Paper to be presented at the DRUID Academy 2013

on

DRUID Academy 2013
at Comwell Rebild Bakker, Rebild/Aalborg

The University Transfer Technology performance of American Universities

Rui M Cartaxo
Instituto Superior de Economia e Gestão/Universidade Técnica de Lisboa
UECE - Research Unit on Complexity and Economics
r.car@sapo.pt

Manuel Mira Godinho
nstituto Superior de Economia e Gestão/Universidade Técnica de Lisboa
UECE - Research Unit on Complexity and Economics
mgodinho@doc.iseg.utl.pt

Gennaro J. Gama
The University of Georgia
Technology Commercialization Office. Office of the VP for Re
GJG@uga.edu

Abstract

The University Transfer Technology performance of American Universities
Rui Cartaxo; Instituto Superior de Economia e Gestão/Universidade Técnica de Lisboa (ISEG/UTL). Enrolled in 2010; expected final date: 2014
The purpose of this paper is to assess the university transfer technology (UTT) performance of Universities in the USA in the past 15 years.
In the process of universities? technology transfer to firms the Technology Transfer Offices (TTOs) are intermediaries between the administrations of universities, teachers and firms. They perform systematic surveys of existing research and knowledge within the universities, encourage researchers to look for technological opportunities in their research and disclose their discoveries to TTOs, and promote and offer the technologies they identify as having market value to potential users.
According to Thursby & Thursby (2002), the UTT to firms is a multi-stage process in this way:
in the 1st stage, inventions disclosures occur; these disclosures are linked to the previous research expenditures accumulated in the university, to the size of the faculty and to the staff employed in the Technology Transfer Offices (TTOs) that intermediate research results.
In a 2nd stage theses disclosures are intermediate inputs to patent applications, which depend obviously of the number

of disclosures, but also on the size of the TTOs staff and on the quality of the research done
In a 3rd stage, some of the patents granted are licensed; the number of licenses and options agreements executed depend on these patents but also on the number of disclosures the TTOs staff and quality of the research.
We extend and develop such a model, which is centered in the licensing growth, in order to include another dimension of UTT, the fostering and creation of technology based firms, the university spin-offs. According to Shane (2002) when patents are an ??effective mechanism for appropriating the returns to innovation?? it is more likely that inventions are licensed and when they are not effective, they are more likely to be licensed back to inventors, by means of the creation of theses spin-off companies.
The data used in this paper stems mainly from the 1997-2011 annual surveys conducted by the Association of University Technology Managers (AUTM). Data stemming from these surveys, together with data collected from other statistical sources, was analyzed in successive steps through exploratory factor analysis and structural equation modelling, combining path and confirmatory factor analysis. The data was also analyzed through econometric regression models. The results of the analysis might be relevant for the other economies, where UTT and the emergence of TTOs are in a lesser advanced stage.

?

Key References

Cervantes, M. (2003). Academic Patenting: How universities and public research organizations are using their intellectual property to boost research and spur innovative start-ups. http://www.wipo.int/sme/en/documents/academic_patenting.htm

Rogers, E.M., Yin, J., Hoffmann, J. (2000). Assessing the Efectiveness of Technology Transfer Offices at US Research Universities. Journal of the Association of University Technology Managers.

Shane, S. (2002). Selling University Technology: Patterns from MIT. Management Science, 48, 122-137.

Siegel, D.S., Veugelers, R., Wright, M. (2007). Technology Transfer Offices and commercialization of university IP: performance and policy implications. Oxford Review of Economic Policy, 23 (4), 640-660.

Thursby, J. G., Thursby M. C. (2002) Who is selling the Ivory Tower? Sources of Growth in University Licensing. Management Science, 48(1), 90-104.

Jelcodes:I23,O32

The University technology transfer performance of American Universities

Authors:

Rui M Cartaxo (ISEG- Technical University of Lisbon)

ISEG (School of Economics and Management) of the Technical University of Lisbon

Rua do Quelhas, 6, 1200-781 Lisboa, Portugal

E-mail: r.car@sapo.pt

Manuel Mira Godinho

ISEG (School of Economics and Management) of the Technical University of Lisbon and UECE (Research Unit on Complexity and Economics)

Rua do Quelhas, 6, 1200-781 Lisboa, Portugal

Tel.: +351-213 925 882

Fax: +351 - 213 971 196

E-mail: mgodinho@iseg.utl.pt

UECE receives support from FCT (*Fundação para a Ciência e a Tecnologia*), Portugal, under the Pluriannual Funding Programme.

Gennaro J. Gama

Technology Commercialization Office, Office of the VP for Research. The University of Georgia.

E-mail: gjg@uga.edu

Abstract

The paper assesses the university transfer technology (UTT) performance of Universities in the USA in the last decades, by means of a series of econometric studies on university technology transfer in the U.S. The data used stems from the 1997-2011 annual surveys conducted by the Association of University Technology Managers

(AUTM). The paper tests Thursby & Thursby (2002) model which states that UTT to firms is a multi-stage process: in the 1st stage, inventions disclosures occur; in a 2nd stage theses disclosures are intermediate inputs to patent applications; in a 3rd stage, some of the patents granted are licensed. It also tests Rogers et al. (2000) claim that the university technology transfer is a "…sequence of six steps or stages", adding licenses yielding income, start-ups and revenue licensing, to the previous three variables.

