTO, the number of disclosures is highly influenced by TTO efforts and can therefore be seen as more relevant to the TTO than the university.

3.3.4 Overview of the independent variables

An overview of the above mentioned variables, together with their label, level of measurement, description and source is displayed in table 3.

Variable	**Label**	**Level**	**Description**	**Source**
Manager concentration	Managers	Metropolitan area	Ratio variable that describes the concentration of managers of enterprises and companies based on the total workforce in a metro/micro statistical area.	United States Census
Scientific and technical services concentration	SciTechs	Metropolitan area	Ratio variable that describes the concentration of scientists and tech experts based on the total workforce in a metro/micro statistical area.	United States Census
R&D intensity	R&D	State	Ratio variable that captures the statewide industrial expenditures on research and development per capita.	National Science Foundation
Startup activity	StrtUpAct	Metropolitan area	Dummy variable controlling for metropolitan areas with high startup activity. The 15 most active metropolitan areas are coded as 1 while other areas are 0.	Kauffman report
University quality/reputation	UniQual	University	Dummy variable controlling for the university quality and reputation. The 10 best US universities are coded as 1 while other universities are coded as 0.	Shanghai Ranking
University size	UniSize	University	Ratio variable describing the size of each university based on the number of academic personnel.	National Center for Education Statistics

Variable	Label	Level	Description	Source
Research expenditures	ResExp	University	Ratio variable capturing the expenditures (federal and industrial) on research by each university.	AUTM
Presence of a medical school	Med	University	Dummy variable controlling for universities with a medical school. Schools that have a medical school are coded as 1 and schools that do not are coded as 0.	AUTM
Private/Public	Private	University	Dummy that controls for the possible differences between public and private schools. Private schools are coded as 1 and public schools are coded as 0.	National Center for Education Statistics
<u>TTO size</u>	TTOSize	TTO	Ratio variable controlling for the size of each TTO based on the number of full time employees.	AUTM
<u>TTO experience</u>	Age	TTO	The amount of years since the TTO employed at leats 0,5 full time employees.	AUTM
<u>Invention disclosures</u>	InvDis	TTO	Ratio variable controlling for the average amount of invention disclosures in a three-year period.	AUTM

Table 3: Overview of dependent variables. Variables in ***bold*** *are the environmental factors, variables in italics are the university factors and* <u>*underlined*</u> *variables are TTO factors. This division is also used in further tables.*

3.4 Possible bias

While the AUTM data is useful for the dependent and a number of independent variables, other data sources are also assessed. The United States Census Bureau, National Science Foundation, National Center for Education Statistic, Kauffman Foundations and Shanghai Ranking Consultancy are all professional (non) governmental organizations. Consequently, there is no reason to believe substantial measurement error exists in the data.
However, it is important to keep in mind the possibility for bias in the data. While the coverage on American universities in the AUTM database is considerable, some universities may have not responded to the question regarding the number of state-based spin-offs in recent surveys, but did so in earlier surveys. As the introduction has shown, the practice of creating spin-offs has increased over the years, thus, one could expect recent results to be higher than earlier ones. To control this bias, a dummy variable (T) is implemented, which indicates whether the results are from the 2013-2015 period or the 2015-2017 period.
Furthermore, the question regarding the number of state-based spin-offs is sometimes left unanswered in two or less years in the period after 2013, making these universities not suitable for the analysis. This may happen due to the fact that these TTOs produce no spin-offs at all, and thus choose not to answer this question instead of responding with 0. In fact, the universities that did not submit data on the establishment of spin-offs in a sufficient amount of years tend to be universities with a low amount of recorded invention disclosures, suggesting bias of low performing universities not to report creation of spin-offs. Therefore, it could be expected that universities with no or few created spin-offs are less willing to submit numbers on spin-offs. Consequently, it is important to keep this in mind, yet it is not expected to influence the analysis in a serious way, since the amount of omitted cases is low and there are plenty of universities left with low amounts or no spin-offs created.

3.5 Modeling approach

In order to comprehend the regional differences in TTO performance in the United States, descriptive statistics are presented through the use of cartography. While some of the variables in the analysis are on a metropolitan level, the level of analysis used is that of the state, as it is the most recognizable level of scale. In order to control for the size of states, the total number of output for each performance indicator is divided by the total number of students in that state.

