Available online at www.sciencedirect.com
ScienceDirect
Journal of Informetrics 2 (2008) 89–100
Journal of INFORMETRICS An International Journal
www.elsevier.com/locate/joi

On material transfer agreements and visibility of researchers in biotechnology

Victor Rodriguez [a,*], Frizo Janssens [b], Koenraad Debackere [a], Bart De Moor [b]

[a] *Department of Managerial Economics, Strategy and Innovation, Katholieke Universiteit Leuven, Naamsestraat 69, B-3000 Leuven, Belgium*
[b] *Department of Electrical Engineering, Katholieke Universiteit Leuven, Kasteelpark Arenberg 10, B-3001 Leuven, Belgium*

Received 29 August 2007; received in revised form 26 September 2007; accepted 17 October 2007

Abstract

When carrying out a research project, some materials may not be available in-house. Thus, investigators resort to external providers for conducting their research. To that end, the exchange may be formalised through material transfer agreements. In this context, industry, government and academia have their own specific expectations regarding compensation for the help they provide when transferring the research material. This paper assesses whether these contracts might have had an impact on visibility of researchers. Visibility is thereby operationalised on the basis of a bibliometric approach. In the sample utilised, researchers that availed themselves of these contracts were more visible compared to those who did not use them, controlling for seniority and co-authorship. Nonetheless, providers and receivers could not be differentiated in terms of visibility but by research sector and co-authorship. Being a user of these contracts might, to some extent, be the reflection of systematic differences in the stratification of science based on visibility.

Keywords: Bibliometrics; Research material; Scientific reputation; *h*-Index; Biotechnology; Material transfer agreement

1. Introduction

Industry, government and academia have their own specific expectations regarding *compensation* for the help they provide when transferring research materials. In this paper, the term ‘industry’ designates biotechnology companies that carry out research. The term ‘government’ denotes public research institutes that do not perform teaching activities. The term ‘academia’ refers to universities. A broad definition of research materials includes cell lines, monoclonal antibodies, reagents, animal models, combinatorial chemistry libraries, clones and cloning tools, databases and software (under some circumstances). As material transfer agreements (MTAs) are used for the supply of research materials between laboratories (Rodriguez, 2005), the provider could expect a recompense in exchange.

This compensation could vary depending on the provider’s institutional sector (academia, industry or government). In academia, the desired recompense for providing the research material may range from acknowledgment or reference in a publication to co-authorship of articles or co-assignment of patents made with the aid of the supplied material, depending on the purpose of the material provider. In industry, the provider could ask the receiver to disclose the results derived from the material or any other research findings that could be of interest. The rationale of the existence of governmental laboratories differs from academic ones, their expectations are more related to national interests.

* Corresponding author.
E-mail address: victor.rodriguez@econ.kuleuven.be (V. Rodriguez).

1751-1577/$ – see front matter
doi:10.1016/j.joi.2007.10.003

Being a provider or receiver might be the reflection of differences between scientific leaders and followers in the social structure of science. The role of scientific leader may be acquired by the creation of the research material and the subsequent requests for it by the scientific community. The relationship between material owners and would-be users could be catalogued as a trade-off of expectations. The provider expects to be recompensed by the receiver for allowing the use of the material and the receiver expects to gain access to the material to carry out the research project. In other words, there is a balanced sense of reciprocity between the two parties: a gift and a counter-gift.

Scientists tend to cite contributions that are useful for their own research. In the gift-swap model of scientific exchange (Hagstrom, 1965), individual scientists contribute their findings to the scientific community and in return can expect to receive various forms of recognition from their peers. Greater visibility is one of them.

Due to the role of scientific leaders, the visibility of the providers could differ from that of receivers after using MTAs because providers may monopolise the research material that is requested by various researchers. Receivers might recompense the provider via citations. This practice might be used to hypothesise the supposedly greater visibility the providers. Methodologically, the notion of visibility can be made operational through the *h*-index, developed by Hirsch (2005), which is based on the citations each article of an author gets. In the same vein, a citations count is another way in which visibility can be operationalised.