Key words: econometric modelling; technology transfer; university-industry relationships; university patenting; university spin-offs

O32 - Management of Technological Innovation and R&D; O34 - Intellectual Property Rights; I23 - Higher Education and Research Institutions; L24 - Contracting Out; Joint Ventures; Technology Licensing

1) Introduction

The purpose of this paper is to assess the university transfer technology (UTT) performance of Universities in the USA in the last decades.

According to Thursby & Thursby (2002), the UTT to firms is a multi-stage process: in the 1st stage, inventions disclosures occur; in a 2nd stage theses disclosures are intermediate inputs to patent applications; in a 3rd stage, some of the patents granted are licensed;

In this paper we test the above mentioned model, which is centered in the licensing growth, and we develop it in order to include another dimension of UTT, the fostering and creation of technology based firms - start-up companies (also referred to as university spin-offs), which are dependent on licensing from the universities.

We do this taking into account Rogers et al. (2000) claim that the university technology transfer is a "…sequence of six steps or stages", focusing not only on the three stage analyzed by Thursby & Thursby (2002), and on the ensuing dependent variables disclosures, patents, licenses, but also on three other ones, licenses yielding income, start-ups and revenue licensing, for a total of six variables.

This task is performed by means of a series of econometric studies on university technology transfer in the U.S. The data used stems mostly from the 1997-2011 annual surveys conducted by the Association of University Technology Managers (AUTM). Data stemming from these surveys was analyzed through econometric panel regression models. The results of the analysis might be relevant for the other economies, where UTT and the emergence of TTOs are in a lesser advanced stage.

The paper is structured into five sections. Section 2 briefly surveys the literature on technology transfer from universities to companies and on the role of TTOs, taking into account our specific empirical object. Section 3 identifies the purpose and scope of the analysis, describes the survey, the data and the variables of the study and outlines the methodology. Section 4 contains the econometric results. To close, section 5 highlights the main conclusions and puts forward a few recommendations for further research.

2) Conceptual Framework

2.1. Technology transfer, licensing and spinning-off in an academic context

For Thursby & Thursby (2002) the transfer of technology is a production process occurring in three stages: (i) an initial phase of development (invention disclosure) by the inventors, when they "... believe that the results of research have commercial potential"; (ii) followed by a phase of patent applications, if they believe" that their knowledge can be patented and licensed"; and (iii) a final stage of licensing.

Powers and McDougall (2005) point out that "traditionally the mechanism by which the university has developed and commercialized a technology has been via the licensing of an intellectual property to a large, established company who ultimately develops the technology into a saleable good". At the same time Powers and McDougall (2005) stress that "a growing trend among universities, however, is to pursue riskier paths for technology transfer through the formation of start-up companies or licenses with young, unproven firms."

Bercovitz and Feldman (2006) describe in detail the licensing university "which provides the right for companies and others to use intellectual property in the codified form of either patents or trademarks." According to them, "contractual licensing agreements involve selling a company the rights to use of a university's inventions in return for revenue in the form of up-front fees" and the regular payments of royalties.

Further Bercovitz and Feldman (2006) characterize university spin-offs, pointing out to various possible definitions for "spin-offs": "firms formed by university, faculty or staff; firms formed around a university license of intellectual property; start-up firms that have joint research projects with the university; and firms started by students or post-docs around research conducted at the university".

Algieri et al. (2011) discuss 4 main strands of factors explaining the creation of new academic start-ups: knowledge knowledge externalities and geographical location, specific characteristics of the universities, local economic and social environment characteristics and the resources and capabilities available in the TTOs.

Colombo et al. (2010), analyzing a sample of the new technology based firms in Italy in the period 1994-2003 show that “…universities producing high-quality scientific research have a beneficial impact on the growth of local high-tech start-ups…” when university scientists are involved in these start-ups.

According to Cervantes (2003), the answer to the question faced by managers of technology transfer and inventors of choosing between licensing a technology or creating a start-up, depends on the nature of the technology to be transferred, the market for this technology and the institution's mission. Focusing on the technology’s characteristics, Mamede and Godinho (2005) point out that the "characteristics of the technology and of the knowledge base […] affect the rate of spin-off. The discussion of issues such as tacit vs. codified technology would certainly be a promising line of research." Following such perspective, one may infer that technologies most likely to be codified or patented are more likely to be licensed, while technologies with a more intense tacit dimension are more likely to be exploited by new spin- offs.

Shane (2002) analyzing the set of 1397 patents assigned to the MIT during the 1980-1996 period shows that when patents are an “…effective mechanism for appropriating the returns to innovation…” it is more likely that inventions are licensed and when they are not effective, they are more likely to be licensed back to inventors. The creation of spin-off companies would thus be a kind of a second best option for the patent holders.

