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The relationships between university IP regimes, scientists' motivations and their engagement with research commercialisation in Europe

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ABSTRACT

Many policy makers regard Technology Transfer Offices as a vehicle for Intellectual Property regimes and a main driver for research commercialisation. The involvement of scientists in the process of research commercialisation is often taken for granted. National regulations can determine the IP regimes at universities and their decisions about the ownership of scientific research results. This paper describes the relationships between four university IP regimes and identifies three driving forces, which motivate individual scientists to engage with the commercialisation of their own research, and the real involvement of scientists with research commercialisation. A representative survey of approximately 2,660 scientists working in all disciplines at some 150 universities in 30 European countries, covering a time frame from 2010 till 2015, shows that around 32% of the scientists are engaged in various pathways of research commercialisation.

We found significantly higher percentages of scientists who are involved in research commercialisation at universities that hold IP ownership on research results and that have obligatory Technology Transfer Office services. The individual driving forces are positively associated with significantly higher levels of engagement with research commercialisation, double the amount of patenting and a threefold higher involvement with spin-off companies. Involvement with a spin-off formation was only positively correlated with scientists-related driving forces, not with the intellectual property regime of the university where they work. We conclude that the driving forces of scientists and university IP regimes are both factors that can contribute to increased levels of research commercialisation. Our data suggest that the former factor is by far the more important.

Keywords: Intellectual property regimes; individual motivation; research commercialisation; patents; spin-offs

1. INTRODUCTION

1.1. BACKGROUND

Many universities in Europe have been involved with the commercialisation of their research in the last 30 years (Genua and Muscio, 2009). The importance of university-industry collaboration, technology transfer and research commercialisation to foster economic growth are widely accepted (Brody, 2016). Innovation policies may include *intellectual property* (IP) regulations, and governments in most countries in Europe have adopted Bayh-Dole-esque patent legislation enabling universities to claim IP ownership on scientific research (OECD, 2005). Nowadays, universities in Italy and Sweden adopt a 'professors privilege' allowing the inventor to become the patentee (Hvide and Jones, 2016, Lissoni et al., 2009). Research in Germany has shown that fewer university inventions were patented after the shift from institutional ownership that followed the abolition of the 'professors privilege' in that country in 2002 (Czarnitzki et al., 2015). A comparison of the impact of university IP ownership in the USA and inventor IP ownership in Sweden on academic entrepreneurship has shown that policies used to screen entrepreneurial decisions by younger, tenure-track scientists may be more effective than general incentives to increase academic entrepreneurship (Åstebro et al., 2017). University IP ownership is not a prerequisite to contribute to higher levels of research exploitation, and patenting by universities may not always be the optimal mode for research commercialisation (Fini, Lacetera and Shane, 2010). On the other hand, university policies that include transparent guidelines on IP ownership and publication freedom are often in demand at times when scientists work in collaboration with companies (OECD, 2013).

Dedicated organisational units for technology transfer at universities, i.e. the so-called *Technology Transfer Offices* (TTOs), can benefit scientists from all disciplines with collaborative research, contract research and consultancy services (Perkmann et al., 2013). Some TTOs provide services like patent applications for scientists at the faculties of science, engineering or medical schools or assist with the formation of spin-off companies. TTOs are usually regarded as the key actor and primary driver in the process of research commercialisation (Marion, Dunlop and Friar, 2012). Their size in terms of dedicated personnel, the number of years since their inception, the expertise and experience of staff have been studied as the performance indicators for TTOs (Siegel, Veugelers and Walsh, 2007; Markman et al., 2004). The output of TTOs can be measured by numbers of contracts, start-ups or spin-off companies (Muster, Wright and Clarysse, 2008), academic patents (Lissoni, 2012) and technology licencing (Conti and Gaule, 2011). It may seem evident that research commercialisation via TTOs requires full cooperation and engagement of individual scientists, but such is not always the case. In fact, the motivation of scientists to engage with research commercialisation has only recently become a topic of research (D'Este and Perkmann, 2011; Lam, 2010). To our knowledge, data about the numbers of scientists that contact university TTOs in the process of research commercialisation are scarce and information as to why they do so are even scarcer. It is important to bridge this knowledge gap because this data can provide an important source for new science and innovation policies. For boards of universities, such information can be important at the moment that strategic plans, including knowledge and TT policies are formulated.

At the institutional, organisational and individual level, a number of factors can affect the engagement of scientists in the commercialisation of their research (Perkmann et al., 2013). Various '*research commercialisation*' (RC) pathways can be appropriate, depending on the scientific discipline. By their very nature, patents may be relevant for engineers and specialists in the life sciences. Other pathways of research commercialisation, such as contract research or consultancy, may be more appropriate for scientists in other disciplines. This paper describes the RC engagement of individual European scientists in all disciplines through their contacts with TTOs. We use a number of variables that can determine the individual RC engagement of scientists in relationships with institutional and organisational factors. Data from a survey across European universities allow us to analyse the effect and impact of these variables on the RC engagement of scientists in general. For four universities with different IP regimes, we analyse in greater detail the relationship between a particular university IP regime and the RC engagement of scientists at that university. Finally, we present our findings and discuss a number of conclusions.