Subsequently, for the purposes of explaining the phenomena shown on the map and answering the remaining research questions, two different regression are applied. A quantitative method is chosen, since it is better able to investigate patterns of a nationwide phenomenon than a qualitative method such as interviews would establish. Furthermore, concepts like environmental context may be too indirect for stakeholders to grasp and, thus, unfitting for interviews. Indeed, in the extensive available literature, quantitative methods are the norm. Naturally, only in papers assessing the organizational characteristics of TTO's (e.g. Siegel et al 2003) qualitative methods are employed. A regression is capable of detecting a relationship between a number of independent variables and one dependent variable. It is also able to say something about the direction and significance of this relationship. However, causality is impossible to claim with OLS regression. Detecting causality is possible with, for example, panel data analysis. However, due to the fact that data for multiple years is required for this method and most variables only have data for one point in time, panel data analysis is not an option for this research. The regressions used for the dependent variables 'spin-off creation' and 'licenses generating income' is a Negative Binomial regression. This regression is applied since the variables are count variables and the standard deviation is far larger than the mean, indicating over-dispersion. Therefore, Poisson regression, another count regression, is unfit. In essence, the negative binomial model allows the conditional mean and variance to vary. The functional form of Negative Binomial regression model is represented as follows (Greene, 2008):

1. $\mu_i = \exp(\beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \beta_n x_{in} + \varepsilon_i)$

In which μ_i is the dependent count variable, β_0 the constant, x_{i1}, x_{i2} and x_{in} the independent variables, b_1, b_2 and b_n the parameters and ε the error term.
Indeed, the dependent variable is restricted and coefficients need to be interpreted by taking the exponent, which gives the change in factors.

The remaining dependent variable is the gross annual license income. As this variable is a variable with almost no zero-values, a count regression is not necessary. An OLS regression is used. The functional form of an OLS regression is as follows:

2. $y = ß_0 + ß_1 x_{i1} + ß_2 x_{i2} + ß_n x_{in} + \varepsilon_i$

In which y is the dependent ratio variable, β_0 the constant, x_{i1}, x_{i2} and x_{in} the independent variables, b_1, b_2 and b_n the parameters and ε the error term. Because of a number of serious outliers, the dependent variable is logged. Therefore, most independent variables will give the growth rate on the performance indicator after taking the exponent. This does not apply to independent that are logged as well. Here, the elasticity effect is of relevance.

Specification of the econometric models
In order to analyze the determinants of TTO output, various models are estimated. Their specification in given below. Y is the performance indicator.

1. Y = ß0(1) +ß1(Manager) +ß2(SciTechs) +ß3(R&D) + ß4 (Startup) + T + εj
2. Y = ß0(2) + ß1(Manager) +ß2(SciTechs) +ß3(R&D) + ß4 (Startup) + ß5(UniQual) + ß6(UniSize)) + ß7(RExp) + ß8(Med) + ß9 (Private) + T + εk
3. Y = ß0(3) + ß1(Manager) +ß2(SciTechs) +ß3(R&D) + ß4 (Startup) + ß5(UniQual) + ß6(UniSize)) + ß7(RExp) + ß8(Med) + ß9 (Private)+ ß10 (TTOSize) + ß11 (Age) + ß12(InvDis)+ T + εl

The environmental variables will be assessed alone first, after which control variables for the university and TTO are added. The resulting final model will give an overview of the various effects of contextual factors.

4. Results

The effects of environmental context on TTO performance is assessed and displayed in this section. Accordingly, descriptive statistics, maps and regressions are used. In order to reflect the multi-dimensional nature of TTO output, three different performance indicators are assessed.

4.1 Descriptive statistics

Table 4 displays the descriptive statistics for universities in the sample. The average American university in this sample creates almost twelve spin-offs per 3 years, has 115,65 active licenses generating income and receives over 14 million dollars in gross licensing income. Furthermore, statistics show that less than half (33,76%) of the universities in this sample are private and more than half (55,86%) has a medical school. On average, TTO's are 29 years old (created in 1989) and hire 5,7 full time employees. The TTOs register an average of 123,8 invention disclosures per year.
Metropolitan areas have industries that generally consist of 7,3% professional, scientific and technical services. Furthermore, average state has an amount of industrial R&D expenditures that equals 759 dollars per inhabitant.

Variable	**N**	**Mean**	**Std. Deviation**	**Min**	**Max**
Spin-offs	137	11,96	13,3	0	71
Licenses	133	115,65	166,75	0	998
GrossInc	140	14.331.644	68.175.360	0	758.408.215
Managers	145	0,094%	0,062%	0%	0,352%
ScieTechs	145	7,317%	2,536%	2,845%	16,217%
R&D	145	759	665	36	2673
Startup	145	0,144	0,353	0	1
UniQual	145	0,078	0,353	0	1
Unisize	142	22.905	13.735	232	66.059
Rexp	145	315.661.561	343.191.637	8.775.544	1.701.110.000
Med	145	0,559	0,498	0	1
Private	145	0,337	0,475	0	1
TTOSize	133	5,721	4,927	0,1	24,91
Age	140	29,12	13,18	4	93
InvDis	145	123,8	133,4	1,67	796,3