2.2. The role of TTOs

In the process of universities’ technology transfer the Technology Transfer Offices (TTOs) are active intermediaries between the administrations of universities, teachers and business firms. They perform a systematic survey of existing research and knowledge within the universities, encourage researchers to look for technological opportunities in their research and disclose their discoveries to the TTO, and promote and offer the technologies they identify as having market value to potential users. For Markman et al. (2005) "the process of commercialization of technologies developed at the university include the inventions, the disclosure of inventions to a university TTO, the assessment of patentability and attempt to transfer and license the IP for the industry.".

This mediating effect of TTOs is stressed by Siegel et al. (2003), for whom an important responsibility of senior staff in the TTO would be helping in establishing the connections through “boundary spanning”, which “refers to actions taken by university technology managers to serve as a bridge between “customers” (entrepreneurs/firms) and “suppliers” (scientists), who operate in distinctly different environments. Without effective boundary spanning, the needs of customers may not be adequately communicated to suppliers.". For Siegel et al. (2007) it is up to the TTO to decide whether an invention should be patented, to assess its commercial value and to market it, seeking for potencial licenses and start-ups.

According to Macho-Stadler et al. (2007), TTOs would be instrumental in developing relationships with industry: "A dedicated transfer unit allows for specialization in support services, most notably, partner search, management of intellectual property and business development." A TTO "can be interpreted as a seller that brings together technology inventions from different research laboratories within a university. The TTO would be like a *technology seller* and would help to "reduce the problem of asymmetric information". For Macho-Stadler et al. pooling of inventions would be a main TTO function. For Hellmann (2007) TTOs have a comparative advantage at identifying potential partner firms for exploitation of University IP, due to specialization of their staff.

TTOs are instrumental in reducing the asymmetry of information between industry and science on the value of inventions as companies are not normally able to assess the quality of inventions *ex-ante*, and as inventors may have difficulty in assessing the business value of their inventions, particularly when they arise in newer technology areas (Markman et al. 2005).

As Macho-Stadler et al. (2007) pointed out, an important dimension of the TTOs’ mission has to do with the management of intellectual property (IP), which often involves patenting but may also involve protection through industrial designs or trademarks. A first step in this process of IP management is to seek protection for the inventions. Patenting has now become a common activity for many universities, which have been building up larger patent portfolios. Mowery and Sampat (2005a) noted that US "Universities increased their share of patenting from less than 0.3% in 1963 to nearly 4% by 1999". These university patenting activities have expanded as part of the context set by the enactment of the Bayh-Dole Act in 1984, but they are part of a broader development which has do to with the emergence and growth of science-based technologies such as IT, microelectronics, biotechnology and nanotechnology (Mowery and Sampat 2005b).

The US experience on university patenting echoed abroad, but not all countries followed similar policies. In Germany, Sweden or Denmark the existence of a *professor's privilege*, allowing academics to patent inventions that stem from their own labs research, prevented universities from building up important patent portfolios. Partially as a result of the *professor's privilege* and of other institutional characteristics "over 60% of academic patents in France, Italy and Sweden are owned by business firms" (Lissoni et al. 2008). However, the overall proportion of academic patenting in Europe is at about the same level as in the US. This is confirmed by a recent study (Lissoni et al. 2010) that shows that the proportion of academic patenting in 5 European countries (France, Italy, Sweden, Netherlands, Denmark) was 4.4% in 1995-2001, which compares with the 4% figure for the USA shown above. In contrast, in the US the difference between university patenting (i.e. patents owned by the universities) and academic patenting (i.e. all patents with at least one faculty inventor) is much smaller. According to Thursby et al (2009) "in a sample of 5811 patents with US faculty as inventors, 26% are assigned solely to firms rather than universities as dictated by US university employment policies and Bayh-Dole".

3) The Model

1. Purpose of the study

According to Thursby & Thursby (2002) the UTT to firms is a multi-stage process in this way:

in the 1st stage, inventions disclosures occur; these disclosures are linked to the previous research expenditures accumulated in the university, to the size of the faculty and to the staff employed in the Technology Transfer Offices (TTOs) that intermediate research results.

In a 2nd stage theses disclosures are intermediate inputs to patent applications, which depend obviously of the number of disclosures, but also on the size of the TTOs staff and on the quality of the research done

In a 3rd stage, some of the patents granted are licensed; the number of licenses and options agreements executed depend on these patents but also on the number of disclosures, TTOs staff and quality of the research.

Rogers et al. (2000), have a similar approach, defining technology transfer from a university as a process where 3 steps occur before the universities "...begin earning income from the transferred technology". In the 1st step, invention disclosure, there is recognition of the information about a new technology developed by a faculty member, a student or a staff member, which is conveyed to the TTO. In the 2nd step, patenting, by which the university owns the intellectual property rights and can license the patented technology to another organization. In a 3rd step a commercial company secures a license from the university for the patented technology.