1.2. UNIVERSITY IP REGIMES, TTOS AND RESEARCH COMMERCIALISATION

The impact of changes in national IP regulations in Europe on academic patenting and the active involvement of scientists in patenting has been studied extensively (Lissoni, 2013, Lissoni et al., 2009, Genua and Rossi, 2011, Lawton Smith, Lindholm Dahlstand and Baines, 2010). However, at an institutional level, the effects of university IP regimes (defined here as the ownership of research results plus the organisation to commercialise them) on the engagement of scientists with the commercialisation of their research are unknown. A university IP regime can be determined by: national regulations on ownership of scientific research results, the presence of a TTO providing a wide range of RC services for scientists in all disciplines, and the quality of TTO services. **Table 1** shows some of the frequently found, institutionalised IP regimes at universities in Europe.

At an organisational level, various models of university TTOs have been described (Schoen et al., 2014: Genua and Muscio, 2009). However, the relationship between the organisation of a TTO (e.g. central location, obligatory services for university staff) and its output in terms of RC engagement, patents and spin- offs are largely unknown. For a comparative analysis of the effects of IP regimes on the engagement of scientists with RC, we can distinguish four broad categories with following characteristics:

1. **'**Full service': University IP ownership and scientists are obliged to use the services of a centrally located TTO
2. **'**Optional service': University IP ownership for scientists, but without obligatory RC services, provided by the university TTO
3. **'**Italian**'**: 'Professor's privilege' and scientists are obliged to use RC services of a university TTO
4. **'**Swedish**'**: 'Professor's privilege' but scientists are not obliged to use the RC services of a university TTO.

Table 1. University intellectual property (IP) regimes for research commercialisation (RC) in Europe(*)

	Obligatory RC services for scientists at centrally located university TTO	
University IP ownership on academic research regulated by national law	Yes	No
Yes and university is IP owner	**'Full service'**	**'Optional service'**
No and inventor owns IP	**'Italian'**	**'Swedish'**

(*) Adapted from Arundel (2013); Von Proff et al. (2012); Geuna and Rossi (2011); Lissoni et al. (2009); Janssens, (2005)

1.3. SCIENTISTS' MOTIVATIONS TO ENGAGE WITH RESEARCH COMMERCIALISATION

Studies in the USA and in a limited number of European countries present cross-national comparative analyses as to why scientists engage with RC (Perkmann et al., 2013). Other studies present only data at country-level, e.g. about scientists at universities in the UK (Haeussler and Colyvas, 2011; Lam, 2010) and Germany (Grimpe and Fier, 2010). Access to extra funding (Walsh and Huang, 2014; Shane, 2004) or legal obligations (Mowery and Sampat, 2005) were the most important driving forces for scientists to engage in university to industry technology transfer in the USA. Some studies describe societal impact as one of the scientists' driving forces (e.g. biotechnology, Patzelt and Brenner, 2008) at the start of new technologies (Zucker et al., 1998). Stimulating IP awareness amongst scientists in various research programmes showed that academic patenting has become important for scientific careers in some disciplines (Van Eecke, Kelly and Bolger, 2009). Other studies describe positive effects of the use of non-financial incentives to involve scientists into drafting of invention disclosures (Panagopoulos and Carayannis, 2013).

Following D'Este and Perkmann (2011) and Lam (2010) we applied the same set of driving forces that can motivate scientists to engage with research commercialisation: *Recognition-driven* (i.e. create visibility, societal impact, win 'prizes'), *Research-driven* (i.e. solving the 'puzzle', technology development) and *Entrepreneurship-driven* (i.e. create business opportunity, economic impact, 'cash in' on eminence). In this paper, we refer to these driving forces as scientists' driving forces.

Our first research question is to determine to what extent scientists at universities in Europe are engaged with research commercialisation. Our second research question is to identify whether scientists' driving forces can be associated with higher levels of RC engagement, patenting and spin- off formation, and, if so, which of these driving forces? Following the Codes of Practice for Technology Transfer (Arundel, 2013) for the European Union, our third research question is whether we can determine that certain university intellectual IP regimes can be associated with higher levels of scientists' engagement with research commercialisation, patenting and formation of spin-off companies?