Table 4: Descriptive statistics

The share of managers in each metropolitan area is generally very low, being less that 0,1%. Due to this very low number, one could wonder whether including this variable will have any effect on the performance indicators. Since the variables are picked based on theory rather than statistical relevance, the variable will remain in the analysis.
Table 5 displays the correlations between fifteen variables, which are divided by three dependent and 12 independent ones. As expected, moderate correlations can be found between created spin-offs and executed licenses. However, surprisingly enough, there is little correlation with these two variables and the gross license income received. Consequently, there appears little reason to believe that high amounts of created spin-offs and licenses generating income would lead to high licensing income. This reinforces the idea that various variables should be assessed when investigating TTO performance. What is more, the number of invention disclosures recorded shows high correlations with a number of variables, namely the number of the spin-offs created, licenses executed, research expenditures and the TTO size. This is hardly surprising, as it was earlier noted that invention disclosures are the raw material for licenses and spin-offs and are to some extent also a form of TTO output. Although variance inflation factors (VIF) do not show worrisome multicolinearity, the variable invention disclosure is omitted from the analysis. This is reasonable, because otherwise the standard errors of a substantial number of variables would be inflated. Furthermore, leaving the variable out will not lead to bias, as the effect is covered by the research expenditures and TTO size.

Table 5: Correlation matrix for all variables

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
(1)Spin-offs	1														
(2)Licenses	*0,61*	1													
(3)GrossInc	0,39	0,08	1												
(4)Managers	0,09	0,11	0,1	1											
(5)SciTechs	0,35	0,27	0.25	0,28	1										
(6)R&D	0,33	0,27	0.25	0,07	0,31	1									
(7)Startup	0,12	0,05	0.19	0,18	0,24	0,16	1								
(8)UniQual	0,51	0,42	0.37	0,05	0,33	0,44	0,05	1							
(9)Unisize	0,37	0,31	0,1	-,02	-,08	0,02	-,14	-,07	1						
(10)Rexp	*0,61*	0,57	0.36	0,11	0,34	0,33	0,08	0,50	0,37	1					
(11)Med	0,23	0,24	0,08	0,04	0,04	-,04	-,04	0,08	0,20	0,36	1				
(12)Private	0,17	0,12	0.34	0,17	0,16	0,23	0,23	0,33	-,44	0,19	0,12	1			
(13)TTOsize	*0,75*	*0,74*	0,45	0,12	0,12	0,38	0,38	0,50	0,33	**0,85**	0,34	0,23	1		
(14)Age	0,46	0.42	0,22	-,06	-,06	0,26	0,26	0,23	0,24	0,53	0,14	0,10	*0,60*	1	
(15)Invdis	**0,84**	*0.68*	0,42	0,13	0,13	0,40	0,40	0,57	0,32	**0,90**	0,24	0,25	**0,84**	0,53	1

Finally, at first glance, it seems that university related variables show strong correlation with the dependent variables while the correlations for the environmental variables are moderate. This could indicate stronger effects for university related variables on TTO output than effects of environmental variables.

4.2 Regional differences

The maps shown in Figure 8 show differences in TTO output per state. Indeed, it can easily be derived that regional differences exist. California and Maryland are the best examples of this divergence. Meanwhile, rural and/or thinly populated states like Alaska, Idaho, South Dakota, Nebraska, Kansas, Arkansas, Mississippi and Alabama are generally poor performers in terms of output per student. Other states are strong in one performance variable and weak in others. For example, the state of Pennsylvania, Illinois and New York generate a high amount of license income but are mediocre in terms of created spin-offs. Contrarily, Utah houses universities that create relatively many spin-offs per 10.000 students but receive relatively little income. Conclusively, certain patterns exist in spin-off creation, though, the results show that they are not homogenous. Table 6 shows the four states with the highest and lowest average rank. The ranking is based on their performance indicator as displayed on the maps. States with the highest score are assigned 1 while the lowest performing state is assigned 49.

State	Average rank	Spin-off ranking	License ranking	Income ranking
Maryland	3,33	1	3	6
California	3,67	2	4	5
New York	5,67	9	7	1
Massachusetts	6	3	8	7
Idaho	42,67	35	46	43
Nevada	43	36	45	47
West Virginia	46,33	47	47	45
Alaska	49	49	49	49

Table 6: Average ranking of the four highest- and lowest performing states in terms of TTO output

The maps displayed in Figure 8 make it clear that regional differences exist and that these discrepancies are not random. However, they do further raise the question whether TTO performance is mostly influenced by the university or by the regional context/indigenous potential. For example, the states of California and Massachusetts house some of the best universities in the world, while also being the states with high R&D expenditures and specialization in scientific and technical services. The sections below will aim to capture a more precise relationship between TTO output and environmental, university or TTO factors.