In our empirical research we will follow along this model by Thursby & Thursby (2002) but we will also bear in mind that Rogers et al. (2000) refer to further steps involving the creation of start-up companies which own or use the university patented technology and the generation of license income by these start-ups or by traditional licensing:

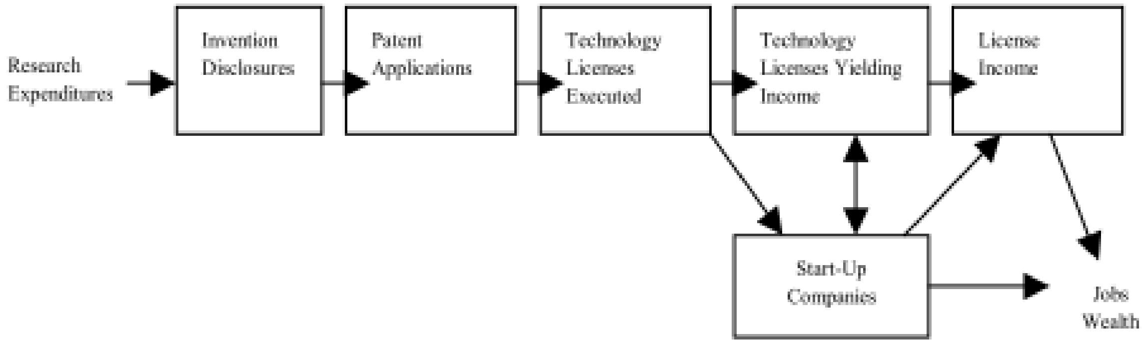

Figure 1: Rogers et al. (2000), pg. 60.

2. Scope of the analysis, hypotheses and methodology

This study analyzes the activity of the US university units in charge of technology licensing and transfer, TTOs. The info we have analyzed is a result of the annual survey conducted by the AUTM. The AUTM database covers the transfer technology activities in both the USA and Canada, including Hospitals and research institutes. For the purpose of the study we have dealt only with the info on USA universities.

The database provides information on a set of variables from 1991 to 2011. The data for the first years is rather incomplete. Furthermore, some variables were introduced as time went by and some others were taken out. Data for "Other FTE"[1] was collected every year but 1996. The number of universities which have answered to the survey every year is very small (36) and some of them (5) lack some data. Info in 1991 was limited to 61 universities and this number steadily increased to 133 in 1997, achieving 152 in 2011.

We have decided to focus on the latest 15 years (1997-2011) and we have included all the universities which had answered to a minimum of 10 annual surveys in this period, i.e. they have at least 10 observations out of 15.

---

1 Full-Time Equivalent. "Other" refers to staff other than Licensing staff.

3. Variables

The variables studied are, first of all, the dependent variables of the above presented models: number of disclosures (Disclosures), new patent applications (NPTAPP) and total patent applications (TPTAPP), licenses (and options) executed (LICEXEC), licenses generating license income (LCGNLI), Start-ups (STRTUP), and value of licensing income received (LIRECD). As independent variables: licensing staff in the TTO (LICFTE), other staff in the TTO (OTHFTE), active licenses (ACTLIC), licensed technologies available (LTAV), federal funded (FEDEXP), industrial funded (INDEXP) and total (TOTEXP) research expenditures; and a dummy variable for the presence of a medical school (MEDSCHL).

We can see in Table 1 the descriptive statistics of these variables. The average number of disclosures is just over 100, for a range between 70 and 1581. The average number of new patent applications is of 62, meaning that in average 58% of disclosures are transformed in patent applications. And the average number of licenses executed is 30, for a transformation rate from patents of 49%. For all variables the coefficient of variations (CV) goes from 1 to 2, meaning a sound dispersion. Licensing income is the exception with a value of 3.7 (overdispersion), with an average value of $US 10M, with values ranging from 1.5 to 824M.

Table 1: descriptive statistics

	Disclosure	ACTLIC	FEDEXP	INDEXP	LCEXEC	LCGNLI	LICFTE	LIRECD	LTAV	MEDSCHL	NPTAPP	OTHFTE	STRTUP	TOTEXP	TPTAPP
Mean	108,3	180,7	1,82E+08	2,08E+07	30,4	77,4	5,0	1,0E+07	4,1	0,6	62,4	5,3	3,3	2,7E+08	92,7
Median	70,0	79,0	1,12E+08	1,06E+07	16,0	34,0	3,5	1,5E+06	2,0	1,0	34,0	3,0	2,0	1,7E+08	56,0
Maximum	1581,0	2213,0	2,98E+09	3,62E+08	313,0	1947,0	95,0	8,2E+08	99,0	1,0	1075,0	103,0	75,0	5,4E+09	1285,0
Minimum	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	48501,0	0,0
Std. Dev.	138,5	261,1	2,5E+08	3,5E+07	38,9	141,0	6,8	3,7E+07	7,7	0,5	94,1	9,0	4,8	3,7E+08	126,0
Skewness	5,0	3,3	5,1	5,0	2,8	6,9	6,5	14,0	5,3	-0,5	4,8	6,1	5,5	6,6	4,2
Kurtosis	42,4	17,5	41,9	36,7	13,8	75,2	61,8	272,6	45,6	1,3	36,1	52,1	56,9	71,0	29,0
CV	1,3	1,4	1,4	1,7	1,3	1,8	1,4	3,7	1,9	0,8	1,5	1,7	1,5	1,4	1,4
Observations	1842	1793	1807	1781	1839	1821	1838	1840	1403	1951	1819	1835	1815	1833	1824

For all variables, with no exception, the median is over the average value and the skewness value is high, sign of positive skew, with the mass of the universities concentrating on low values.

