How academic patents shape innovations

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Research commercialisation in Europe: a matter of governance of university Technology Transfer Offices?

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Abstract

Many European universities installed technology transfer offices (TTOs) in the last decades but quantitative data about their organisation, governance and performance are scarce. Based on a survey of 2, 650 scientists at 150 European universities, this paper describes the relationships between TTO governance model types, the engagement of scientists with research commercialisation through contacts university TTOs and their output in terms of industrial collaboration, contract research, consultancy, patenting and spin-offs. The data[1] suggest that a 'classical' TTO governance model - providing services for scientists at a centrally located office, which is fully integrated into the administration of one university- can be associated with a significant higher level of research commercialisation. Next, the paper describes an analysis of appropriation patterns (of some 3, 400 academic patents in a time period between 1994 and 2014) in relationship with the implementation of studied TTO governance model types in the Netherlands in the year 2004. Appropriation of academic patents by multinational firms or regionally located SMEs changed significantly after the implementation of TTOs and the latter was positively associated with a 'discipline-integrated' TTO governance model implemented outside of the university administration.

Keywords

Research commercialisation, universities, technology transfer offices, governance models

Declaration of Interest

None

[1] https://doi.org/10.17026/dans-xgg-r2nu of the Royal Netherlands Academy of Arts and Sciences

1. Introduction

With the institutionalisation and dynamics of commercialisation of their scientific research results, many universities have become power houses of innovation on global level (Etzkowitz, 2008, Etzkowitz and Leyesdorff, 2000). Research commercialisation has become an increasingly important topic in innovation policies in many countries (OECD, 2014) and many universities organize the commercialisation of their research via Technology Transfer Offices (TTOs). In Europe, the importance of the licensing performance of university TTOs has been described (Conti and Gaulé, 2011) as well as their positioning in networks with the industry (DeBackere and Veugelers, 2005). Earlier research has unearthed relationships between changes in IPR regulations and universities patenting (Audretsch and Göpteke- Hultén, 2015; Genua and Rossi, 2011). The mission of a university (Goldfarb and Henrekson, 2003), the presence of an engineering faculty (Van Looij et al., 2011) and the location of the TTO (Della Malva et al., 2009) are positively associated with the number of academic patents. But to date there is only a limited number of studies, which present empirical evidence about the relationships between the organisation and governance of university TT processes (Genua and Muscio, 2009) and their output in terms of collaboration with industrial partners, creation of spin-off companies and the filing of patents (Schoen et al., 2014). To my knowledge the relationships between national innovation policies, the governance of university TTOs and their effects on the transfer of academic patents to third parties, have not been studied at all.

In comparison with research in the USA (Mowery et al., 2001; Jaffe, Trajtenberg and Henderson, 1993; Acs et al., 1992; Jaffe, 1989) it is almost impossible to identify quantitative data, showing how and if innovation policies or national patent acts contribute to higher levels of appropriation of academic patents by companies in Europe. These data are important as information for national, regional and university policymakers, when they design and implement new policies or programs. This research intends to bridge this gap and will examine the relationships the governance of university TTOs on the one hand side and their performance and output on the other hand side. The paper can contribute to literature by testing three hypotheses about the impact of the governance of university TTOs on research commercialisation. Therefore following research questions will be addressed: can differences in university TT governance models be associated with different levels of TTO output; can differences in university TT governance models be associated with differences in distribution patterns of transferred academic patents; and which TT governance models can universities implement to stimulate TT for regional economic growth and innovation?

After the theoretical framework with hypotheses (Section 2) and the methodology (Section 3), the paper describes empirical evidence from the analyses of quantitative data about research commercialization by scientists working at 150 universities in Europe. These data on research commercialisation have been aligned with three TT governance models that are common at university TTOs in Europe (Section 4). A case study examines the effects from a national innovation policy on the implementation of university TTOs and research commercialisation by scientists in The Netherlands (Section 5). I wish to conclude that there is evidence that TT governance models, as initiated by the implementation of an innovation policy, can indeed be positively associated with levels of research commercialization by scientists. Certain TT governance models may even affect the distribution of transfer of academic patents to companies (Section 6). The findings of this research may have implications for policy makers.

2. Theory and hypotheses

In many member states in the European Union (EU) the formal tasks of universities, i.e. education and research, have been extended with a third mission of research commercialization (RC). This process started in the 1980-ties in the United Kingdom and universities in other countries followed (Genua and Muscio, 2009). The RC output can be defined and quantified in terms of contract research, collaboration with industrial partners, consultancy, and creation of spin-off companies and the filing of patents (OECD, 2014). Contract research and collaboration between universities and companies already existed since decades, but the institutionalisation of RC via staff of university TTOs is of more recent date (Freitas et al., 2013). **Table 1** describes four TT governance models that have been implemented at universities in the EU (Schoen et al., 2014) and these descriptions will be used in this research.