2. RESEARCH METHODOLOGY AND INFORMATION SOURCES

Prior studies unearthed a number of factors which can affect the engagement of scientists with the commercialisation of their research, e.g. their age (Frosch et al., 2015), their scientific discipline (Perkmann et al., 2013) and their official position at a university (Shane, 2004). Following this theory, we use the control variables age, gender, scientific disciplines and university positions to identify the effects of these variables on the engagement of scientists with research commercialisation. Next, we include the scientists' driving forces and the university intellectual property regimes as model variables to quantify their effects in following equation:

$$RC_{i,Q} = C + a.\,A_{i,Q} + \beta.X_{i,Q} + \gamma.D_{i,Q} + \delta\,.UP_{i,Q} + d.\,Driver_{i,Q} + IP\ regime\ type_{i,Q} + \xi_{i,Q} + error\ term$$

where i and Q refer to the value of the control and model variables of the individual scientist i or scientist Q. So the RC of an individual scientist (RC_i) is determined by the sum of control variables, i.e. age (A), gender (X), discipline (D), university position (UP) plus *model* variables, i.e. driving forces and IP regimes types, plus random Driving forces, random IP regime types and individual (ξ) effects.

In line with the research questions, we organised a survey to collect data from a target audience at universities in Europe, i.e. individual scientists working in all disciplines (earth, engineering, economics, mathematics and computer sciences, medical and life sciences, natural sciences, social sciences and humanities). Under the assumption that most research commercialisation activities at universities will be carried out by Ph.D. students and associate or assistant professors, for example patenting (Giuri et al., 2007), we made an effort to quantify the target audience. Considering a total population of 508 million persons and a Ph.D. education level of 0.2 %[5], the size of the potential target audience of scientists is approximately one million. With a confidence interval of 95% and an accuracy rate of 2%, a recommended sample size (n) of 2,396 scientists can be regarded as representative for this survey (Survey Monkey, 2016). We did not survey the personnel of university TTOs, because this study focussed on the scientists' driving forces which motivate them to engage with RC given the IP regimes at their universities.

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 working in thirty countries were randomly selected. Survey Monkey was used as a platform for electronic administration of response data, and a questionnaire was sent to the target audience. Participation with the survey was voluntary and anonymous, and respondents did not receive any financial compensation. We expected a low response rate because we do not have formal relations with scientists in Europe. Some 1,000 scientists were excluded from the sample due to their leave of absence or retirement, and some 300 respondents opted-out. The target audience received five reminders between November 2015 and March 2016, and they received the summarised survey results in June 2016. The delivery rate of the emails varied around 50% in follow-up messages, and we assume that some 30,000 scientists received the questionnaire. The questionnaire was used to collect data at both the individual and the organisational levels:

- Driving forces that motivate scientists to engage with research commercialisation, their actual engagement with RC and time allocated for the commercialisation of their research;
- Regulations about IP ownership and use at their university plus the importance of patents for the commercialisation of their research at present and in their university career;
- Contact with university TTOs and quality of obligatory and optional RC services of the TTO;
- Individual background information of the scientist (age, gender, university position, scientific discipline).

The questions in the survey had bearing on the time frame between 2000 and 2015 in order to be able to measure interesting developments. At the close of the survey, we received responses in the form of fully filled-out questionnaires from 2,665 scientists working at 148 universities in Europe. The response rate of 8.9% was low but meets the minimal sample size of 2,396 to produce representative data on scientists at universities in European countries. We compared the available individual background data of respondents in terms of age, gender, disciplines and university position as specified in the four university intellectual property regimes with university data from open sources (for 'Full service' type, see Dutch universities and Dutch scientists, for 'Italian' type see Italian universities, for 'Optional service', see Finnish universities and for 'Swedish type' see Swedish universities). We observed no major differences. For age and gender, we also used another source, namely the OECD statistics indicator D 5, Education indicators (2016). We therefore assume that the data collected from respondents will not differ significantly from the data from non-respondents, and so we are of the opinion that our survey data can be regarded as representative.

3. MAIN EMPIRICAL RESULTS

First, the data collected from 2,665 scientists working at 148 European universities in 28 EU member states plus Norway and Switzerland were validated and categorised per country (see Appendix 1). We found the majority of respondents to be older than 35 years, male, and to have a position as an associate or assistant professor with work in the medical, life sciences and health, engineering or natural sciences. **Table 2** shows the summarised statistics in terms of scientists' engagement with RC, patenting and the formation of spin-off companies. 40% of the scientists found the driving forces as formulated not applicable for them, and 40% responded that their engagement with RC was research-driven. Entrepreneurship-driven scientists are mostly RC engaged scientists. We also found that some 40% of the scientists work at universities of the 'Full service' type: with fixed rules on university IP ownership on research results and obligatory RC services at a centrally located TTO. Some 55% of scientists contacted their university TTOs for legal, business or financial assistance and in case of spin-off creation. In general, these scientists found the quality of received TTOs services satisfactory, but they could have benefitted from greater assistance with new business development.

