Do Co-Publications with Industry Lead to Higher Levels of University Technology Commercialization Activity?

Wong Poh Kam
NUS Entrepreneurship Centre
National University of Singapore
PohKam@nus.edu.sg

Annette Singh*
NUS Entrepreneurship Centre
National University of Singapore
annette_singh@nus.edu.sg

Abstract
This paper examines the impact of university-industry R&D collaboration as measured by university-industry co-publications (UICs) on university technology commercialization output for leading US and Canadian universities, after controlling for the quantity and quality of their research and for their commercialization resources. Results showed that UICs do have a significant positive influence on universities' patenting (both in terms of simple patent counts and citation-weighted patents) and spin-off formation. Implications of these findings and possibilities for future research are discussed.

Key Words: University patenting, spin-offs, publication quantity & quality, university-industry collaborative research, co-publications

Subtheme: Start-ups, spin-offs, science parks, business incubators, technology transfer offices, joint research projects, in-firm (company) universities, business acceleration centers, corporate incubation, university proof-of-concept centers, etc

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*Please contact the authors for an updated version of this paper

1. Introduction

As argued by Etzkowitz et al (2000) and Etzkowitz (2003), universities around the world are increasingly shifting from their traditional primary role as educational providers and scientific knowledge creators to a more complex “entrepreneurial” university model that incorporates the additional role of commercialization of knowledge and active contribution to the development of private enterprises in the local and regional economy. As a result universities become an increasingly important component of the national innovation system, and need to operate increasingly within a Triple-Helix nexus involving close interaction with government and private industry (Wong et al 2009).

This is reflected in the growing empirical literature on the determinants of university technology commercialization activities in recent years. Studies adopting the resource-based view in particular have investigated the effects of the resources and capabilities of universities on their commercialization output (see e.g. O’Shea et.al. 2005, Vinig and Van Rijsbergen 2009 and Wong and Singh 2009). One potential determinant factor that has received somewhat less attention is the intensity of university-industry R&D collaboration as measured by the propensity of the universities to generate co-publications with industry. This paper examines the relationship between university-industry R&D collaboration and university technology commercialization by investigating the extent to which the latter may be influenced by the involvement of universities in research collaboration with industry, as evidenced by their propensity to generate co-publications with industry

2. R&D Collaboration and its Impact on University Technology Commercialization

2.1 University-Industry R&D Collaboration

The literature has identified several forms of university-industry R&D collaboration, including joint research projects, university researchers working in firms or firm employees working in universities, university researchers engaging in short-term consultancies, participation in formal and informal networks, or formation of university-industry research centers (Calvert and Patel 2003, Perkmann and Walsh 2007). Collaborative arrangements can vary in scale (from small to large), temporal nature (from temporary to permanent) and structure (from individual projects to organizations).

Although research cooperation between universities and industry has a long history, it has become the subject of recent interest, particularly as expectations of universities’ contribution to economic development have grown (Calvert and Patel 2003). Factors from all three strands of the Triple Helix have played a part in this. From the point of view of universities, collaborative research arrangements with industry are seen as a supplementary source of R&D funds as public funding for research becomes more constrained (Wayne 2010). In addition, universities that are – or are seeking to become - “entrepreneurial universities” also pursue collaborative research with industry in order to establish and consolidate their positions in knowledge markets and innovation networks (Tijssen 2006). From the perspective of the industrial sector, collaborative research with universities is becoming more desirable as firms become more aware of how it can improve their own R&D capabilities and help them to produce more innovative products (Broström and Lööf 2008). These factors, along with recognition of the fact that university-industry research collaboration can be an important source of innovation, have prompted governments to actively promote such collaborative research. An increasing amount of public funding is being provided for university-industry R&D projects, eg the Advanced Technology Program in the US and within the European Commission’s Framework Programmes (Perkmann and Walsh 2007, Ambos 2008).

The importance of university-industry research is partially reflected in the proportion of industrial funding of university R&D, with industry-sponsored R&D being the most rapidly growing source of R&D funding for universities (Powers 2003). Concomitantly, the number of co-publications in scientific and technical journals involving authors from academia and industry has also been increasing (Lundberg 2006, Calvert and Patel 2003). It is also becoming apparent in university technology transfer strategies. Whereas US universities in the 1980s and 1990s emphasized patenting and licensing strategies, leading universities such as University of California Berkeley and Stanford are now sharpening their focus on collaborative research relationships with industry and seeking to integrate their strategies on these different forms of technology transfer (Mowery 2007) .