Table 1. University TT governance models and the TTO location

Name	Description	TTO location
Classical	TTO staff only serves the personnel of 1 university and the office and its' personnel are integrated into the administrative structure of the university	Central on university campus
Autonomous	Similar to classical model, but with a higher degree of autonomy from the university's central administration (e.g. budget allocation, human resources management)	Decentral at a faculty, research institute or medical centre
Disipline- **integrated**	TTO staff serves the TT activities of 1 or several universities and is organized outside a university's administrative structure	External, outside of the university campus
Discipline- **specialised**	TTO staff serves the TT activities of one scientific discipline (e.g. engineering or life sciences) of several universities and is organized outside a university´s administrative structure	External

The TTO productivity performance may depend on organisational and institutional factors, e.g. TTO size, experience or regulations about IP ownership (Siegel et al., 2003) and their location (Friedman and Silberman, 2003). At the same time, it is assumed that the TTO productivity performance or RC output can be determined by the overall engagement of scientists with the commercialisation of their research (Perkmann et al., 2013). Next control factors, which can be associated with the engagement of scientists with RC: their age (Frosch et al., 2015), scientific discipline (Van Looy et al., 2011) and university position of a scientist (Shane, 2004), will thus be taken into consideration. Following this line of theory, it can be estimated that:

Equation 1: RC_{TTO} is determined by $\sum RC_{1,n} = f(G_{1,n}, L_{1,n}, X_{1,n})$

where RC_{TTO} can be measured in terms of scientists that contact their TTO for funding, contract research, IPR and spin-off development. RC_i is the engaged with research commercialisation for individual scientist 1 till RC_n for scientist n. As can be seen in equation 1, the RC of scientists is determined by independent, model variables G (TT Governance model at a university) and L (TTO Location at a university) and by X, being a vector consisting of other control variables (age, scientific discipline and university position). Following equation 1 and the definitions of university TT governance models as described in table 1, the first hypothesis can be formulated as **H1**: The RC output of a university TTO, as determined by the TTO contact with and RC engagement of scientists, can be associated with TT governance models.

In line with theories about the relationships between IP commercialisation and the organisation of TTOs (Siegel et al., 2007; 2003), the use of incentives for scientists (Panagoupolis and Carayannis, 2013) and the location of a TTO (Friedman and Silberman, 2003), it can be estimated that:

Equation 2: $\sum$ (Academic patents) is determined by: $\sum P_{1,n} = f(G_{1,n}, L_{1,n}, X_{1,n})$

where P is the number of patented inventions by scientist 1 till scientist n, which in turn can be determined by independent, model variables G (TTO Governance model at a university) and L (TTO Location at a university) and X, being a vector of other control variables (age, university position and scientific discipline of the scientist in relation with economic sectors). It is assumed that in general universities follow an IP policy to assign academic patents, which have been based upon the results from scientific research, to companies. Then hypothesis 2 can be formulated as **H2:** The number of university patents, as determined by the number of patenting scientists, can be associated with university TT governance models.

According to literature about knowledge spillovers from universities to companies the proximity effect occurs locally (Acs et al., 1992; Jaffe, 1989). The research methodology in these studies is based on a (modified) knowledge production function (Griliches, 1979), which also shows the effects from academic research on the number of corporate patented inventions. The states in the USA and broad technological areas were used as units of observation, and the number of corporate patents was found to be positively associated with research at a local university (Jaffe, 1989). A further analysis between co- localization, patents and patent citations showed that the advantages of the proximity effect decrease over time (Jaffe et al., 1993). But the impact of academic research on regional innovation is not only affected by geographical proximity, but also by university- industry collaboration (Ponds et al., 2010; Boschma, 2005). Then a study about the propensity to co-locate with a university showed that this phenomenon was highest in those industries where tacit knowledge plays an important role (Audretsch and Feldman, 1996). To my knowledge, TT governance models of university TTOs have not been taken into account as independent variable in studies about knowledge spillover or university-industry collaboration. Focusing on academic patents only, hypothesis three can be formulated as **H3:** The transfer of academic patents to companies in the region of a university can be associated with university TT governance models.

3. Methodology and data sources

An international survey was organised to collect data from individual scientists directly and to avoid any problems (e.g. conflicts of interest, data of interdependent variables) TTO staff, deans or university directors were excluded from participation. The unit of analysis in this research is a scientist, which has been engaged in RC with or without the services from TTO staff in the years between 2010 and 2015. The survey's questionnaire contained four sections to collect following data;

1) Scientist´s engagement with RC in general and with patents and spin-offs in particular;
2) TT governance model of -, contact with - and quality of the university TTO;
3) Regulations on IP use, patent ownership at their university and the importance of patents for commercialisation of their research results and career; and
4) Individual data of the scientist (e.g. age, university position, scientific discipline).