Table 2. Summary Statistics on Scientists' engagement with Research Commercialisation (RC), Patenting and Spin-offs

	Scientists		Scientists engaged with RC	Patenting scientists	Scientists involved with spin –offs
	Numbers	(%)	(%)	(%)	(%)
Total	2,665	100			
RC engaged scientists	845	31.7	31.7		
Scientists that filed patents	426	16.0		16.0	
Spin- off involved scientists	227	8.5			8.5
Variables					
1.Age					
< 35 years	573	21.5	25.1	8.5	5.9
35 -50 years	1,101	41.3	34.2	19.3	6.7
>50 years	991	37.2	33.2	20.3	7.9
2.Gender					
Male	1,532	57.5	37.1	21.2	8.4
Female	631	23.7	27.6	12.7	6.0
No information provided	502				
3.Scientific disciplines					
Earth	94	3.5	28.7	5.3	5.3
Engineering	504	18.9	45.4	26.8	12.5
Mathematics and computer sciences	218	8.2	31.7	7.2	9.2
Medical or Life sciences and	810	30.4	32.5	18.4	5.5
health	453	17.0	31.6	24.1	12.2
Natural	134	5.0	20.9	0	2.2
Social, economic and humanities	464	17.4	17.2	3.9	1.7
Not indicated by respondent					
4.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	202	7.6	33.7	19.8	
No information provided by respondent	463	17.4	16.8	3.5	3.7 (A)
5.Scientist's driving forces					
Recognition	223	8.4	44.1	19.0	5.0
Research	1,006	37.7	48.0	22.9	9.4
Entrepreneurship	330	12.4	55.0	32.2	27.0
Other	53	2.0	56.7	11.4	0
Not applicable according to respondent	1,032	38.3	6.6	3.5	2.7
6.University IP regime					
'Full service'	1,128	42.3	39.0	21.3	9.4
'Italian'	135	5.1	32.6	17.0	10.4
'Optional service'	461	17.3	30.8	17.1	6.9
'Swedish'	154	5.8	33.7	18.2	14.9
No information provided by respondent	787	29.5	20.3	7.9	6.7

(A) Percentage of respondents in other university positions and those who did not provide information together

We found that, irrespective of the scientists' driving forces, university IP regime, age, university positions and scientific disciplines, 32% of the scientists were engaged in several pathways of RC (e.g. contract research, cooperation with the industry, consultancy, patents, spin-offs). Some 60% of scientists spend 10 to 25% of their time on joint research with industry and contract research at a university. Some 45% spent more than 25% of their time on these RC activities. Interestingly, we found that patent awareness amongst scientists in all disciplines is above 80%, and that 60% of scientists found patents important for the commercialisation of their present research and 50% for their careers. On the other hand, only 16% of the scientists have filed patents and 8% have been involved in the formation of a spin-off company.

The relationships between RC of scientists in general and the individual driving forces and university IP regimes become more evident if we focus on the numbers of RC engaged and patenting scientists only. We also found one relationship between spin-offs companies with scientists' driving forces but no relationship between spin-offs companies with the university IP regimes. We assume that differences in both the university IP regimes and scientists' driving forces on the one hand may be associated with different levels of engagement in RC, patenting and spin-off formation on the other hand. To confirm these assumptions, a number of statistical analyses were executed. **Table 3** shows the results of rank correlation analyses between the pairs of studied model variables. We found significant correlations between both university IP regimes and RC engaged scientists, and between university IP regimes and patenting scientists. Both correlation coefficients are small but positive. The correlation between university IP regimes and the engagement of their scientists in the formation of spin-off was found to be insignificant. The three associations between the scientists' driving forces and scientists' RC engagement, patenting and involvement with the formation of spin-off companies are significant, positive and quite large. The rank correlation coefficients of the driving forces are between two to eight times larger than those of the university IP regimes.

Table 3. Relationships between University IP regimes and Scientists' driving forces and their engagement with Research Commercialisation (RC), Patenting and Spin-offs

	Number of scientists	RC engaged scientists (%)		Patenting scientists (%)		Scientists engaged in spin –offs (%)	
1. University IP regimes			**RC engaged scientists**		**Patenting scientists**		**Scientists engaged in spin –offs**
'Full service'	1,128	39.0	*Rank correlation coefficient* **0.19** (***)	21.3	*Rank correlation coefficient* **0.11** (***)	9.4	*Rank correlation coefficient* **0.04**
'Italian'	135	32.6		17.0		10.4	
'Optional service'	461	30.8		17.1		6.9	
'Swedish'	154	33.7		18.2		14.9	
Not classified	787	20.3		7.9		6.7	
2. Scientists' driving forces							
Recognition	223	44.1	*Rank correlation coefficient* **0.41** (***)	19.0	*Rank correlation coefficient* **0.42** (***)	5.0	*Rank correlation coefficient* **0.30** (***)
Research	1,006	48.0		22.9		9.4	
Entrepreneurship	330	55.0		32.2		27.0	
Other	53	56.7		11.4		0	
Not applicable for scientist	1,032	6.6		3.5		2.7	

Bivariate Spearman rank correlation analyses (***) significant at 0.01 level (two- tailed)

We also applied multiple ordinal regression analysis techniques to obtain more detailed information about the significance of the studied variables that can potentially be correlated with scientist's RC engagement[6]. We found that the model fit was not violated (at a Nagelkerke pseudo R^2 = 54%), and that the percentage of locations of variables in our model can be accurately predicted. **Table 4** shows that scientists' RC engagement is significantly correlated with the scientists' driving forces, the university IP regimes and two control variables (i.e. scientific discipline and university position). Especially, the university position of scientists is most significantly correlated with the RC engagement of individual scientists. Again, it becomes evident that entrepreneurship-driven scientists are most RC engaged.