A review of recent empirical literature shows that the concern as to whether MTAs affect the progress of science (Rodriguez, 2007a; Rodriguez, 2008; Rodriguez & Debackere, 2007) has been translated into testable hypotheses for life sciences (Campbell et al., 2002; Rodriguez, Janssens, Debackere, & De Moor, 2007a,b; Walsh, Arora, & Cohen, 2003; Walsh, Cho, & Cohen, 2005; Walsh, Cohen, & Cho, 2007). A recent study synthesised that biotechnology itself adapted perfectly to the commercialisation wave (Rodriguez, 2007b). The phenomenon of disclosures and industrial relations has been discussed extensively in previously published works. For instance, relevant references are made in co-operative relationships between firms and universities (Mora-Valentin, 2002), commercialisation of biotechnology (Enzing, van der Giessen, & Kern, 2004) and trans-disciplinarity (Adam, Carrier, & Wilholt, 2006).

Substantial research effort has been devoted to studies on author citations (Braun & Glänzel, 2000; Garfield, 1963; Glänzel, 2000; Kostoff, 1998; Leydesdorff, 1998; Moed, 2000; Peritz, 1992), stratification system within the science institution (Allison, Long, & Krauze, 1982; Cole & Cole, 1967, 1974; Evans, 2005), Nobel laureates (Crawford, 1998; Garfield & Welljams-Dorof, 1992; Zuckerman, 1967, 1996) and star scientists (Zucker & Darby, 1996, 2001). It is to be pointed out, however, that there has been relatively little analysis of the visibility acquired through the exchange of research materials.

In this paper, we analyse the relationship between MTAs and visibility by assessing whether MTAs might have had an impact on the visibility of individual researchers by taking into account the control variables seniority and co-authorship. Visibility is thereby operationalised on the basis of a bibliometric approach. The first empirical strategy is a one-way analysis of variance to test the null hypothesis that the visibility of a typical researcher who used MTAs is equal to that of the one who did not. The second empirical strategy aims at detecting the variables that discriminated most effectively between MTA providers and MTA receivers.

The paper is organised as follows. The next section begins with the sectoral recompense of researchers. Then, the concept of visibility and ways to operationalise it are laid out. Next, data and methodology are presented, followed by the results. Finally, some concluding remarks are made.

2. Recompense in government, industry and academia

The labels of basic and applied research are changing with regard to biosciences and biotechnologies. A priori definitions of polar ideal types are vague, imprecise and awkward for empirical operationalisation (Callon, 1997; Kidd, 1965; Latour, 1993). The commercial development of basic research discoveries and commercial interest in academic research in its early stages speed up the applicability of basic research. Thus, the distinction between basic and applied research is currently difficult to maintain. Nonetheless, the institutional setting where this research is conducted and the nature of the compensation for exchanging research material is much easier to distinguish. Researchers from industry, government and academia could expect to be recompensed differently for research materials they provide to extramural colleagues.

Researchers in government comprise a significant component of the same scientific labour force as that of scientists in academia. Even though the reason or purpose of the existence of governmental laboratories differs from academic ones, they have had some common educative functions. These arise from their research activities that involve collaboration with the higher education sector and include the supervision of students, lecturing in universities and training research staff. This role of providing future gatekeepers and linking individuals into wider technological communities is significant in facilitating technology transfer (Debackere & Rappa, 1994).

Industrial researchers make situational adjustments to their other professional orientations (e.g. communality and autonomy) and they must be taken into account when referring to their organisational affiliation (Barnes, 1971). In particular, many science graduates are trained in the pure science ethos but quickly set it aside after a period in an industrial laboratory (Avery, 1960). Most industrial scientists accept the framework of industrial science, do not object to commercial restrictions on publications and are not publishing to try to develop professional reputations beyond their home organisations. They are satisfied with organisational status and recognition, which is accomplished by developing processes and products that are patentable (Ellis, 1972). As the industrial research laboratory is subject to the controls emanating from the business goals of the organisation, a different orientation from academia and government tends to be inculcated (Bailyn, 1985).

In academia, priority of discovery is the basis for a scientist's reputation and this prestige for contributions to the literature is the fundamental recompense in the community of scientists complying with Mertonian norms (Dasgupta & David, 1994). The race for priority serves two very important purposes: it hastens discoveries and it accelerates their subsequent disclosure through publications (Merton, 1973). Traditionally, scientists are socialized in this norm of openness during their doctoral studies, where the importance of advancing the body of knowledge through publishing articles is always emphasised. Nonetheless, many doctoral students in biology, chemistry and other biosciences find themselves working for companies that may not share this desire for openness (McMillan & Deeds, 1998).