Assuming that most RC activities are carried out by PhD students and (associated/ assistant) professors (e.g. patenting, Giuri et al., 2007) the size of the potential target audience for this research can be quantified. With a total population in the EU of approximately 508 million persons (in 2010) and when a 0, 2 % of them received an education at PhD level at universities (Eurostat, 2016), the target audience in this research consist of approximately 1 million scientists. Using a confidence interval of 95 % and an accuracy rate of 2 % a recommended sample size (n) of 2, 396 scientists can then be regarded as representative for this survey (Survey Monkey, 2017). From the *Web of Science* database at the Centre for Science and Technology Studies (CWTS) of the Leiden University in The Netherlands, some 60,000 email addresses of European scientists were randomly selected. The questionnaire was sent to scientists working at some 150 universities in 30 countries in Europe using the Survey Monkey platform for electronic administration of response data. Participation was voluntary, anonymous and respondents were not financially reimbursed. During the survey scientists received five follow- up messages between November 2015 and March 2016, with an additional message and a report with summarized results in June 2016. At the close of the survey responses (mostly fully filled-out questionnaires) from 2, 665 scientists working at 148 universities in Europe have been received. The response rate of 8.9 % is low but acceptable, since it suffices the threshold sample size of 2, 396 which enables the production of representative data on scientists at universities in the EU.

In the case study, the implementation of the Technopartner program in The Netherlands has been described as an instrument to measure the effects of the implementation of an innovation policy. This program enabled the introduction of various TT governance models at universities and their impact on research commercialization e.g. academic patents can be measured. By the year 2015 approximately 42,000 f.t.e. are employed by the Dutch universities as scientists in all disciplines (http://www.vsnu.nl/en). With a confidence interval of 90 % and an accuracy rate of 5 %, a sample size (n) of 268 scientists can then be regarded as representative for the Dutch survey (Survey Monkey, 2017). A methodology developed by the Fraunhofer Institute (Dornbusch et al., 2013) was used as a benchmark to identify academic patents in The Netherlands. Academic patents are defined as the assembly of both university- invented and university-owned patents, with the criterion that tenured university staff is mentioned as inventor in the patent application (Lissoni, 2012). From the open source KNAW databases (https://dans.knaw.nl/) and with the assistance of the departments of Human Resources of the universities, the names of some 64,000 tenured scientists, who were working in all scientific disciplines between 1994 and 2014, were hand collected. Two algorithms were applied to match the names of university employed scientists with the names of inventors, who are mentioned in patent applications with an origin in the Netherlands (Van Dongen et al., 2014). After identification, quantification and validation, all academic patents were organised by university of origin of the invention and categorized by its´ university TTO governance model. Universities, public research organisations (PROs), multinational corporations (MNCs), SMEs, university spin- off companies and foreign organisations (with headquarters outside The Netherlands) have been taken into consideration as patent applicants. Because the filing of academic patents from 2004 onwards can be associated with the start of the Technopartner program, including the implementation of TTOs with different TT governance models, a distinction was made between academic patents filed in the time frame before and after the year 2004. Names and patent data from start-ups and spin-offs were collected from the evaluation reports of the Technopartner program (Technopolis-evaluation-technopartner) and also matched with identified academic patents.

4. Empirical results about research commercialisation and TT governance models in Europe[2]

The survey yielded data of approximately 2, 650 scientists working at some 150 universities in 30 countries in Europe. Tenured scientists at the faculties of earth, engineering, mathematics and ICT, medical, life sciences and health and social, economics and humanities participated in the survey. The majority of respondents is older than 35 years, male and has a position as associate- or assistant professor in the in medical, life sciences and health and engineering sciences. IP awareness amongst participants was surprisingly high at some 80 percent, including scientists at the faculties of economics and sociology. **Table 2** shows the summarized statistics on scientists' engagement with RC, patenting and spin- off formation (resp. 32, 16 and 7 percent). In general, the results show that scientists at

Table 2. Summary statistics (*)

	Number of Scientists	Scientists (%)	RC engaged scientists (%)	Patenting scientists (%)	Spin- off involved scientists (%)
			31.7	16.4	6.6
Variables					
1.Age					
< 35 years	573	21.5	25.1	8.5	
35 -50 years	1,101	41.3	34.2	19.3	
>50 years	991	37.2	33.2	20.3	
2.Scientific disciplines					
Earth	94	3.5	28.7	5.3	5.3
Engineering	504	1.,9	45.4	26.8	12.5
Mathematics and computer sciences	218	8.2	31.7	7.2	9.2
Medical or Life sciences and health	810	30.4	32.5	18.4	5.5
Natural	453	17.0	31.6	24.1	12.2
Social, economic and humanities	134	5.0	20.9	0	2.2
3.University position					
PhD student	156	5.9	13.5	4.5	3.2
Post doc	496	18.6	26.0	11.5	5.6
Associate or assistant professor	765	28.7	34.9	18.3	6.7
Professor	582	21.8	46.6	29.4	12.2
Other	200	7.6	33.7	19.8	-
4. Scientists that did or did not contact their university TTO					
With contact	524	19.8	50.9	69.1	69.1
No contact	421	16.0	10.8	7.8	18.3
Not applicable	152	5.8			
5.TT governance models confirmed by scientists					
Classical, centralised	621	23.3			
Autonomous, decentralised	124	4.7			
Discipline- integrated	56	2.1			
Other	22	0.8			
No idea	134	5.1			
Not applicable	73	2.8			

N= 2, 645 and (*) the total of the percentage do not match 100 %

senior positions in engineering, natural or life sciences are most engaged with RC, patenting and spin-offs. Only 51 % of the scientists, who are RC engaged, contacted their university TTO, but these percentages are much higher for patenting and spin-off formation. It is also evident that the classical TT governance model is most frequently used at universities in Europe and the centrally located TTO is most contacted by scientists as well. Most interesting is the finding that those scientists, who are

[2] : https://doi.org/10.17026/dans-xgg-r2nu at the Royal Netherlands Academy of Arts and Science

most engaged with RC activities (a.o. patenting or spin- off formation), contacted classical governed TTOs at a central location. Another interesting observation is that (8 – 18) % of responding scientists is involved with patenting and spin-offs without any assistance of the TTO staff of their university.