2.2 Co-publications as a Measure of University-Industry R&D Collaboration

Co-publications – that is, co-authored publications with multiple affiliation addresses – have become the standard way to measure research collaborations. Co-publications give access to even informal networks and can be seen as an output of research cooperation where some diffusion of knowledge and skills has taken place (Lundberg et al 2006, Tijssen 2006). Of course, many collaborations do not eventuate in a co-authored paper. Or, in the reverse scenario, a publication may be co-authored where in fact no significant research collaboration has taken place. Another complication arises when a single author lists more than one institutional affiliation (as may occur when a researcher is on sabbatical and has undertaken a visiting fellowship or is on secondment) although no collaborative arrangement exists between the institutions. Set against these limitations are the advantages of co-publications for analyzing research collaborations, including the fact that they provide systematic, publicly available and internationally comparative data (Calvert and Patel 2003, Tijssen 2006). This gives it clear advantages over alternatives such as industry funding of university R&D, which is not publically available and may include contract research where no collaboration has taken place. Generally the consensus is that co-publications provide a reasonable proxy measure of university-industry research cooperation (Calvert and Patel 2003, Tijssen et al 2009).

There has thus been increasing use of university-industry co-publications (UICs) in recent literature analyzing university-industry research collaborations. Co-publications have been used to study university-industry research collaborations in the UK (Calvert and Patel 2003), the Netherlands (Ponds et al 2007) and the Eastern European EU states (Glänzel and Schlemmer 2007). Isabelle (2007) investigated the relative production of patents and co-publications as outputs of public-private collaborative R&D in France, while Levy et al (2009) analyzed co-publications as one of four channels of university-industry collaboration in an analysis of science-industry collaborative patterns of a European university. This paper follows these studies in using UIC as a proxy measure of university-industry research collaboration to investigate the impact of such collaboration on university technology commercialization output.

2.3 The Impact of R&D Collaboration on University Technology Commercialization

There is some reason to expect R&D collaboration to have a positive effect on university technology commercialization output. Tijssen's (2006) model of the early stages of a university's transformation into an entrepreneurial university has three phases. In the first phase, the university becomes more aware of the potential for commercialization, the second phase is characterized by identifying opportunities for commercialization, and the third phase by developing commercialization opportunities such as through patenting, licensing technologies, or forming spin-offs. While noting that the actual process universities experience as they undergo an entrepreneurial shift would not be simply linear but involve many iterations and overlaps between the three phases, Tijssen's model does provide a useful framework for conceptualizing the process. University-industry interactions, including cooperative research, fall into the second phase, with these interactions having the potential to become the catalyst for the commercialization processes in the third phase: "It seems reasonable to assume that those universities that make attractive research partners…are probably also more inclined to embrace or promote a more business-oriented research culture themselves, and may eventually pursue their own entrepreneurial activities" (Tijssen 2006 p. 1574). Following this model then, as the university engages itself in research collaboration with the private sector it can be expected over time to increase its commercialization output.

While Tijssen's model is primarily aimed at explaining the early stages of universities' entrepreneurial shift, it seems intuitive that a more industry-oriented research focus will continue to have a positive effect on the technology commercialization output of institutions which are further along in the process of becoming entrepreneurial universities. Two key reasons for this can be found in the literature. The first pertains to the type of research conducted in the university. University-industry collaboration generally involves more applied research and targeted outcomes. The results are thus more likely to be conducive to being developed into commercially-oriented inventions than government-funded basic research (Powers 2003, Tijssen 2006, Di Gregorio and Shane 2003). Di Gregorio and Shane (2003) further argue that since industry-funded research tends to be less risky and has less information asymmetry problems than basic research, it is easier to subsequently commercialize. The second reason pertains to the benefits of having developed relationships with industrial researchers and other contacts. Interaction with industry gives faculty members access to such contacts and networks which can facilitate the commercialization of their inventions. For example, Sætre (2009) argued that interaction with industry can assist university spin-offs in obtaining information needed about the new business, providing access to external resources, finding external support and services, providing them channels to advertise the new companies and searching for needed business advice. It also exposes university researchers to technological problems faced by firms and thus open research areas with commercial potential which they may not otherwise have encountered (D'Este and Patel 2007).