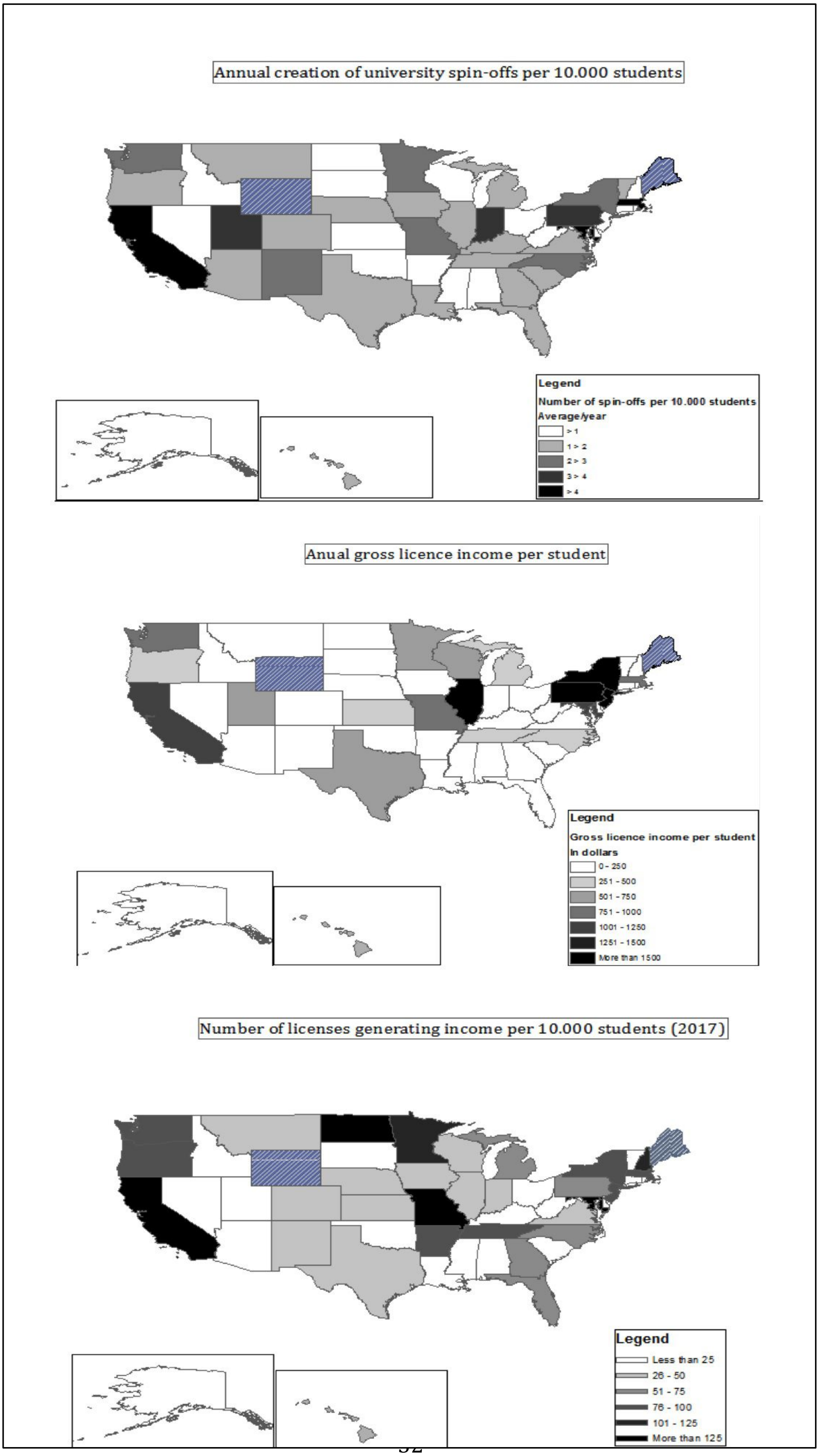


Figure 8: Maps showing state level differences in TTO performance

4.3 Contextual effects on TTO performance

The performance of TTO's is assessed in the regressions below. Due to the nature of count variables spin-offs and licenses, a different kind of regression is used to estimate the parameters of the independent variables. Similarly, this regression was discussed in the methodology. Negative binomial regressions account for the restrictive character of count variables. This implies that coefficients can be interpreted by using the exponent. The exponent reveals the multiplicative effect on the dependent variable. The performance variable 'Gross Licensing Income' is logged and therefore growth rates are assessed. Here, an increase in x leads to $((\exp(ß_x)-1)*100\%$ change in y. The exception is the variable research expenditures, which is also logged. In case of the latter, the resulting coefficient can be interpreted as the elasticity effect, in which a 1% increase in x leads to a $(ß_x)\%$ increase for y. Because of high correlations with the dependent and a number of independent variables, the number of invention disclosures is left out of the regressions. For clarification purposes, it should be said that regressions were also run with clustered standard errors (on the metropolitan area level), but results did not change in any noticeable way (see appendix).

4.3.1 Spin-off creation

The table below shows the results for models explaining the total spin-off creation in a three-year period, measured between 2013 and 2017.

The table above shows that the share of jobs in professional, scientific and technical services positively influence the number of spin-offs created in the home state. The variable has a coefficient of 0,159, which means that for every increase of 1% in share of workers in this sector, the expected amount of created spin-offs in a three-year period increases with multiplies with 1,172 Nevertheless, this significance vanishes when controlling for university and TTO characteristics.