With a confidence interval of 95 % and an accuracy rate of 5 %, a sample size of 334 persons suffices for further statistical analyses. Considering the total number of 524 scientists, who contacted a TTO with a specific TT governance model, **table 3** shows the results from the rank correlation analysis between pairs of variables. As can be observed, both the percentage of scientists that contacted their

Table 3. Relationships between TT governance models and scientists engaged with Research Commercialisation (RC) at universities in Europe (%)

TT governance model and TTO location at university	Scientists that contacted a TTO with this TT governance model (%)		RC engaged scientists (%)		Patenting scientists (%)		Spin– off involved scientists (%)	
Classical, centralised	75.4		80.0		80.4		84.9	
Autonomous, decentralised	14.1	*RCC* ***0.88*** (***)	14.1	*RCC* ***0.46*** (***)	12.5	*RCC* ***0.53*** (***)	6.7	*RCC* ***0,4*** (***)
Discipline-integrated, regionalised	5.2		4.1		5.4		5.0	
Other	5.3		1.9		1.7		3.4	

RCC= rank correlation coefficient, bivariate Spearman rank correlation analyses (***) significant at 0, 01 level (two- tailed)

TTO and the percentage of RC engaged scientists differ significantly per TT governance model. The correlation coefficient between TT governance models and the percentage of scientists that contact a certain TT governed TTO (i.e. classical, autonomous, discipline –integrated) is significant, positive and high. The correlation coefficient between TT governance models and RC engaged scientists is positive and medium high. This analysis also yield the result that the production performance of a classical TT governance model with a centrally located TTO can be associated with: 1) the highest percentages of contact between scientists and the university TTO and: 2) with the highest percentages of RC engaged scientists' (including patenting and spin-off formation).

Based upon the results in **table 3**, the first hypothesis can be accepted and it is likely that the second hypothesis can be accepted as well. However, the latter hypothesis needs to be tested in the context of a national study, since a national innovation policy may affect research funding, IP rules and regulations and university patents.

5. The effects of an innovation policy on university TT governance models, research commercialisation and the transfer of academic patents in The Netherlands[3]

Since 1995 the Netherlands' Patent Act provides universities the same ownership entitlement as the Bayh- Dole Act does in the USA. Some universities in The Netherlands provided RC services for scientists, but their limited human and financial resources, the outreach of TTO staff and their output (i.e. invention disclosures, patents, spin- offs) severely hampered (VSNU, 2013). The Netherlands' innovation system, the high quality of scientific research and the high rate of (company) patenting

[3] : https://doi.org/10.17026/dans-xgg-r2nu of the Royal Netherlands Academy of Arts and Sciences

were considered positive features. But the role and position of universities as serious actors in the innovation system was relatively weak and their budgets did not include substantial resources for RC, TT or spin-off formation (OECD, 2005). On the contrary, the low level of private R&D, the less than optimal interaction between industry and academia, insufficient innovative entrepreneurial activity at universities and the limited capacity for RC were considered negative features (OECD, 2005).
In the year 2003 the Netherlands' government initiated a program with a special Subsidy on Knowledge Exploitation (SKE), enabling universities to install or develop their TTOs applying different TT governance models (OECD, Technopartner p.84,85). This program also provided schemes to universities to professionalize their patent policy and reimbursed 50-70 % for the costs of patent applications after licensing an academic patent to a start-up company or transferring a patent to a company. The general objectives of the program were to increase the number of start-ups and improve their quality by mobilizing risk capital through a seed fund facility. The program was operational between 2004 till 2010 and was comparable to the SBIC program in the United States (https://www.sba.gov/sbic). In this case study we will use the Technopartner program as an instrument to measure the effects of the implementation of a national innovation policy on the governance of TTOs and RC.