As we can see on Table 2, all variable are positively and strongly correlated, with the exception of licensing income received (LIRECD) and of the dummy variable.

Table 2: Correlation coefficients

	Disclosure	ACTLIC	FEDEXP	INDEXP	LCEXEC	LCGNLI	LICFTE	LIRECD	LTAV	MEDSC HL	NPTAPP	OTHFTE	STRTUP	TOTEXP	TPTAPP
Disclosures	1,00	0,79	0,91	0,77	0,76	0,88	0,89	0,38	0,58	0,21	0,91	0,89	0,83	0,93	0,96
ACTLIC	0,79	1,00	0,77	0,64	0,88	0,87	0,77	0,36	0,61	0,18	0,70	0,78	0,64	0,78	0,75
FEDEXP	0,91	0,77	1,00	0,81	0,72	0,85	0,87	0,36	0,52	0,31	0,86	0,90	0,76	0,97	0,90
INDEXP	0,77	0,64	0,81	1,00	0,58	0,70	0,73	0,27	0,44	0,24	0,73	0,76	0,65	0,82	0,76
LCEXEC	0,76	0,88	0,72	0,58	1,00	0,81	0,70	0,32	0,59	0,14	0,66	0,74	0,63	0,72	0,73
LCGNLI	0,88	0,87	0,85	0,70	0,81	1,00	0,87	0,37	0,60	0,15	0,79	0,86	0,77	0,89	0,83
LICFTE	0,89	0,77	0,87	0,73	0,70	0,87	1,00	0,40	0,59	0,24	0,79	0,89	0,73	0,88	0,84
LIRECD	0,38	0,36	0,36	0,27	0,32	0,37	0,40	1,00	0,26	0,17	0,35	0,37	0,32	0,36	0,36
LTAV	0,58	0,61	0,52	0,44	0,59	0,60	0,59	0,26	1,00	0,08	0,45	0,65	0,43	0,56	0,52
MEDSCHL	0,21	0,18	0,31	0,24	0,14	0,15	0,24	0,17	0,08	1,00	0,17	0,24	0,14	0,27	0,21
NPTAPP	0,91	0,70	0,86	0,73	0,66	0,79	0,79	0,35	0,45	0,17	1,00	0,78	0,78	0,86	0,94
OTHFTE	0,89	0,78	0,90	0,76	0,74	0,86	0,89	0,37	0,65	0,24	0,78	1,00	0,70	0,90	0,85
STRTUP	0,83	0,64	0,76	0,65	0,63	0,77	0,73	0,32	0,43	0,14	0,78	0,70	1,00	0,81	0,80
TOTEXP	0,93	0,78	0,97	0,82	0,72	0,89	0,88	0,36	0,56	0,27	0,86	0,90	0,81	1,00	0,90
TPTAPP	0,96	0,75	0,90	0,76	0,73	0,83	0,84	0,36	0,52	0,21	0,94	0,85	0,80	0,90	1,00

4) Estimation results

As we have said above, we have decided to focus on the latest 15 years (1997-2011) and included all the universities which had answered to a minimum of 10 annual surveys in this period, i.e. they have at least 10 observations out of 15. Although it would have been possible to include universities with a very small number of observations (less than 10 down to even 1 observation, i.e. universities which would have answered to an annual survey only) this would lead to an unbalanced panel, with accrued difficulties of econometric estimation.

We thus have a typical balanced short panel as a large number of units (N=133 universities) is observed for a number of periods of time (T=15) which is relatively small if compared with the number of units, as T is largely inferior to N. It often happens in this database that although a university answered to the survey in a given year there is this or that value which is void. If this is the case for a variable included in the model this observation is excluded, thus meaning that the number of observations for the estimated models have minor fluctuations.

The econometric models applied were "fixed effects" panel models. The "fixed effects" model …"allows for unobserved individual heterogeneity that may be correlated with the regressors"[2]. Omitted variables are a cause of heterogeneity and when it is likely that these variables are correlated with the included variables[3], the "fixed effects" model is adequate.

As stressed above, in the 1st stage, inventions disclosures occur; according to Thursby & Thursby (2000) these disclosures depend on the staff employed in the Technology Transfer Offices (TTOs), on the previous research expenditures accumulated in the university (lagged federal and industrial research expenditures) and on the size of the faculty, adding to unobservable inputs such as the faculty's propensity to disclose and the probability of invention disclosure:

[2] Cameron & Triverdi (2005), pg. 697.