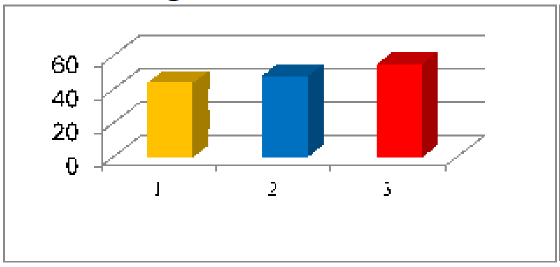
Table 4. Correlations between 4 variables and Research Commercialisation (RC) engaged scientists

	Number of scientists	RC engaged scientists (%)
Variable		
1.Scientists' driving forces		
Recognition (**)	223	44.1
Research (**)	1,006	48.0
Entrepreneurship (**)	330	**55.0**
2.University IP regime		
´Full service´ (**)	1,128	39.0
´Optional service´ (**)	135	32.6
'Italian' (**)	461	30.8
'Swedish' (**)	154	33.7
3.Scientific discipline		
Social, economy and humanities (**)	134	20.9
Earth (**)	94	28.7
Natural (**)	453	31.6
Mathematics and computer science (**)	218	31.7
Medical and Life sciences and Health (**)	810	32.5
Engineering (**)	504	45.4
4.University position		
PhD student (***)	156	13.5
Post doc (***)	496	26.0
Assistant or associate Professor (***)	765	34.9
Professor (***)	582	**46.6**

(**) significant at 0.05 level and (***) significant at 0.01 level

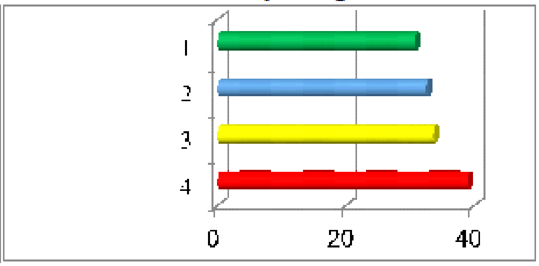
Figures 1 and 2 show that the RC engagement of scientists is significantly correlated with the driving forces that can motivate them to engage with RC and with the type of IP regime at their university. Figures 3, 5 and 7 show that scientists' RC engagement, patenting and involvement with formation of spin-off companies are all significantly correlated with the disciplines in which the scientists work. Figures 4, 6 and 8 show that RC engagement, patenting and the involvement with the formation of spin-off companies are significantly correlated with the university positions of scientists. Looking at the target audience in our survey, which consisted of scientists working in all disciplines at universities in countries in Europe, we found that entrepreneurship-driven professors in engineering sciences at universities with a 'Full service' IP regime correlated with the highest levels in terms of RC engagement, patenting and formation of spin-off companies.

Figure 1. Scientists' RC engagement (%) vs. driving forces (**)



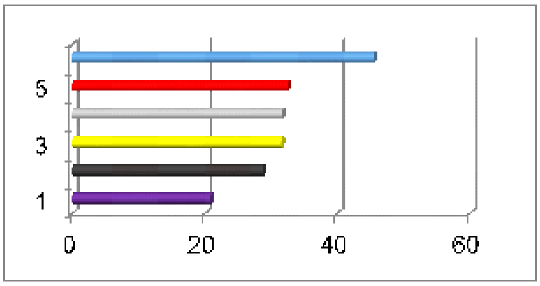
(**) significant at (0.05) level
1. Recognition-driven, 2.Research-driven
3. Entrepreneurship-driven

Figure 2. Scientists' RC engagement (%) vs. university IP regimes (**)



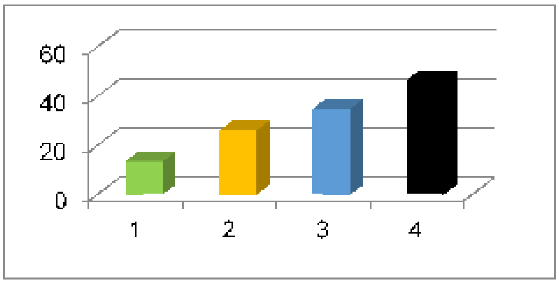
(**) significant at (0.05) level
1. 'Optional service', 2. 'Italian', 3. 'Swedish',
4. 'Full service'

Figure 3. Scientists' RC engagement (%) vs. disciplines (D) (**)