For the interpretation of the analysis of the data from this research, some typical characteristics of the development of TT governance models at universities in The Netherlands have to be taken into consideration (KNAW, 2014). At a *classical, centralised TT governance model* the board is responsible for most decisions (e.g. funds for filing of patent applications, rules about IPR ownership, transfer of IPR to spin offs, incentives for academic inventors). In an *autonomous, decentralised TT governance model*, this mandate is in the hands of a faculty dean, faculty contract managers or with the TTO manager and the TTO is usually located at one faculty or at a medical centre. In a *discipline-integrated, regionalised TT governance model* the university board aligns its' TT strategy with companies and a regional economic development board. The *discipline-specialised TT governance*

Table 4. University TT governance models and the location of their TTO in The Netherlands

University	**Scientific disciplines**	***TT governance model*** [(a)]	**Location of TTO**	**TTO name**
Wageningen University	Plant breeding, earth and life science	**Discipline- integrated**	IPR helpdesk on campus	None
University of Twente	Engineering and business	**Discipline- integrated regionalised**	Outside campus	Kennispark Twente kennispark
Delft University of Technology	Engineering and business	**Autonomous, decentralised**	Within 1 faculty	Valorisation centre Valorisation centre
Eindhoven University of Technology	Engineering and economics	**Classical, centralised**	On campus	TU/e innovation lab innovation-lab
Radboud University Nijmegen	Medical, life sciences and health, economics	**Autonomous, decentralised**	Close to medical centre and faculty of science	Directorate Valorisation Valorisatie
Free (VU) University Amsterdam	Earth, medical, life sciences and health, economics	Developed from classical, centralised to **discipline-integrated regionalised**	On campus	TTO VU & VUMC vumc.nl/onderzoek
Leiden University	Medical, life sciences and health, social	**Classical, centralised**	Close to medical centre and faculty of science	LURIS luris
Utrecht University	Medical, earth, life sciences and health, economics	**Classical, centralised**	On campus	Holding utrechtholdings

[(a)] TT governance models are described in table 1 and their RC results are mentioned in annual reports of universities

model was not operational. The Technopartner program enabled twelve consortia consisting of universities, companies and regional development agencies to file some 760 patents (http://evaluation-technopartner-program). During the program some 700 start-ups have been created, which by the year 2010 provided jobs for approximately 1, 800 f.t.e. This TT effect can be regarded as one of the main results from the Technopartner program after the implementation of the national innovation policy in 2004. In the program the universities were the lead partners in the consortia providing RC services like business development and IPR. At the same time each university could develop an appropriate TT governance model and IP strategy aligned with its' mission and stakeholders. **Table 4** shows the summarized data of the TT governance models and location of the TTOs for eight out of twelve universities in The Netherlands. Matching the names of tenured scientists at these eight universities with patents that have been filed between 1994 and 2014, it was possible to identify some 3, 400 academic patents. These patents can be aligned with the three TT governance models of the TTOs in this study. **Table 5 and table 6** show the general data of the RC survey amongst scientists at eight universities in The Netherlands and the results of the statistical analysis of these data. Compared with data from scientists at universities in other countries in Europe, the autonomous, governed university TT model with a decentral located TTO office, is more common and frequently contacted at

Table 5. Summarized statistics for 8 universities in The Netherlands (*)

	Number of scientists	Scientists (%)	RC engaged scientists (%)	Patenting scientists (%)	Spin- off involved scientists (%)
Variables			38,4	18,3	4,9
1. Scientists that did or did not contact their university TTO					
With contact	79	24.1	51.6	75.0	93.8
No contact	18	3.0	8.7	6.7	
Not applicable	20	6,1			
2. Confirmed TT governance models by scientists					
Classical, centralised	55	16.8			
Autonomous, decentralised	40	12.2			
Discipline-integrated	1	0.3			
Other	3	0.9			
No idea	27	8.2			
Not applicable	5	1.5			

N= 328 and (*) the total of percentages do not match 100 %

Dutch universities. One can observe that in The Netherlands more RC engaged scientists have been assisted by the TTO staff, as compared with their peer scientists in other countries in Europe. Especially, the number of scientists that contacted their university TTO when involved in the formation of a spin-off is much higher. At a confidence interval of 90 % and an accuracy rate of 10 %, a sample size of 68 persons suffices for further statistical analyses. The results in **table 6** show that TT governance models can be positively associated with significant differences in numbers of scientists that contact their TTO and RC engaged scientists. The correlation coefficient between TT governance models and the percentages of scientists that contact TTOs which are governed by such model is significant, positive and high. The correlation coefficient between TT governance models and the percentage of RC engaged scientists is positive and medium high. Looking at the rank correlation coefficients in table 6, both the first and second hypothesis can be accepted for universities in The Netherlands.

Table 6. Relationships between TT governance model and scientists engaged with Research Commercialisation (RC) in The Netherlands

University TT governance model	Scientists that contacted a TTO with this type of TT governance model (%)		RC engaged scientists (%)		Patenting scientists (%)		Spin –off involved scientists (%)	
Classical, centralised	55.2		62.9		65.1		53.3	
Autonomous, decentralised	42.1	*RCC* **0.86** (***)	35.5	*RCC* **0.49** (***)	30.2	*RCC* **0.53** (***)	40.0	*RCC* **0.41** (***)
Discipline-integrated , regionalised	1.3		0		2.3		2.7	
Other	1.3		1.6		2.3		0	