[3] As we shall see below.

$$DISC^u = f_1(TTOFTE^u, LAGFED^u, LAGIND^u, TOTFAC^u_{i=1,2,3}; PROP^u_1, \Pi_1)$$

As the faculty number for each university across the period was not available we had to omit this variable from the econometric estimation. This omission causes most probably a bias on the estimation but the fixed-effects model is still *consistent* provided that the omitted variable (Faculty) is correlated to the other regressors as we have seen above. It is *a priori* most probable that this is the case as we could expect that bigger universities, with larger faculty, would also invest more money in research and would have bigger TTOs. This assumption was absolutely confirmed for the 2011 data, where all correlations between Faculty and the other explanatory variables were found to be positive and exceeding 0.6.

The Disclosures variable was regressed against a vast set of combinations of possible explanatory variables. If these were not statistically significant at 5% or the sign of ths coefficient was not in accordance with what was expected, the specific combination was discarded.

The econometric model adopted has as explanatory variables TTO licensing (LICFTE) and support staff (OTHFTE); lagged research expenditures which were funded by the federal government (FEDEXP), by for-profit corporations (INDEXP) and total research expenditures (TOTEXP); a dummy variable which acknowledges the existence/non existence of a medical school in the university. The results of the estimation are in line with what was expected with (lagged) expenditures coefficients as well as the other coefficients assuming positive values. All coefficients are statistically significant at 5% and F-statistic is also significant. r2 and even adjusted r2 are very close to 1.

Table3: Diclosures

	Coefficient	Std. Err.	t-Stat.	Prob.	Impact
LICFTE	1,372394	0,350954	3,910467	0,0001	1,37
OTHFTE	1,445131	0,334964	4,314288	0,0000	1,45
FEDEXP(-1)	1,14E-07	2,2E-08	5,181818	0,0000	***1,14***
INDEXP(-1)	1,18E-07	5,47E-08	2,157221	0,0319	***1,18***
TOTEXP(-1)	1,33E-07	1,23E-08	10,81301	0,0000	***1,33***
MEDSCHL	15,45354	6,88058	2,245965	0,0249	15,45
C	28,89078	4,798818	6,020395	0,0000	
r2	0,963192				
adj. r2	0,959369				
F-stat.	252		**P (F-stat)**	0,0000	

Staff impacts, both around 1.4, mean that, in average, along the period, each additional Full-time equivalent (FTE) staff would increase the annual number of inventions disclosures by around 1.4 (1.37 and 1.45 respectively, for the various staff). Expenditures impact is expressed by 10 million $US. This means that for each 10M of research expenditures, disclosures would increase by a figure of 1.14 to 1.33, according to the different origin of funding. It is important to acknowledge that Disclosures depend, on one hand, on the various Human Resources employed and, on the other hand, on research expenditures occurred, no matter what was the funding source, on similar levels (similar impact).

The value of the coefficient on the dummy variable medical school indicates that the existence of this kind of school in a given university would mean an increase, in average, of more than 15 disclosures a year.

In a 2nd stage, theses disclosures are intermediate inputs to new <u>patent</u> applications, which depend also, according to Thursby & Thursby (2000), on the size of the TTOs staff and on the quality of the research done:

$$PATENTS^u = f_2(DISC^u, TTOFTE^u, QUAL^u_{i=1,2,3}; PROP^u_2)$$

We again regressed the dependent variable against a vast series of possible explanatory variables in different combinations. As no information was available across the period on the quality of the research done and we had again to estimate the equation using the fixed-effects estimator and omitting this explanatory variable.

Table4: Patents

	Coefficient	Std. Err.	t-Stat.	Prob.	Impact
Disclosures	0,625697	0,024126	25,93455	0,0000	0,63
LICFTE	0,86566	0,375824	2,303365	0,0214	0,87
INDEXP(-1)	0,000000251	6,11E-08	4,10802	0,0000	**2,51**
C	-14,1338	2,375069	-5,9509	0,0000	
r2	0,895021				
adj. r2	0,884261				
F-stat.	83		**P (F-stat)**	0	

As expected, Disclosures variable has a positive and significant coefficient, of less than 1. For each additional disclosure there is, in average, across the period and universities, an increase in patent applications of 0.63. This time the variable related to the existence of a medical school was not statistically significant. We could thus infer that the existence of a medical school has a positive impact on the number of disclosures in a given university but has no impact whatsoever on the rate of transformation of disclosures in patent applications.

An additional unit of professional licensing staff (LICFTE) would generate an additional 0,87 patent applications. Curiously enough, this time there is not the presence of a significant OTHFTE variable, which could mean that in this further stage of technology transfer it is up to licensing professionals staff to execute the bulk of the work. Finally, the impact of a 10M€ research expenditures of <u>industrial</u> funding is much stronger than in the previous stage but this is probably due to the non-significance of research expenditures with other type of funding, reason why they were dropped of the model. It should be stressed this nature of Industrial funded research expenditures on this econometric estimation of patent applications.