2.3.1 Empirical Studies of UICs and University Technology Commercialization

A body of empirical research has found that increased ties to industry do result in greater levels of commercialization (O'Shea et al 2005, Powers 2003). In particular, at the organizational level, a number of studies have found the level or proportion of industry-funding of university research funding to have a significant influence on patenting and spin-off formation (Powers and McDougall 2005, Wayne 2010, O'Shea et al 2005, Powers 2003, Di Gregorio and Shane 2003).

Although this does provide evidence that a greater commercial orientation of universities can result in increased commercialization, it does not necessarily specifically inform on the relationship between R&D collaboration and university technology commercialization, since industry-funded research may not involve collaboration (eg it may include contract research, in which a firm commissions a university to undertake research on behalf of the firm). Further, as an input measure, industry-funded research does not necessarily reflect the outcome of the research. Given this, UICs provide an alternative indicator in investigating the relationship between university-industry R&D collaboration and technology commercialization, since the very fact that the research was published implies that the results were perceived to be sufficiently novel and significant to warrant dissemination (Lundberg et al 2006).

Despite the growing interest in using co-publications to study university-industry research collaboration, few have attempted to quantify their effect on university technology commercialization. A number of studies (eg D'Este and Patel 2007 and Carayol and Matt (2004)) have examined co-publications at the individual and laboratory level respectively and found that joint publications with industry generally increase the output of commercialization activities. At the organizational level, Tijssen (2006) studied the effect of public-private co-publication intensity on university patenting in the field of immunology for 187 European universities over 1996-2001. Contrary to expectations his results revealed an inverse relationship between co-publication intensity and patenting. It is possible however that these results were partially due to the fact that that the period under analysis was the late 1990s, when entrepreneurial activities were as a whole less developed in Europe. Tijssen notes that the data could also have been used to see if the universities developed entrepreneurial activities in a later period.

The above review shows that despite the strong interest in university-industry research collaboration, empirical knowledge remains limited (D'Este and Patel 2007). This is particularly true regarding its impact on university technology commercialization, particularly at the organizational level. Given the increasing resources given to university technology transfer in general, and university-industry R&D collaboration in particular, this is a significant gap. A greater understanding of how the different elements of technology transfer inter-relate would assist governments and university administrators in formulating policies and strategies that will use these resources to be more effectively. We attempt to begin filling this gap by investigating the effect of university-industry R&D collaboration (as measured by co-publications) on technology commercialization output (as measured by patenting and spin-off formation) for leading US and Canadian universities. Following the literature review above, our hypothesis is:

***Hypothesis**: University-industry co-publication (UIC) intensity will have a positive effect on universities' commercialization output*.

In analyzing university-industry R&D collaborations as measured by UICs however, an additional factor must be considered – specifically, the research output of the university. There is a correlation between universities' UICs on one hand, and the quantity and quality of their research output on the other. Tijssen (2009) for example, found a significantly positive relationship between UIC intensity and the quantity and quality of universities' publication output.

Moreover, since knowledge must be generated before it can be commercialized, research quantity and quality (commonly measured using publication counts and citations rates) have been found to directly influence university technology commercialization output (Vinig and Rijsbergen 2009, Wong and Singh 2009). The effect of publication quantity and quality on patenting has been investigated in a number of studies, at both the individual and institutional levels, generally finding a positive relationship between them (eg Owen-Smith and Powell 2003, Baldini 2006, Wong and Singh 2009). There has been somewhat less research on the relationship between publications and spin-offs, particularly on the effect of publications quality on university spin-off formation. In terms of publications quantity, Vinig and Rijsbergen (2009) found that the publication output of universities is positively and significantly associated with spin-off formation in the US. Grandi & Grimaldi (2003) found that scientific excellence, which included a measure of publication quantity, is positively related to the prediction of success of academic spin-offs.

Obtaining an accurate picture of the effect of UICs on university technology commercialization thus necessitates controlling for the effects of the universities' overall publication quality and quantity.