Unsurprisingly, the models show that universities benefit from economies of scale: bigger universities and higher research expenditures result in a higher number of spin-off creation.

However, the fact that private universities are creating significantly more spin-offs may be considered odd, especially considering the insignificant status of highly ranked universities in the model. While the sign of the coefficient was difficult to predict based on theoretical evidence, it turned out to positively influence spin-off creation. Indeed, the amount of created spin-offs in a three-year period for private schools is approximately 1,5 times higher than for public schools. Meanwhile, according to the model, a 1% increase in research expenditures leads to 0,36% increase in spin-offs. Finally, we can notice that an increase of students leads to a small yet significant increase of created spin-offs, this being 1,00002 times as many spin-offs per extra student.

Thus, based on these results, there is a clear effect of university characteristics on spin-off creation, diminishing the effects of environmental variables. Indeed, metropolitan labor characteristics, R&D intensity and startup activity do not have a significant effect on universities' spin-off creation. Moreover, private schools are significantly more active in creating spin-offs, even when controlling for university size and research expenditures. Private universities could be forced into being more creative in generating revenue, since they do not receive governmental income, resulting in the creation of spin-offs. It could also be a result of the personal characteristics of staff and students, leading to higher tendency to become an entrepreneur. However, a real probable cause is unfortunately unclear, since data on this scale of level is unavailable and papers addressing this issue are unknown.

Spin-offs	Model 1	Model 2	Model 3
Managers	0,263 (1,741)	-0,4 (1,268)	-,014 (1,212)
SciTechs	0,159 *** (0,051)	0,066 (0,038)	0,030 (0,032)
R&D	,0002 (,0001)	-0,00001 (0,001)	-,00007 (0,00012)
Startup	0,007 (0,272)	0,093 (0,221)	0,003 (0,208)
Med		-,062 (0,158)	-,143 (0,152)
Rexp[a]		,472*** (0,083)	0.366*** (0,094)
Private		0,437** (0,179)	0,425** (0,175)
UniSize		0,00003*** (5,84e-06)	0,00002*** (5,58e-06)
UniQual		0,386 (0,311)	0,287 (0,315)
Age			0,006 (0,007)
TTOSize			0,032 (0,02)
T	0,458 (0,335)	-,570** (0,28)	-,906** (0,355)
Constant	0,624 (0,48)	7,45*** (1,36)	5,05*** (1,55)
Pseudo R2	0,0245	0,1098	0,1181
Log likelihood	-466,41	-419,17	-385,86

Table 7: Negative binomial regressions on spin-off creation
** p < 0.10, ** p < 0.05, *** p < 0.01*
a: Variable is logged

The pseudo R square should be interpreted with caution, as it is not estimated to be similar to regular R squares. The pseudo R square clearly improves when adding university and TTO variables. The final pseudo R square, 11,8% is decent compared to similar research that used negative binomial regressions in tech transfer related papers (Messini Petruzelli, 2011; Hülsbeck et al, 2013; O'shea et al, 2005).

4.3.2 Licenses generating income

The table below shows the models estimating the number of licenses generating income in the year 2017.

Licenses generating income	Model 1	Model 2	Model 3
Managers	1,595 (1,675)	2,014* (1,176)	1,194 (1,03)
SciTechs	0,135** (0,06)	-0,013 (0,034)	-0.025 (0,034)
R&D	,0002 (,0002)	-8,57e-07 (0,0001)	-,0001 (0,0001)
Startup	-0,228 (0,326)	-,286 (0,233)	-,286 (0,210)
Med		-,362** (0,173)	-,477*** (0,155)
Rexp[a]		1,137*** (0,083)	0,905*** (0,101)
Private		-,249 (0,195)	-,253 (0,189)
UniSize		-1,05e-06 (8,07e-06)	-,00001 (6,64e-06)
UniQual		0,281 (0,255)	0,019 (0,28)
Age			,0007 (0,008)
TTOSize			,0983*** (0,0255)
T	0,644 (0,521)	-1,124*** (0,373)	-,773** (0,344)
Constant	3,402*** (0,4)	-16,24*** (1,398)	-12,17*** (1,69)
Pseudo R2	0,0117	0,1061	0,1153
Log likelihood	-742,93	-661,67	-638,39

Figure 8: Negative binomial regressions on the number of licenses generating income
** p < 0.10, ** p < 0.05, *** p < 0.01*
a: variable is logged

TTO performance in terms of the number of licenses generating income show similar characteristics to spin-off creation. Once again, the share of scientific, technical and professional services in the region significantly enter the model, but becomes irrelevant when controlling for university and TTO characteristics. Furthermore, bigger TTO's produce more licenses generating income, while the total research expenditures also significantly influence this performance variable. It is remarkable how is the share of managers in the region becomes a significant variable at a 10% level when controlling for university variables. Furthermore, we can notice that presence of a medical school is significant, yet in a different direction than expected. This is odd, as the average amount of licenses created by schools with a medical school is higher than for schools without a medical school, as can be seen in table 6. Furthermore, regressions without any non-environmental variables would result in the variable *Med* to be positively significantly different from zero at a 1% level. It thus appears that, when controlling for university and TTO characteristics, the sign becomes significant in a negative direction.