In a 3rd stage, some of the patents granted are licensed; the number of licenses and options agreements executed depend on these patents but also on the number of disclosures occurred, on the TTOs staff and on the quality of the research:

$$LCEXEC = f_3(DISC^u, PATENTS^u, TTOFTE^u, QUAL^u_{i=1,2,3}; PROP^u_3, \Pi_3)$$

We have repeated the procedure used for the 1st and 2nd stage, with the results below on table 3

Table 5: Licenses and options executed

	Coefficient	Std. Err.	t-Stat.	Prob.	Impact
Disclosures(-1)	0,031872	0,014842	2,147419	0,0319	0,032
TPTAPP	0,04834	0,014303	3,379711	0,0007	0,048
C	23,61695	2,375069	1,276212	0,0000	
r2	0,832408				
Adj. r2	0,815962				
F -stat.	51		**P (F-stat)**	0	

The number of licenses (and options) executed was found to depend on the disclosures occurred on the previous year and on the total USA patent applications filed, which combines new patent applications with new filings, continuations, etc. This particular combination is of paramount importance. The right (statistically...) lag is of one year for the disclosures and none for the total patent applications. The model doesn't work with different lags (2 years for disclosures and 1 year for patent applications, for instance) and it doesn't work with new patent applications. This means that (at least from the statistical point of view) additional 100 disclosures this year will lead to an increase, in average, of 3.2 licenses and options next year. It also means that in average an university will be able to license around 5% of the additional total patent applications filed that same year in the USA.

Rogers et al. (2002) define broadly further steps leading to the university beginning to earn income from the licensing activity. These steps comprise mainly the evolution of 3 variables: licenses generating license income, start-up companies and licensing income itself. We have thus decided to study the behaviour of these variables as well.

Table 6: Licenses generating license income.

	Coefficient	Std. Err.	t-Stat.	Prob.	Impact
ACTLIC	0,135764	0,012395	10,95313	0,0000	0,14
LICFTE	1,077537	0,457607	2,354721	0,0187	1,08
FEDEXP	2,33E-07	1,74E-08	13,3908	0,0000	2,33
LCEXEC	0,377887	0,062077	6,087391	0,0000	0,38
NPTAPP	0,145457	0,025951	5,605063	0,0319	0,15
STRTUP	5,434041	0,391798	13,8695	0,0000	5,43
C	28,89078	2,96352	9,748805	0,0000	
r2	0,935778				
adj. r2	0,929541				
F	150		**P (F-stat)**	**0**	

It was found that the number of licenses generating license income was dependent on the number of active licenses in the university's portfolio, the number of licensing professionals in the TTO, the research expenditures funded by the federal government, the number of licenses executed the same year, the new patent applications and last, but not least, the start-up companies, which are new companies that that were dependent on licensing of the university's technology.

There is a substantial impact of the number of start-up companies which depend on each university's technologies as these start-up companies have an impact over 5 on the number of licenses generating income.

The number of start-up companies is dependent on the number of licenses generating income and on total research expenditures in the previous year, on the number of disclosures occurred and on the new patents filled that year. Impacts are low as the average number of start-ups is only 3,27 and median is only 2, i.e. at least for 50% of observations the annual number of start-up companies created is under or just up to 2.

Table 7: Start-ups

	Coefficient	Std. Err.	t-Statistic	Prob.	Impact
LCGNLI(-1)	0,012617	0,001657	7,614363	0,0000	0,013
Disclosures	0,007695	0,002263	3,400354	0,0007	0,008
NPTAPP	0,004669	0,001793	2,604016	0,0093	0,005
TOTEXP(-1)	4,46E-09	8,35E-10	5,341317	0,0000	0,045
C	0,070141	0,179452	0,390862	0,6960	
r2	0,803582				0,804
adj. r2	0,783605				0,784
F	40		**P (F-stat)**	0	

The License income received is very unevenly distributed with a strong asymmetry on the right. The average value per university per year is of 10.1M $US but the median is of only 1.5M. The value is highly dependent on the very few *big winners* and is thus not strongly correlated to any variable in the model. The best logical fit we could find was with the number of licenses generating income, with a small r2:

Table 8: License Income

	Coefficient	Std. Err.	t-Statistic	Prob.	Impact
LCGNLI	**30549,63**	**13387,63**	**2,28**	**0,02**	**30549,63**
C	**7792504,00**	**1261611,00**	**6,18**	**0,00**	
r2	**0,37**				
adj. R2	**0,32**				
F-stat.	6,74		**P (F-stat)**	0,00	

5) Conclusions

The results of our econometric studies broadly confirm Thursby & Thursby (2002) theory of university technology transfer in three stages. Although data on faculty and university quality were not available for the various universities across the period (1997-2011) the fixed effects estimator provides consistent estimates for the various equations, provided that the omitted variables are correlated to the other regressors, which we could confirm for faculty.