3. Data and Methodology

In this study we assembled data on the UIC intensity of 82 research-intensive North American universities (70 from the US and 12 from Canada) and examined their influence on the universities' technology commercialization output, after controlling for the quantity and quality of their research and for their commercialization resources.

The universities included in our sample fulfill three criteria: they have been listed in the World University Ranking (WUR) published by the Times Higher Education Supplement (THES) and Quacquarelli Symonds (QS); they have been listed in Shanghai Jiao Tong University's Academic Ranking of World Universities (ARWU); and they have been granted at least one US patent since 1976. Patent data for the universities was obtained from the database of the United States Patent and Trademark Office (USPTO) and from a database of US patents provided by Patsnap Technologies. Data on the number of spin-offs formed and the characteristics of the universities' technology transfer offices (TTOs) were obtained from the AUTM (Association of University Technology Managers) licensing survey report summaries and AUTM's STATT (Statistics Access for Tech Transfer) database.

The following model is estimated:
University technology output = $\beta_0 + \beta_1$UIC intensity $+\beta_j$(control variables) + ε

The measures for each of the variables in the model is described below.

3.1 Dependent Variables

Three alternative measures of university technology commercialization output were used as the dependent variable. The first is the number of US patents issued to each university. As long as a university was named as an assignee to a patent, a full patent was counted to that university, regardless of the number of co-assignees for that patent.

The second dependent variable is the number of citation-weighted patents. This was used in addition to simple patent counts since patent quality varies widely, and analysis of quality-weighted patents therefore provides a more accurate evaluation of universities' patenting productivity (Mowery 2007). The method used for weighting the patents is discussed in Annex A.

The third dependent variable is the number of spin-offs formed by the universities. This was used as an indication of a different aspect of university technology commercialization, in which the university is engaging in formal entrepreneurial activity, as opposed to patenting in which the focus is protecting the university's intellectual property.

One limitation of using a cross-section study design is that changes over time are not captured (Powers 2003). In order to address this limitation somewhat, the dependent variables were calculated as the average annual numbers of each indicator over three years, from 2006 to 2008.

3.2 Predictor Variable

For the UIC explanatory variable we drew on a new set of data developed by Tijssen et al (2009) on the intensity of university-industry co-authored research publications published during 2002-2006 covering 350 universities in the world. Using Web of Science as their source, Tijssen et al defined UICs as those publications which have at least one author affiliate address referring to a university and one to a private sector institution. The UIC Intensity Indicator is calculated as the percentage of university-industry co-publications within the university's total publication output.

3.4 Control Variables

3.4.1 Publication-Related Control Variables

Since previous research indicates that the quality and quantity of universities' research influences their technology commercialization output, we included a measure of publication quantity and quality as control variables. Our measure of research output was obtained from the SCI sub-index from the ARWU. This SCI sub-index gives the university's score based on the number of its publications listed in the Science Citation Index-Expanded (SCI-Expanded) and Social Science Citation Index (SSCI) databases[1], with the scores being normalized to a maximum of 100 for the university with the largest number of journal articles. Our publication quantity indicator was obtained by averaging ARWU's SCI sub-index over four years to give an average score based on the number of journal articles produced from 2002 to 2005.

Our measure of research quality was derived from the score for citations per faculty sub-index provided by the WUR. The citations per faculty sub-index is compiled using information from Thomson Reuters' Essential Science Indicators (ESI) database, with the 2005 sub-index covering data over the preceding ten years up to 2005. As with the SCI sub-index, the scores for the citations per faculty sub-index are normalized to a maximum of 100.

3.4.2 Other Control Variables

Previous research has also found certain university resources for technology commercialization to positively influence commercialization output. The first of these is the resources available for commercialization, proxied by the personnel resources in the TTO, while the second is the university's experience in technology transfer (O'Shea et al 2005, Powers and McDougall 2005, Powers 2003, Vinig and Rijsbergen 2009). Our measures for these two resources are operationalized as the number of licensing professionals (FTE) as of 2005 and the age of the TTO as of 2005 respectively.

In addition to these, since the number spin-offs formed may be related to the volume of technologies produced by the universities (O'Shea et al 2005, DiGregorio and Shane 2003), for the spin-off model we control for the average annual number of patents issued from 2003 to 2005.