Licenses generating income	Mean	S.D.	N
No medical school present	*69,53*	*98,91*	*54*
Medical school present	*148,90*	*195,41*	*78*

Table 9: Mean and standard deviation of universities with and without a medical school on the number of licenses generating income

The final model shows that a 1% increase in research expenditures leads to a 0,9% increase in licenses. Meanwhile, one extra full time employee in a TTO leads to 1,1 times as many licenses generating income.
Similarly to spin-off creation, environmental variables show no significant effect on the number of licenses generating income. Once again, it is shown that licenses generating income are more dependent on variables at the university level. However, TTO characteristics show a stronger effect on licenses generating than spin-off creation. Furthermore, private schools are not more successful in creating licenses generating income, while presence of a medical school has a negative effect on the dependent variable. Finally, what is important to note is the log likelihood that is further away from zero than the log likelihood in table 4. This indicates that the model is better in explaining the number of spin-offs than the number of licenses that generate income.

4.3.3 Average gross licensing income

As the average gross income cannot be regarded as a count variable, a regular regression is used to estimate the coefficients. To deal with outliers, the variable is logged. Therefore, coefficients are interpreted similarly to previous models.
Table 7 shows the models estimating the average annual gross licensing income, measured in the period 2013-2017.
The results show that share of scientific, technical and professional services in the economy significantly explain the average gross licensing income for a university, along with the state level R&D intensity. However, the R2 of 0,1299 indicate that only 12,99% of the variance is explained by the environmental variables in the model, which can be regarded as a weak model fit. Actually, the dependent variable is much better explained adding university and TTO variables, as indicated by the R2's.
As it happens with the amount of spin-offs, private schools significantly earn more income from licensing than public schools. It is shown that, keeping other variables constant, private schools create generate 183,7% more income than public schools. Indeed, it turns out that private schools are more active in finding new sources of income compared to public schools. Furthermore, the model shows that increased research expenditures and full time employees will lead to higher licensing income.

Moreover, a 1% increase in research expenditures leads to 0,84% increase in licensing income, while an extra full time employee results in 10,5% more income.

Log(GrossIncome)	Model 1	Model 2	Model 3
Managers	-2,048 (3,3)	-1,338 (12,23)	-1,45 (2,053)
SciTechs	0,238*** (0,088)	0,0425 (0,038)	0,015 (0,056)
R&D	,0006** (,0003)	0,0002 (0,002)	0,00004 (0,0002)
Startup	0,444 (0,581)	0,12 (0,41)	0,088 (0,368)
Med		0,324 (0,304)	0,088 (0,285)
Rexp[a]		1,296*** (0,151)	0.814*** (0,176)
Private		1,075*** (0,179)	1,043*** (0,337)
UniSize		0,00002 (0,00001)	0,00001 (0,00001)
UniQual		0,46 (0,582)	0,312 (0,556)
Age			0,016 (0,012)
TTOSize			0,1** (0,05)
Constant	12,1*** (0,62)	-11,62*** (2,62)	-2,78 (3,109)
R2	0,1299	0,6340	0,6410

Table 10: Ordinary least squares regressions on the gross annual licensing income
** p < 0.10, ** p < 0.05, *** p < 0.01*
a: Variable is logged

What can be derived from these results is that the gross licensing income clearly is a function of university and TTO efforts. Every dollar invested in research is paid back with 84 cents in licensing income. While, at first glance, it does not seem to be the best investment, it is important to note that licensing income is far from the only source of income for universities and research expenditures are not exclusively spend on licensing activities. Keeping that in mind, the model reinforces the notion that licensing has become an important and financially interesting activity for universities. Contrarily, the environmental context and potential benefits do not play a significant role.

5. Conclusion and discussion

Based on the results, the concluding answers to the research questions are provided. Subsequently, the discussion will attempt to fit the results into the existing findings and discussions in the field. In the section thereafter, ideas for future research are coined. Finally, a critical reflection on the data and process is given.

5.1 Conclusion

This study has investigated the effects environmental context may have on the multi-dimensional forms of TTO performance. Since TTO's are institutions linked to the university, it was vital to control for university variables, as well as variables linked to the TTO itself. The main research question can therefore be seen as questioning whether certain environments, given the characteristics of universities and TTO's, are more beneficial to TTO performance.

The first step in answering the main question was to determine whether there are any noticeable regional differences in the US, based on a state level. The resulting maps show that states with generally high levels of R&D intensity, California and Massachusetts, also perform particularly well in the various forms of invention commercialization efforts. The gross licensing income is generally higher for universities in the states New York and Pennsylvania, while universities in these states do not perform noticeably well in terms of spin-off creation and licenses generating income. This can also be seen as an indication for the notion that TTO performance indicators are barely substitutable.