Thursby & Thursby (2002) assertion that disclosures, depend on the various lagged research expenditures and on the various resources employed by TTOs was confirmed. And so it was the assertion that on successive stages, the dependent variables (Patents on 2^{nd} stage and Licenses on the 3^{rd}) depend on the dependent variable for the previous stage and on the resources available in the TTO.

It was also found that Patents depend also on the lagged research expenditures funded by industrial source which is not surprising and opens a line for further research as this link between industrially funded research expenditures and patents is most important.

Licenses behaviour was found to slightly deviate from Thursby & Thursby (2002) as they depend on lagged disclosures, which in a way takes into account the lag between invention and commercialization, and on the total patents (new plus reissues, etc.) but not on TTO staff.

The existence of a medical school has a positive effect on the annual number of disclosures but it has no impact on patents and licenses, apart from the indirect effect implicit on disclosures.

We have extended Thursby & Thursby (2002) model with Rogers et al. (2000) understanding of six stages UTT, and we have also performed econometric studies of the new variables added. Start-ups depend on lagged total research expenditures and licenses generating license income, and also on total patents and disclosures. Licensing income is strongly skew and the only possible link we could find was with the number of licenses generating income.

Future research should be concentrated in trying to get, if possible, faculty and quality data for the various universities for the different years and on improving the econometric estimation methods with the use of panel count models, as most of dependent variables assume discrete values only.

Also, research on whether it is start-ups that lead to Licenses generating income or the other way around should be pursued. The (subtle) difference between the concept of university spin-off and the one of start-ups in the AUTM database should also be dealt with.

Bibliography

Algieri, B., Aquino, A., Succurro, M. (2011). Technology Transfer Offices and academic spin-off creation: the case of Italy. *Journal of Technology Transfer*, DOI: 10.1007/s10961-011-9241-8

Bercovitz, J., Feldmann, M. (2006). Entrepreneurial Universities and Technology Transfer: A Conceptual Framework for Understanding Knowledge-Based Economic Development. *The Journal of Technology Transfer*, 31(1), 175-188.

Cervantes, M. (2003). Academic Patenting: How universities and public research organizations are using their intellectual property to boost research and spur innovative start-ups. http://www.wipo.int/sme/en/documents/academic_patenting.htm

Colombo, M.G., D'Adda, D., Piva, E. (2010). The Contribution of university research to the growth of academic start-ups: an empirical analysis. *Journal of Technology Transfer* 35, 113-140.

Godinho, M. M., Mamede, R. (2005). Creating Knowledge-Based Firms Out of Existing Organizations (working paper, Keins project).

Hellmann, T. (2007). The role of patents for bridging the science to market gap. Journal of Economic Behavior & Organization, 63, 624-647.

Lissoni, F., Llerena, P., McKelvey, M., Sanditov, B. (2008). Academic Patenting in Europe: New Evidence from the KEINS Database. Working Papers of BETA 2008-16, Bureau d'Economie Théorique et Appliquée, UDS, Strasbourg.

Macho-Stadler, I., Pérez-Castrillo, D., Veugelers, R. (2007). Licensing of university inventions: The role of a technology transfer office. *International Journal of Industrial Organization*, 25(3), 483-510.

Markman G.D., Gianiodis P.T., Phan P.H., Balkin D.B. (2005). Innovation speed: Transferring university technology to market. *Research Policy* 34, 1058-1075.

Mowery, D. C., Sampat, B. N. (2005a). The Bayh-Dole Act of 1980 and University–Industry Technology Transfer: A Model for Other OECD Governments? *The Journal of Technology Transfer,* 30(1-2), 115-127.

Mowery, D.C., Sampat, B.N. (2005b) Universities in National Innovations Systems, in J. Fagerberg, D.C. Mowery, R.R. Nelson, R.R. (Eds), *The Oxford Handbook of Innovation*. Oxford University Press.

Powers J.B., McDougall P.P. (2005). University start-up formation and technology licensing with firms that go public: a resource-based view of academic entrepreneurship. *Journal of Business Venturing,* 20(3), 291-311.

Rogers, E.M., Yin, J., Hoffmann, J. (2000). Assessing the Efectiveness of Technology Transfer Offices at US Research Universities. Journal of the Association of University Technology Managers.

Shane, S. (2002). Selling University Technology: Patterns from MIT. Management Science, 48, 122-137.

Siegel, D.S., Waldman D., Link, A. (2003). Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study. *Research Policy* 32(1), 27-48.

Siegel, D.S., Veugelers, R., Wright, M. (2007). Technology Transfer Offices and commercialization of university IP: performance and policy implications. *Oxford Review of Economic Policy,* 23 (4), 640-660.

Thursby, J. G., Thursby M. C. (2002) Who is selling the Ivory Tower? Sources of Growth in University Licensing. *Management Science*, 48(1), 90-104.

Thursby, J., Fuller, A., Thursby, M. (2009). US faculty patenting: Inside and outside the university. *Research Policy*, 38(1), 14-25.