4. Results

Multiple regression analysis was used with separate regression analyses for each measure of technology commercialization output. Our initial regression model using the level values of the dependent and explanatory variables revealed the existence of heteroscedasticity problems. To address this, we transformed the dependent variable by applying a square root function. Descriptive statistics of all the variables are shown in Table 1.

The Pearson correlations for all variables used in the regression analysis was computed in order to check for multicollinearity (Table 2). The bivariate correlation between two independent variables, the publication quality and average number of US patents issued from 2003 to 2005 is somewhat high (0.70), but calculation of variance inflation factors showed that the maximum Variance Inflation Factor (VIF) is 2.4. This is well below the threshold level of 10 (Powers and McDougall 2005), and so we concluded that the model does not suffer from multicollinearity.

A block step entry procedure was used with the non-publication control variables being entered in step 1, the publication control variables in step 2 and the independent variables in step 3. The regression results are shown in Tables 3 to 5. Including the publication variables generally improves the goodness of fit, particularly in the case of the models for simple and citation-weighted patents.

[1] The 2005 SCI sub-index also includes publications listed in the Arts & Humanities Citations Index (AHCI). However, we do not believe this change of definition materially changes our results. The correlation between the sub-index for 2005 is highly correlated with the data for 2006 (r=0.998, p=0.000), 2004 (r=0.995, p=0.000) and 2003 (r=0.993, p=0.000)]

4.1 Regression for Number of US Patents Issued

The results for the full model support our hypothesis – UIC intensity is indeed a significant positive determinant for patents (b=.558, $p < 0.01$) (Table 3).

In terms of the publication-related control variables, both publication quantity and quality were found to positively influence patenting (b=.057, $p < 0.01$ and b=.059, $p < 0.01$ respectively). It is worth noting however that the impact of UIC intensity is stronger than for either of these. Among the other two control variables, only the age of the TTO was significant, although the magnitude of the variable was very small (b=.031, $p < 0.05$).

4.2 Regression for Number of Citation-weighted US Patents Issued

Our hypothesis is also supported when using citation-weighted patents as the dependent variable (Table 4). The results are similar for the regression for simple patent counts. Thus the coefficient for the UIC intensity is b=.896 ($p < 0.01$). Similarly, the coefficient for the publications quantity variable is b=.069 ($p < 0.01$) while for the publications quality variable it is b=.090 ($p < 0.01$).

4.3 Regression for Number of Spin-offs Formed

As shown in Table 5, our hypothesis is also supported in the case of spin-off formation, as UIC intensity also has a positive significant impact on the number of spin-offs formed (b=.305, $p < 0.01$). Neither publications quantity nor quality had any significant effect. With regards to the other control variables, the coefficient for the number of patent previously issued is strongly significant, though the magnitude of the coefficient is small (b=.015, $p < 0.01$), while the number of licensing personnel is only weakly significant (b=.039, $p < 0.1$).

5. Discussion

The major empirical finding of this paper is that joint R&D collaboration between university and industry, as measured by university-industry co-publications, is indeed a significant determinant factor for all three measures of commercialization output after controlling for the effects of quality and quantity of publication output and relevant characteristics of the TTO. Specifically, higher UIC intensity leads to greater spin-off formation and higher patenting performance, both in terms of the absolute number of patents issued and in terms of higher-quality patents.

Our results also provide some preliminary evidence that Adams' et al (2001) finding is mirrored in universities. Adams et al found that university-industry research collaboration (specifically, university-industry research centers) tend to lead to increased patenting on the part of firms. Our study shows that this increase in technology commercialization resulting from university-industry collaborative research occurs not just in firms but is also true of universities.

These results shed further light on the importance of university-industry R&D collaboration as an element in successful technology transfer programs. A number of studies have found that relationship-based links with industry, as can be found in collaborative research, are important channels of university technology transfer, and are more commonly used than those forms that receive more attention in the literature such as licensing and patenting (Perkmann and Walsh 2007, D'Este and Patel 2007). Our results show that the benefits of such collaboration extend to having a direct contribution to universities' technology commercialization output. Research co-operation has the potential for greater contribution to economic development, not just from the direct result of the collaborative project, but also as a flow-on result to other forms of knowledge transfer from the university. This has clear public policy implications. If governments wish to encourage universities to pursue technology transfer in a way that will stimulate economic growth and maximize the exploitation of benefits from public-private R&D collaboration, they may need to realign policies and incentive structures so as to integrate the two types of knowledge transfer (Powers 2003).