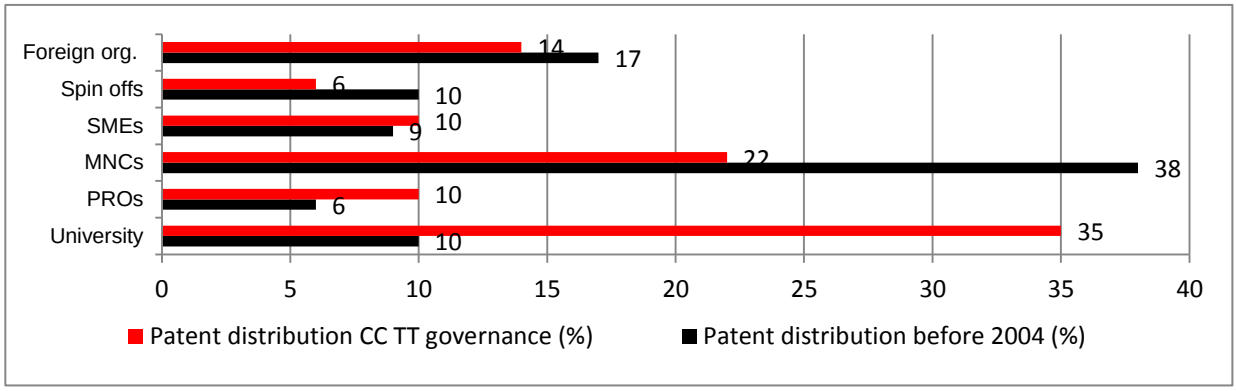
RCC= rank correlation coefficient, bivariate Spearman rank correlation analyses (**) significant at 0, 01 level (two- tailed)

Finally, the effects of the implementation an innovation policy on the development of different TT governance models and the transfer of academic patents have been examined in this case study. . Some universities already institutionalised RC facilities by mid-1990's but the Technopartner program can also be taken as a starting point for this part of the research. Again the year 2004 has been used as division line for the implementation of a TT governance model and choice for a location of a university TTO. Academic patents have been categorized by university where the scientific research took place on the basis which a patent has been filed and the scientist was tenured and mentioned as inventor at the date of filing of the patent application. **Figure 1** presents the developments in the appropriation of academic patents categorized by TT governance models and over time. With the institutionalisation of university TTOs and the implementation of TT governance models in 2004 one observes that, contrary to the objectives of Technopartner, less academic patents have been appropriated by spin-offs. **Figure 1a** shows that those universities, that implemented a *classical* TT governance model since 2004 with a centrally located TTO (i.c. Universities of Utrecht and Leiden and the Eindhoven University of Technology), filed three times as many patents than before the year 2004. On the other hand, only half as many patents, originating from research at these universities, have been appropriated by Dutch multinational companies (MNCs). **Figure 1.b** shows that those universities that implemented an *autonomous* TT governance model with a decentralised TTO (i.c. Radboud University Nijmegen and Delft University of Technology) filed five times more patents since 2004. Here, one can observe that Dutch multinationals appropriated only 10 % less patents, which originated from research at those universities. **Figure 1.c** shows the same trends as for the autonomous TT governance model at those universities that implemented a *discipline- integrated* TT governance models, with a *regionalised* focus (i.c. University Twente, Free (VU) University Amsterdam and Wageningen University and Research Centre). But, a key finding here is that only universities that implemented TTOs with this TT governance model, enabled Dutch SMEs that are located in the region of a university, to appropriate twice as many academic patents that originated from research.

Table 7 summarizes data of figure 1 about the appropriation of academic patents, as part of the RC developments, which occurred after the implementation of a new innovation policy in The Netherlands in 2004. This table shows the appropriation of academic patents by applicants as one of the effects of the Technopartner program in The Netherlands. Patenting involvement of scientists, as part of the RC, was accelerated with the introduction of a new innovation policy and partly enabled by the Technopartner Program. Before 2004, the BioPartner program enabled scientists in the life sciences to start spin-offs and file patents. The table shows some striking differences in the numbers of filings of

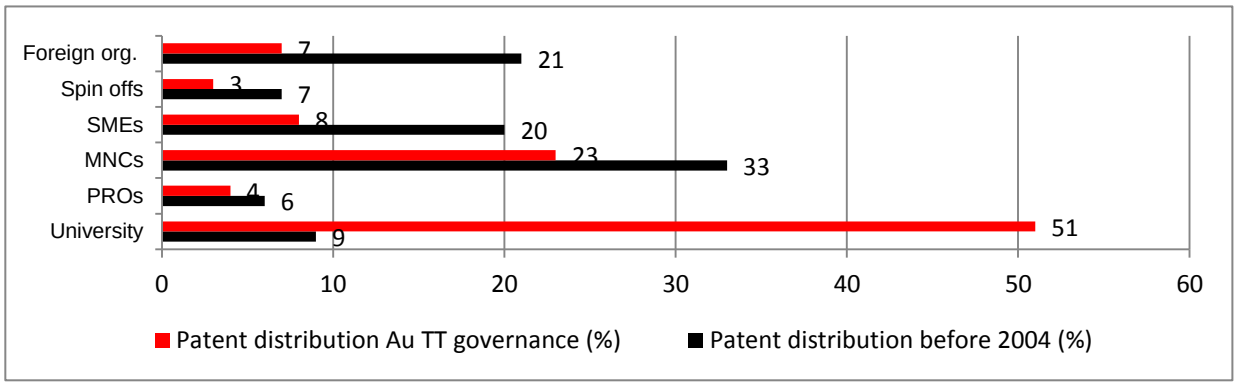
Figure 1. Appropriation of academic patents (%) by various applicants after the implementation of:

a. Classical governance model at a centralised TTO (CCTT)