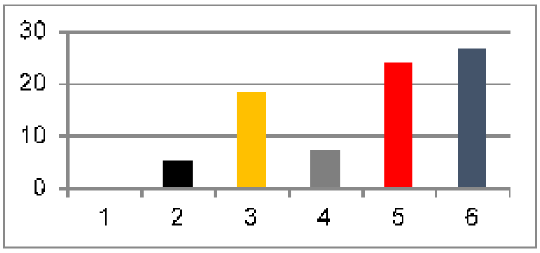
(**) significant at (0.05) level

Figure 4. Scientists' RC engagement (%) vs. university positions (UP) (***)



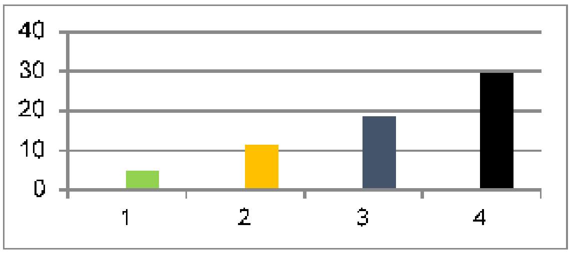
(***) significant at (0.01) level

Figure 5. Patenting (%) by disciplines (D) (**)



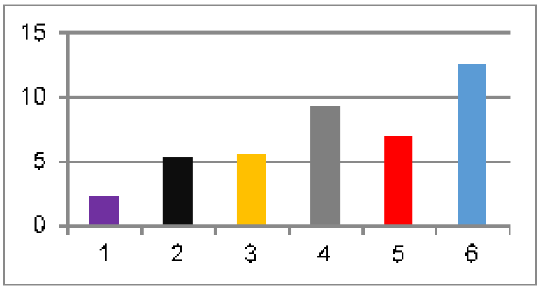
(**) significant at (0.05) level

Figure 6. Patenting (%) vs. university positions (UP) (***



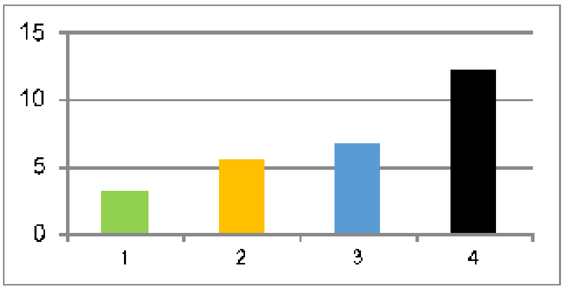
(***) significant at (0.01) level

Figure 7. Spin-off involvement (%) vs. disciplines (D) (*)



(*) significant at (0.1) level

Figure 8. Spin-off involvement (%) vs. university positions (UP) (**)



(**) significant at (0.05) level

(D) 1. Sociology, economy and humanities, 2. Earth- and 3. Natural sciences, 4. Mathematics and ICT, 5. Medical and Lifesciences and Health, 6. Engineering

(UP) 1. PhD student, 2. Post doc, 3. Associate or assistant professor, 4. Professor

Finally, **table 5** shows some of the effects from the university IP regimes on the RC engagement of their scientists at four well known universities in Europe. Although the universities differ in mission, profile and background we found striking differences in RC engagement, TTO contact and patenting between the 'Swedish' IP regime and the other three IP regimes. Apparently, scientists at the Karolinska Institutet in Sweden attributed a lower value of importance to patents and IP for their careers. They had no contact with a Technology Transfer Office to file patent applications, but they had some time to develop a spin-off company. Because of the "Professors' privilege" this company can appropriate and exploit patents which are based upon their own research. Scientists at the Politecnico de Milano in Italy found that patents are important for their careers and for their present research. The majority responded that they have enough time for spin-off development. These scientists were obliged to contact the TTO to file patents and appreciated the TTO services for RC as good 'value for money'. Comparing the data from scientists at the Karolinska Institutet with data from scientists working at Aalto University in Finland, we observed higher levels of RC engagement and patenting. Finland is a country where universities own IP rights on all research by law, and the Aalto University has an IP regime with a TTO that provide 'Optional service' for scientists. When we compare the data of scientists at Karolinska Institutet with data from scientists at the National University of Ireland at Galway, we observed a much higher RC engagement and patenting rate at the latter institute. We observe that the majority of scientists contacted the TTO of the National University of Ireland at Galway (NUIG), which provide 'Full service' for scientists.

Irish universities rank highly according to an assessment in the EU *Codes of Practice for Technology Transfer* (Arundel, 2013). We found that the percentage of scientists at the National University of Ireland at Galway that engage with patenting to be double the European average (16%) and their engagement with the formation of spin-off companies more than double the European average (8%). At the other end of the spectrum, Swedish universities rank low according to those Codes of Practice. In the absence of a formal IP policy or a centralised TTO at the Karolinska Institutet, we found that scientists are 37% less engaged in RC as compared with the European average. The scientists at Karolinska Institutet, who responded in this survey, did not file patents but were engaged with the formation of spin-off companies at a level which is at a level of 63% of the European average. The figures for scientists' driving forces (6) and indicators 7, 9 and 10 in **table 4** confirm the general findings from the statistical analyses in this paragraph. But due to the low numbers of responding scientists at each of these universities, the presented figures in the table are not representative for the university at large.