The same is true for university administration. Universities seeking to pursue the third mission of technology transfer to industry on top of their traditional research and teaching missions may also need to refine their strategies, following the examples of those who have begun to integrate their commercialization policies with collaborative research strategies (Mowery 2007). This will however necessitate managing the tensions that will arise, such as the conflict between universities' traditional role of disseminating new knowledge as a public good, and controlling it as a private good (Ambos

2008, Powers 2003), and concerns about the freedom of academic research. These can be expected to become more intense as research partnerships universities and firms multiply. Our results highlight the importance of resolving this tension since success in developing patented technology which can later be commercialized is facilitated by maintaining a high level and quality of research.

Our findings of the positive influence of UIC intensity on university patenting output are contrary to Tijssen's finding of 2006 that UIC intensity has a negative influence on patenting. There are several differences between the two studies which may explain these differences, including the scope of science disciplines, the period of time, the countries and the source of patents[2]. Further analysis would be needed to give a definitive explanation, but we suggest that this is due to the fact that as a whole North American universities, particularly the US universities, have been involved in the process of transforming themselves into entrepreneurial universities for a longer period of time, and so for them the process outlined by Tijssen (2006) has had more time to develop. This is particularly so since the data used in our study is more recent, with commercialization data from 2006 to 2008 rather than 1996 to 2001. This period has seen extensive developments in universities becoming involved in "third mission" activities

One interesting finding from our results is that of all the publication-related variables, spin-off formation is influenced only by UICs, unlike patent output which is also impacted by publication quantity and quality. This adds to the pool of evidence regarding the impact of research quantity and quality on formation of spin-offs at the organizational level. Our findings are that neither of these factors are significant with regards to the formation of spin-offs, at least for US and Canadian universities. Previous patent performance however, is a significant factor. Taken together then, our results seem to show that while research quantity and quality leads to more and higher quality patenting output it does not have such a direct effect on spin-offs formation. Rather the influence of research quantity and quality on spin-offs comes indirectly, through the influence of patenting.

5.1 Limitations and further research

One limitation of this study is that it does not take into account the different fields of science. However, the magnitude and intensity of collaborative research varies with industrial sector and scientific discipline. Previous studies have found that collaborative research is more commonly used than contract research in the chemicals, metals and automotive sectors, while the latter is more common in software development (Perkmann and Walsh 2007). Similarly, UICs have been found to be particularly predominant in disciplines such as clinical medicine, physics and materials science, biomedical sciences and basic life sciences (Tijssen et al 2009). Specifically taking account of the different scientific fields in which universities and industries co-publish would therefore yield a more nuanced understanding of the relationship between UIC and technology commercialization.

Other possibilities for future research, particularly in view of the results of Tijssen's (2006) study, would be to extend the analysis to more countries in order to discover whether the positive causal relationship between UICs and university technology commercialization is also true for other regions.

[2] Tijssen's (2006) study used patent data from the EPO

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Table 1 Summary statistics

	n	Minimum	Maximum	Mean	Std. Deviation
Average no. US patents issued for 2006-2008	82	0	141.7	28.1	28.04
Average no. of citation-weighted US patents issued 2006-08	82	0	293.3	50.3	53.89
Average no. spin-offs formed 2006-2008	82	0	22.3	4.5	3.94
TTO age as at 2005	82	6	80	22.2	13.18
2005 Licensing FTE	82	1.0	20.6	6.9	4.91
Average no. US patents issued for 2003-2005	82	0	142	25.6	27.77
Average of normalized score for publication quantity 2002-2005	82	28.3	100	48.8	13.72
Average normalized score for citations / faculty 1996-2005	82	.0	100	14.9	14.40
UIC intensity indicator 2002-06	82	2.6	6.2	4.3	.91