The maps should be merely seen as a form of descriptive statistics, but they do show insight in regional differences. Nevertheless, the maps should not be seen as indicative of possible relations between TTO performance and regional characteristics.
The effects of environmental factors on TTO performance seems practically ignorable when controlling for size and quality factors of universities and TTO's. The share of professionals in scientific and technical services do have significant effects on all three performance indicators. Likewise, the statewide R&D intensity also shows significant results for gross license income received. However, this is only occurs in models that only include environmental variables.
Thus, the answer to the main research question 'What is the role of regional context of universities on their respective tech transfer office performance in the United States?' can be formulated as following: The investigated regional characteristics do not seem to have an effect on TTO performance. Environments with high shares of managers, scientists and technicians, high R&D intensity and startup activity are not particularly beneficial to neither spin-off creation, the number of licenses generating income nor the gross license income. These performance indicators are more reliable on inputs from the university and the TTO.

Results indicate that, in all cases, the size of a university in terms of students and research expenditures is dominant in explaining the output of TTO's. This does not require much theoretical background, but it does prove that increased investments in research will be reimbursed by a large extent with only licensing income. TTO's with more personnel also showed to be significantly more active in generating licenses and license income. Furthermore, private schools turned out to be more active in creating spin-offs and generating license income. According to Holstein et al. (2016), historic relationship with the region is vital in explaining the approach to entrepreneurial activity for universities. In that sense, it is remarkable that the data shows that private universities are much more active in spin-off creation, which was only measured in the home state, since private universities are typically not as engaged in their local communities as public universities (Wright et al., 2017). A possible explanation for this is the fact that most high-ranked universities are private and typically active in spin-off creation. However, the variable for university quality was not significant in this sample.

5.2 Discussion

The Bayh-Dole Act was an effort to reinforce global comparative advantage by shifting ownership rights of intellectual property to the university. The policymakers were influenced by the success of Route 128 and Silicon Valley, where universities had an influential role in the economic boost of the region (Grimaldi et al., 2011). In the past, presence of universities has been highly influential to the economic upturn of, for example, Boston (Pike et al., 2017). The aim of this study was to find out if these kinds of regions, characterized by high R&D intensity, specialization in scientific and technological services and managers and startup activity, would also 'give back' to the university, by providing a fertile ground for TTO performance. This effect turned out to be absent. However, the results presented in this research fit into the theoretical discussions in the field. The fact that universities are heterogeneous in terms of their research efforts (as shown by their research expenditures) is translated into a higher propensity to commercialize their research. Smaller universities with smaller research budgets may not aim to generate high growth spin-offs based on state-of-the-art inventions. Their strategy may be more focused on generating student-led spin-offs (Siegel and Wright, 2015a).

Some experts have argued that existence of Bayh-Dole and TTO's are suboptimal from an economic standpoint (Abrams et al, 2009). Although there are many examples of highly successful spin-offs and licenses, TTO's are generally not generating a net positive income and the models have shown that there are no increasing returns to scale (1 dollar increase in research expenditures results in 84 cents increase in licensing income). Nevertheless, this argument is hardly important, as generating income is not the main goal of TTO's (see table 1 in chapter 2).
However, discussions on the ethical considerations of TTO's may still persist. First of all, the traditional academic culture as described by Merton clashes with the business culture created by the Bayh-Dole Act. Merton's ideas translated to his CUDOS norms (science is communal, universal, disinterested, and rests on organized skepticism) do not coincide with the exclusive nature of patenting and licensing. Although the data in this research does not provide new insights in this discussion, it is important to critically reflect on the fundamental nature of the universities' new third mission (next to teaching and research). Resulting frictions between faculty and TTO's may take various forms. TTO officials are not researchers themselves and may be closer to the Bayh-Dole ideals than Merton's ideals. Researchers who do not aim for profit could wish for an open license while the TTO aims for exclusivity. More commonly is the argument from researchers that they themselves are better and more efficient in commercializing their own invention, since he/she knows best about the invention and its potential users. Subsequently, researchers may even try to avoid any interference from the TTO

and create a start-up outside the university (Kumar, 2010). This is technically not allowed, but there are possibilities to find a way around the laws of technology transfer (Link et al, 2007). Furthermore, Huyghe et al. (2016) showed that commercialization outside the TTO may also happen unintentionally, as only a minority of researchers in Europe are aware of the existence of a TTO at their university.

The data used in the research has shown that TTO's are willing to create spin-offs in their own state. While it is unclear what the effects would be if Bayh-Dole and TTO's did not happen, one could say with a high degree of certainty that university-industry technology transfer has contributed greatly to the indigenous potential of regions. Therefore, TTO's can be seen as welcome institutions that should receive more attention especially in Europe, where TTO's are less common and/or less developed. The fact that environmental context are not necessarily important in the performance of a TTO as opposed to internal factors, such as research expenditures and TTO staffing, should be seen as motivation for all universities in a sense that their own input has more (significant) effect on the output.