Table 5. Relationships between scientists' engagement with Research Commercialisation (RC) and the IP regime of their university (%)

Variables and other indicators	University IP regime (*)			
	'Full service'	'Optional service'	'Italian'	'Swedish'
1.Name of university (country)	National University Galway (Ireland)	Aalto University (Finland)	Politecnico de Milano (Italy)	Karolinska Institutet (Sweden)
2.University IP ownership by law	Yes	Yes	No	No
3.Central TTO and obligatory services for scientists	Yes	No	Yes	No
4. Scientists per discipline				
Earth	-	-	10	-
Engineering	39	70	71	-
Mathematics	6	4	10	-
Medical	44	9	10	90
Natural	11	17	-	-
Social	-	-	-	10
5.University IP policy	Commercialise or license	Used for research and innovation services	Transfer and use by industry	Unclear
6. Scientists' driving forces:				
- Recognition				
- Research	33	80	50	43
- Entrepreneurship	33	20		14
- Other	33		50	43
7.Scientists that have contacted the TTO for RC	*71*	65	67	18
8. Kind of TTO support asked for by scientists;				Unknown
- Patenting	38	*63*	33	
- Business support	38	13	-	
- Funding research	25	25	-	
- Spin off agreements			33	
- Legal			33	
- Licensing				
9. Patenting scientists	33	*44*	28	0
10. Scientists involved with spin-offs	19	9	*24*	5
RC engaged scientists (%)	*67*	*61*	*52*	***19***

(*) 'Full service' — University IP ownership, with obligatory RC services at a university TTO
'Optional service' — University IP ownership, without obligatory RC services at a university TTO
'Italian' — "Professors' privilege", with obligatory RC services at a university TTO
'Swedish' — "Professors' privilege", without obligatory RC services at a university TTO

4. CONCLUSIONS AND DISCUSSION

The results of this research show that:

1. Overall, some 32% of European scientists in all disciplines are involved in several pathways of research commercialisation, 16% with patenting and 8% with the formation of spin-off companies;
2. RC engagement of scientists can be statistically significant, associated with driving forces of scientists that motivate them to engage with the commercialisation of their research. We found that entrepreneurship-driven scientists are significantly more engaged than scientists driven by recognition or research;
3. RC engagement of scientists can also be associated with the IP regimes of universities. At universities with 'full service' IP regimes, significantly more scientists are involved with RC compared with scientists working at universities with other IP regimes.

We found that entrepreneurship-driven scientists show the highest correlations with RC engagement. Based upon the statistical analyses with data from European scientists in all disciplines, we conclude that the position of scientists at their university is the most important variable showing the highest correlation with RC engagement, patenting and spin-off formation. Looking at the formulated RC equation, we conclude that scientists' disciplines, driving forces and university IP regimes — in decreasing order of importance — determine their contribution to RC. In turn, the driving forces of scientists that motivate them to engage with RC are much more important than the IP regimes at their universities. Obligatory RC services for scientists at TTOs and the location of TTOs were studied as an integral part of the IP regimes of universities. We can also conclude that these services provided at a centrally located TTO play a minor important role compared with the other three variables. We found that entrepreneurship-driven scientists, at a position of professors in engineering sciences, correlate with the highest levels of RC engagement. Finally, we conclude that the observed paramount important role of professors in RC pathways in all scientific disciplines may provide fertile ground for future policy development in research commercialisation, including IP ownership.

Studies on RC and the output of TTOs can easily present a bias when they focus on patents or spin-offs only. By their very nature, patenting and spin-off formation can accommodate the transfer of technology from the faculties of engineering, science or medical schools. Indeed, at engineering faculties, we found much higher percentages of scientists engaged in research commercialisation, involved with patenting and spin-off formation. However, for scientists in medical schools or life sciences and health, we found figures in the same order of magnitude as compared to scientists in other disciplines. The research questions in this study also addressed knowledge transfer outside the IP system (Fini, Lacetera and Shane, 2010), and we included other pathways of RC (e.g. joint research, contract research, consultancy, training of company employees, attendance to conferences). In general, scientists in social studies or economics do not perceive those pathways of RC as a form of research 'valorisation' (de Jong, 2015). It is interesting that our study shows that at European level at least some 20 % of the scientists in these disciplines are involved in those pathways of research commercialisation.