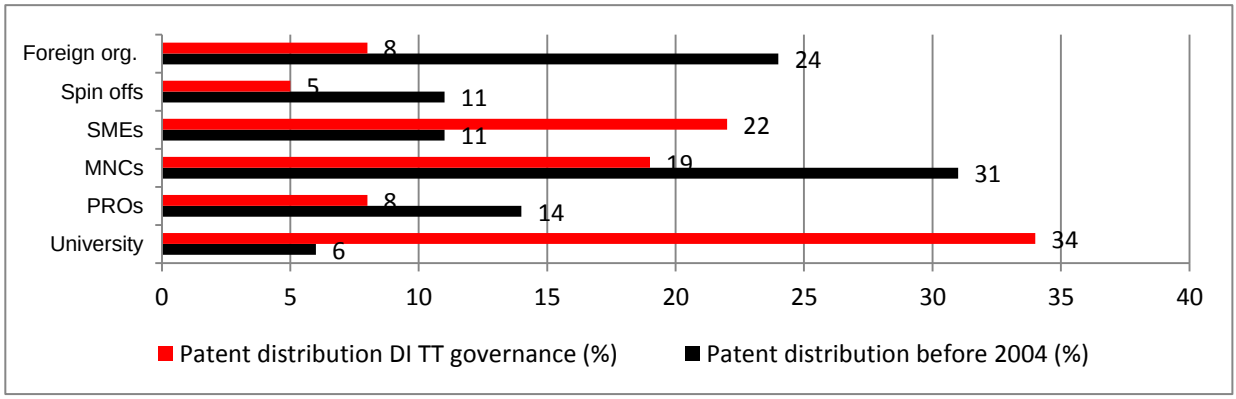
N= 919 (between 1994 and 2003, in black color), N= 768 (from 2004 till 2014, in red color)

b. Autonomous TT governance model at a decentralised TTO (AuTT)



N= 391 (between 1994 and 2003, in red color), N= 551 (from 2004 till 2014, in red color)

c. Discipline- integrated TT governance model at a regionalised TTO (DI TT)



N= 435 (between 1994 and 2003), N= 332 (from 2004 till 2014)

Table 7. Appropriation of academic patents by their applicants before and after the implementation of a university TT governance model in 2004 (%)

	Academic patents [(a)] categorized by model		
Patent applicant	*Classical TT governance model*	*Autonomous TT governance model*	*Discipline- integrated TT governance model*
Universities	+25	+42	+28
PROs	+ 4	-2	-8
Dutch MNCs	-16	-10	-12
Dutch SMEs	+1	-12	**+11**
Spin off companies	-4	-4	-6
Foreign organisations	-3	-14	-16

(a) + indicates an increase and - indicate a decrease

academic patents by applicants, which can be associated with the implemented university TT governance models and the IP policy of a university. Comparing these patent filing data before and after the implementation of TT governance models, one can observe that: 1) universities filed a higher percentage of patent applications since 2004; 2) Dutch MNCs and foreign organisations appropriated a lower percentage of academic patents; and 3) that Dutch SMEs appropriated a higher percentage of academic patents, originating from research at those universities that implemented a discipline-integrated TT governance model.

Looking at data from **figure 1.c** and **table 7**, hypothesis 3 can be accepted for the discipline- integrated TT governance model only. In this model, scientists at universities can apply for the services of an externally located organisation (outside the campus) that provides TT services, while the university follows an IP policy which is focussed on regional economic growth.

6. Conclusions and discussion

Data from this research, suggest that:

a. The RC output of European university TTOs can be associated with their TT governance model, and the highest RC output is realised at universities with a TTO that applies a classical TT governance model and is located at a central location; and

b. The patent output of a university TTO as determined by the level of patenting by their tenured scientists, can be associated with the TT governance model at a European university; and

c. The implementation of a discipline– integrated TTO governance model at university TTOs in The Netherlands, contributed to the appropriation of a significant higher level of academic patents by SMEs in the region, where the university is located.

Although the response rate was low, the survey yielded representative data for scientists at universities in Europe. Potential problems, e.g. dealing with a larger percentage of non- responses for some questions about RC activities in relationship with university TT governance models, have been solved either accepting a lower confidence interval or a higher accuracy rate. In line with qualitative research (Siegel, Waldman and Link, 2003) new empirical and quantitative evidence from this research in Europe, shows that the RC output of university TTOs (in terms of patents and spin-offs) is positively

associated with its' organisation and TT governance model. Positive and high correlation coefficients were found between university governance TT models and contact with researchers, which might also be attributed to its' location (central, decentral or outside the university campus). Medium high correlation coefficients were found between patenting and spin- off formation on the one hand, and university governance TT models, on the other hand. Since the RC output of university TTO governance models as the independent variable, may also be dependant from other variables which have not been examined in this research (e.g. IP awareness, obligation to contact a TTO for patents, patenting by scientists as important factor for their career or contract research) future research is welcomed to describe and estimate these interdependencies. I wish that the research methodology and key findings may be of interest for scientists in their future research.