Table 2 Pearson correlations

	Average no. US patents issued for 2006-2008	Average no. of citation-weighted US patents issued 2006-08	Average no. spin-offs formed 2006-2008	TTO age as at 2005	2005 Licensing FTE	Average no. US patents issued for 2003-2005	Average of normalized score for publication quantity 2002-2005	Average normalized score for citations / faculty 1996-2005	UIC intensity indicator 2002-06
Average no. US patents issued for 2006-2008	1								
Average no. of citation-weighted US patents issued 2006-08	.975**	1							
Average no. spin-offs formed 2006-2008	.647**	.661**	1						
TTO age as at 2005	.420**	.396**	.298**	1					
2005 Licensing FTE	.460**	.421**	.410**	.393**	1				
Average no. US patents issued for 2003-2005	.895**	.885**	.576**	.365**	.304**	1			
Average of normalized score for publication quantity 2002-2005	.569**	.521**	.379**	.293**	.613**	.508**	1		
Average normalized score for citations / faculty 1996-2005	.710**	.724**	.405**	.209	.281*	.700**	.457**	1	
UIC intensity indicator 2002-06	.411**	.420**	.488**	.119	.243*	.329**	.250*	.325**	1

n=82

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3 Regression to predict the square root of average US patents 2006-08

	1	**2**	**3**
Constant	2.603** (.492)	-.004 (.734)	-2.074† (1.045)
TTO age as at 2005	.043* (.019)	.030* (.015)	.031* (.015)
No. Licensing FTE	.173** (.052)	.030 (.049)	.015 (.048)
Average of normalized score for publication quantity 2002-2005		.058** (.018)	.057** (.017)
Average normalized score for citations / faculty 1996-2005		.068** (.014)	.059** (.014)
UIC intensity indicator 2002-06			.558** (.208)
Adj R^2	.230	.525	.561
F	13.073**	23.422**	21.694**
N	82	82	82

Standard errors in brackets
** Significant at the 1% level
* Significant at the 5% level
† Significant at the 10% level

Table 4 Regression to predict the square root of average citation-weighted US patents 2006-08

	1	**2**	**3**
Constant	3.366** (.710)	.029* (1.064)	-3.296* (1.498)
TTO age as at 2005	.059* (.028)	.041† (.022)	.041† (.021)
No. Licensing FTE	.228** (.074)	.039 (.071)	.015 (.068)
Average of normalized score for publication quantity 2002-2005		.071** (.026)	.069** (.025)
Average normalized score for citations / faculty 1996-2005		.105** (.021)	.090** (.020)
UIC intensity indicator 2002-06			.896** (.298)
Adj R^2	.202	.504	.551
F	11.245**	21.553**	20.859**
N	82	82	82

Standard errors in brackets
** Significant at the 1% level
* Significant at the 5% level
† Significant at the 10% level

Table 5 Regression to predict the square root of average no. of spin-offs formed 2006-08

	1	**2**	**3**
Constant	1.208** (.168)	1.124** (.334)	-.047 (.463)
TTO age as at 2005	-.002 (.007)	-.002 (.007)	-.001 (.006)
No. Licensing FTE	.051** (.018)	.048* (.022)	.039† (.020)
Average annual 2003-05 US patents issued	.015** (.003)	.017** (.004)	.015** (.004)
Average of normalized score for publication quantity 2002-2005		.003 (.008)	.003 (.008)
Average normalized score for citations / faculty 1996-2005		-.006 (.008)	-.009 (.007)
UIC intensity indicator 2002-06			.305** (.089)
Adj R^2	.357	.346	.427
F	16.006**	9.582**	11.01
N	82	82	82

Standard errors in brackets
** Significant at the 1% level
* Significant at the 5% level
† Significant at the 10% level

Annex A Construction of a citation-weighted patent count

Following Trajtenberg (1990), a linear weight was used, with the citation-weighted patent count (WPC) in year t being

$WPC_t = \sum_{i=1}^{n_t}(1+C_i)$, where n_t= number of patents issued to the university in year t for the years 2003 to 2005, and C_i is the number of citations received by each patent i up to the year 2006.

This is a somewhat crude approximation of the true citation-weighted patents count, for two reasons. Firstly, truncation bias means that citations to more recently issued patents are under-represented. Secondly, citations received by patents typically peak four to five years after the patent is issued (Mowery and Ziedonis, 2002). Since our patents are those issued between 2006 to 2008, and data availability restricts our citation data to 2009, we have captured only a small fraction of the citations that will eventually be made to the patents in our database.