Our findings on patenting by research- and entrepreneurship-driven scientists are in line with studies in Sweden and the UK (Hvide and Jones, 2016, Lawton Smith et al., 2010, Lam, 2010) but contrast with research in Germany (Grimpe and Fier, 2010). Our finding that some 30% of the scientists at universities in 30 countries in Europe is engaged with the RC of their research is comparable with the levels of 25% of RC engaged scientists found in the United States and Japan (Nagaoka and Walsh, 2009). The average 16% of European scientists that file academic patents is in line with figures in other research (Audretsch and Göpteke- Hultén, 2015 and Lissoni, 2012). However, we observed significantly higher levels of academic patenting by scientists at universities with a 'Full Service' IP regime, especially for entrepreneurship-driven scientists at senior university positions in the engineering and life sciences. In some countries, such as Italy and Ireland, these higher rates of academic patenting can be attributed to particular IP policies that stimulate scientists to file patents as an important incentive for their scientific career. The level of patenting by European scientists is some 20% lower than for U.S. scientists, and the average age of European scientists that file patent applications is higher than Japanese scientists (Nagaoka and Walsh, 2009).

The majority of European scientists who are involved with the formation of a spin–offs in this research found the TTO support to acquire financial means and/or business development insufficient. Only scientists in Italy were satisfied about the time that their universities allocate to them to develop a spin–off company based upon their own intellectual property. Time constraint and the predominant emphasis on education and research might prohibit professors to engage in RC and start-up companies (Åstebro, Bazzazian and Braguinsky, 2012). On the other hand, unaligned or non- transparent university TT policies about IP ownership and/or shares in the new venture may results in time consuming negotiations between a TTO and the founder of or investor in a university spin- off and are one of the causes that reduce the number and delay the growth of start- ups (Technopolis, 2015). Within the scope of this research on the RC engagement of scientists in Europe, we did not include TTO staff, deans of faculties or boards of universities in the survey. To avoid unilateral interpretation of the data on RC engagement, we wish to emphasise that the data collected in our survey (e.g. patents, spin-offs) may not correspond with the data or the formats published by TTOs or other open access sources.

At universities where the formation of spin-offs is not be part of the mission (Richards, 2012), special entrepreneurship courses provide students and alumni good opportunities to turn technologies into business with assistance from (associate) professors (Hartmann, 2014). Interestingly, we found that the number of involved scientists with spin –offs in Sweden equals almost double the amount of the European average. With a population of approximately 10 million inhabitants and a limited number of multinational firms, Swedish policy advisors advocate that future economy growth depend on successful start-ups. Free courses on entrepreneurship, soft funding for start- ups and patent applications have attributed to the recent growth of a number of successful start-ups, like Skype or Spotify (Techworld, 2015).

We applied a bottom-up approach in our research methodology and found significant differences in RC that are associated with scientists' driving forces and university IP regimes. To our knowledge, this study on scientists' individual engagement with the commercialisation of their research is unique in that this study is the first of its kind that generates cross- national data on individual scientist at university, country and pan-European level. The fact that we surveyed scientists from all disciplines, who participated on a voluntary and unpaid basis, contributed to the collection of unbiased data. Although the response rate in the survey was low, we have shown that the sample size of respondents was large enough and therefore representative for the target audience of European scientists.

Future research in this area will benefit from both larger samples sizes at country and university level. University-level and research funding agencies at the national or European Union levels can also make valuable contributions. A project combining our research methodology and data with the data recorded by university TTOs in Europe (e.g. ASTP-Proton) might provide an interesting avenue for future research. We suggest using standardised formats for data collection and including data on the financial budgets for scientific research and research commercialisation. In the longer term, this line of research can unearth very interesting data from intercontinental comparisons including universities and countries with different innovation systems and RC policies (e.g. Australia, Brazil, China, Japan, South Korea, Russia and USA). Other areas for future research on RC engagement by scientists may include the effects of the reduction in research funding, stricter regulations on the interaction between universities and the private sector (Martinez, Lissoni, Sanz-Menendez, 2016). The use of appropriate incentives for (senior) scientists and the effects of the governance of university TTOs (Schoen et al., 2014) on RC engagement are also interesting areas.

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CONFLICT OF INTEREST

All authors declare no conflict of interest as to their possible involvement with the work at TTOs or personnel working at the Technology Transfer Offices.

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APPENDIX 1: UNIVERSITY IP REGIMES IN EUROPEAN COUNTRIES

	Obligatory RC services for scientists at centrally located TTO		
University IP ownership on academic research regulated by national law	Yes	No	No information
Yes	**´Full service´** Austria, Belgium, Czech Republic, Denmark, France, Ireland, Spain, Netherlands and United Kingdom, plus Norway	**´Optional service´** Finland, Germany, Greece, Hungary, Poland, and Portugal	
No	**'Italian'**	**'Swedish'**	
Not enough information	Switzerland	Bulgaria, Croatia, Cyprus, Estonia, Iceland, Latvia, Macedonia, Romania, Serbia and Slovakia	Luxembourg

FOOTNOTES

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[5] Eurostat, 2016 approached in March 2017.

[6] This regression technique is allowed given the experimental set-up in this research with a large number of universities in more than 25 countries (Brian and Jenkins, 2013).