From an institutional point of view the Netherlands' Patent Act provides universities the same ownership entitlement as the Bayh- Dole act does in the USA. However, the increase in numbers of university patents in The Netherlands has been far less spectacular than in the USA (e.g. KNAW, 2014; Lissoni, 2012; vs. Henderson, Jaffe and Traijtenberg, 1996; Mowery et al., 2001). The alignment between national innovation policy, introduction of university TT governance models and IP strategy has proved to be a lengthy process that started in 2004. From 2012 onwards uuniversity boards and TTO managers were advised to align their TT governance model and the IP strategy with R&D managers of Dutch multinational firms and regional development agencies (IP paragraph in the Top Sector policy, 2013 government.nl/encouraging-innovation). The Dutch case study shows that the numbers of academic patents filed by universities has grown substantially after the implementation of all TTO governance models. Although a national study showed that some 65 % of the academic patents have been sold or licensed to companies (KNAW, 2014), university TTO managers still receive criticism for their lack of support to scientists and entrepreneurs who want to start a company based upon academic inventions.

Surprisingly, neither a classical, centralised nor an autonomous, decentralised TT governance model contributed to a larger exploitation of academic patents by spin- off companies. Here, our findings on the effects of an autonomous, decentralised TT governance model differ from results from 16 European case studies (Schoen et al., 2014) which were however based upon interviews with TTO staff and data from TTO and university websites. An earlier TTO survey at 11 universities in Europe (Debackere and Veugelers, 2005) yielded data that provided evidence of an increased patent transfer to spin- offs that universities with an autonomous, decentralised TT model on the condition that a TTO can provide the right incentives for RC engaged scientists. The importance of providing the right incentives to scientists to engage them in the process of research commercialisation and to TTOs at universities (Silberman and Friedman, 2003) has also been shown in Italy and other EU member states (Muscio, 2010). In Italy (a country with universities with a "professors' privilege") case studies on university – industry TT show the success of centralised TT governance models with an IP strategy focusing on academic patent appropriation by firms (Rossi, 2010).

At the same time university TT towards SMEs depends to a large extent on personal contacts between scientists and entrepreneurs (Freitas et al., 2013). Case studies in Sweden (another country with universities with a "professors' privilege") describe successful TT pathways at two universities where graduates and postdocs were allowed to exploit academic inventions in start-ups (Åsterbro et al., 2012). In these cases the university TTOs did not facilitate these pathways at all.

In the case study, the used dataset of academic patents is large enough to justify the acceptance of the third hypothesis for one of the studied TT governance models. The actual number of academic patents in the Dutch case study can be higher than the numbers quantified, as the data sources of tenured academic staff may not be a 100 % complete. Following the research methodology, all identified academic patents have been validated in cooperation with university TTO staff. Therefore it is expected that more than 95 % of all academic patents has been identified.

Patenting and transfer of technical academic inventions have a positive impact on future product introductions by SMEs (Andries and Faems, 2013). Earlier research showed that the results of TT with academic patents can also be determined by economic sectors (Lissoni, 2013; 2012). A more detailed part of this study about TT of academic patents at a classical, centralised TT governance model at the Eindhoven University of Technology shows increased appropriation of academic patents by high-tech SMEs and start-ups. But the impact of the same, classical TT governance model on TT of academic patents to university spin-offs in the Lifesciences sector at Utrecht University was completely the opposite. For an effective TT, the choice to implement specific TT governance models should therefore also be based upon scientific disciplines at a university (engineering, computer sciences vs. medical, life sciences and biotechnology) and sectors in which, regionally present, companies operate. The exploitation of academic patents by start- ups is a proven vehicle to commercialise engineering inventions (Valorisation at 4 TU , 2016) and can also be successful in other sectors, like the life sciences, provided that young entrepreneurs will team- up with experienced entrepreneurs in that sector (Van der Steen et al., 2010). On the other hand, biopharmaceutical firms are often in a better position than university spin-offs to bring biotech inventions to the marketplace, as regulatory bodies find it increasingly difficult to approve new biologicals and medical products (Konara et al., 2016).

Since the regulations and practices of university TTOs in The Netherlands fully comply with six points of the Code of Practice, and reasonably well with the remaining twelve points (Arundel, 2013), the findings from the case study can be relevant for (university) policy makers in other EU countries. For those policy makers, who intend to extrapolate these findings or implement some of them at other universities in other countries, I suggest that a number of additional variables (i.e. national innovation policy, university mission, research funding, IP regimes, contract law and academic entrepreneurship culture) will be taken into consideration as well. In fact, the relationships between these additional variables and the engagement of scientists in research commercialisation merit future research in multiple ways.

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Conflict of interest
The author declares no conflict of interest as to possible involvement with the work at TTOs or personnel working at Technology Transfer Offices.

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