5.3 Future research

In terms of academic interest, the phenomenon of the university spin-off has received relatively little attention. This is mainly because of the fact that returns from these spin-offs are unknown. This research has merely investigated the number of spin-offs created, but is unable to say anything about the success of these spin-offs. Fortunately, two other indicators were additionally assessed in order to gain a broader view of TTO performance. Future research should look into the precise effects of spin-offs in the region in terms of employment growth and multipliers for the region. An effective way to do this is by extending the AUTM survey to include spin-off characteristics.

Furthermore, there may well be unobserved effects at the individual university level regarding policy explaining spin-off creation. For example, Johns Hopkins (Maryland), one of most active universities in creating spin-offs, requires master students at the business school to take a course which involves a partnership with the TTO. In this course, students conduct market analysis and develop a plan for the commercialization of a TTO disclosed invention. Another example is Brigham Young University (Utah), which has developed a remuneration system much more favorable for academic personnel, making it more worthwhile for researchers to disclose and commercialize their inventions. Brigham Young also happens to be one of the most active spin-off creators in the US (AUTM, 2017; Siegel and Wright, 2015a). These anecdotal examples should provide enough incentive to delve into the effects of these university level policies and practices.

Finally, while this research attempted to look into the effects of a limited number of potentially facilitating factors for academic entrepreneurship, the dynamics between the entrepreneurial ecosystem and university-industry technology transfer remains largely unexplored. While some of the components are commonly important, the interrelationships remain uncharted and may vary between universities. Not only regional entrepreneurial components and the university may interact, but the university itself also creates an interacting internal academic ecosystem. This ecosystem consists of incubators and science parks, entrepreneurial courses, TTO's, external/surrogate entrepreneurs on campus and alumni in support of entrepreneurial activities. Indeed, as noted by Siegel and Wright (2015b), the scope of these ecosystems may differ for universities in a rural region, as compared to universities in major metropolitan areas.

5.4 Critical reflection on data and process

This study had the pleasant characteristic that it was conducted with quantitative data on a national scale. Due to this method, conclusion could be made based on a fairly large population. The data used for this research was collected from professional and/or governmental institutions, thus a personal bias is not present while collecting the data. The sample of universities could be regarded as somewhat small, but it did cover more than 80% of the universities in the US with over 200 publications in the fields of Science and Engineering. Therefore, the sample can be regarded as sufficiently representative for all universities in the US with entrepreneurial ambitions.

However, an issue with the data is the fact that different aggregated scales had to be used in order to generate variables. For example, R&D intensity and spin-off creation were measured at the state level, while ideally this would have been measured at the metropolitan level, since this lower level is believed to better capture the effective entrepreneurial ecosystem for the university.

Conservative count models were used as a method to derive results, controlling for the over dispersed characteristics of the data. Ideally, panel data would have been used in order to find potential causal effects. Due to absence of most of the data in various years, this could not be realized.

On a final personal note, the process of writing this thesis has been very informative and, especially towards the end, pleasant. Without doubt it can be regarded as the culmination of all the skills I have obtained during my studies and I was therefore motivated to make the most of it. While I am aware there is much more to learn, I am sure I will reflect on this work with a sense of satisfaction in the future.

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Appendix

Regressions with clustered standard errors (State)

	Spin-offs^	Licenses^	Log(GrossIncome)
Managers	0,147 (1,305)	1,194 (1,086)	-,307 (1,841)
SciTechs	0,030 (0,045)	-,025 (0,028)	-,068 (0,04)
R&D	-,00007 (0,0001)	-,0002 (0,0001)	0,00013 (0,00014)
Startup	0,003 (0,219)	-,287* (0,161)	0,003 (0,521)
Med	-,143 (0,142)	-,477*** (0,155)	0,162 (0,391)
Rexp[a]	0,365** (0,149)	0,906*** (0,091)	0.717*** (0,248)
Private	0,425* (0,239)	-,252 (0,161)	1,201*** (0,27)
UniSize	0,0002*** (7,73e-06)	0,00001 (6,38e-06)	0,000016 (0,000011)
UniQual	0,303 (0,214)	0,02 (0,275)	0,217 (0,582)
Age	0,006 (0,007)	0,0007 (0,007)	0,015 (0,012)
TTOSize	0,032* (0,019)	0,1*** (0,027)	0,098* (0,05)
T	-.906*** (0,301)	-,773* (0,406)	
Constant	-5,05** (2,39)	-12,17*** (1,324)	-1,19 (3,81)
Pseudo R2	0,1181	0,1153	
R2			0,5767

Table 11: Regressions on all performance indicators using clustered standard errors
** p < 0.10, ** p < 0.05, *** p < 0.01*
a: Variable is logged
^: Negative Binomial Regression