The post-academic mode of science, fostered by the Bayh–Dole Act and similar mirroring regimes around the world, introduced a market model for government-funded research based on intellectual property rights and financial incentives (viz. royalty or equity). Lawyers and economists often assume that the alternative to exclusive rights is secrecy, while sociologists tend to equate exclusive rights with secrecy and take the stance that the alternative is open access. Secrecy and exclusive rights tend to be equated because in most cases the only way to preserve the exclusivity of an idea or discovery is to keep it secret. When patent protection extends into fields that are of interest to governmental, industrial and academic researchers, neither of these assumptions about the relationship between exclusive rights and secrecy holds true (Eisenberg, 1989). Finally, the *triple helix* model focuses on the future location of research in academia–industry–government relations and how an overlay of communications operates on the underlying institutions (Leydesdorff & Etzkowitz, 1998).

3. Visibility

Historically, research materials were freely exchanged, without formal arrangements. Academic scientists participated in a gift economy, a system of material exchange premised on reciprocity, reputation and responsibility. Research materials were made available in exchange for credit. Academic scientists were supposed to transfer research materials for prestige and the academic system of exchange was supposed to be based on the reciprocity and personalized exchange of gifts (Mauss, 1967).

Through the quality and generosity of donations, receiving and repaying, academic scientists demonstrated authority. For gaining reputation, the system of obligations was crucial. As a marker of obligations, gifts remain bound up with the donor, such that the donor's identity worked to animate the gift. Research materials were sent out into the world so as to reward the donor accordingly. One transferred, research material could garner recognition and status for the donor and the more recognition the gift received, the greater the value of the original and subsequent gifts (Hagstrom, 1965).

Although a large majority of scientific publications (viz. articles, letters, notes and reviews) are never cited, some are referred to with great intensity (Aksnes & Siversten, 2004). When an article is highly cited, even more people become aware of it and its visibility augments the chances of increasing the number of citations (Aksnes, 2003). In fact, high citation scores are the results of many researchers' decisions to cite a particular article.

The concept of visibility is usually operationalised through citation counts to gauge the overall impact of a scientist's research output on the scientific community and is generally held to measure quality (Cole & Cole, 1967). An average citation per paper gives an indication of the aggregate level of influence, while highly cited papers reflect the more important contributions in any given field.

The evidence that citation signals quality is indicated by the literature. Garfield (1970) studied the work of Nobel Prize winners and found that they were among the top 0.1% most cited authors. Zuckerman (1996) found that publication counts, citation counts and peer ratings were inter-correlated. Finkenstaedt and Fries (1978) found that citation counts correlate often with other measures of quality such as employment in prestigious universities, listing in important bibliographies of scientists and scientific awards as well as recognition from colleagues. Research on citation has shown highly skewed distributions, with most articles having few citations, while a handful of articles has exceedingly large numbers of citations.

Apart from citation counts, visibility can also be operationalised using the *h*-index. Scientists have an *h*-index equals to h if h of their N_p publications have at least h citations each, and the rest $(N_p - h)$ have fewer than h citations each. Visibility may continue to increase over time, even after the scientist has stopped publishing (Hirsch, 2005). The *h*-index is the highest number of publications a scientist has produced, published over n years, which have each received at least that number of citations. For instance, someone with an *h*-index of 50 has published 50 articles that have each had at least 50 citations (Ball, 2005). In another example provided by Van Raan (2006), a scientist has 21 publications, 20 of which are cited 20 times, and the 21st is cited 21 times, there are 20 publications – including the one with 21 citations – having at least 20 citations, and the remaining publications has no more than 20 citations. Therefore, the scientist's *h*-index equals 20.

Recently, more detailed examination has refined the picture of visibility. In biosciences and biotechnologies, *h*-indices tend to be higher than those in physics (Hirsch, 2005), that is to say they are discipline based. Bornmann and Daniel (2005) found that on average the *h*-index for successful applicants for post-doctoral fellowships was consistently higher than that for non-successful applicants. Van Raan (2006), dealing with research groups rather than individual scientists, showed that the *h*-index and several standard bibliometric indicators both correlate in a quite comparable way with peer judgements. Rousseau (2007) verified that the *h*-index is resilient to missing articles and citations. Burrell (2007) conjectured that the *h*-index is, according to a simple stochastic model, linear in career length, log publication rate and log citation rate, at least for moderate citation rates.

Visibility studies are closely related to the analysis of elite researchers. These *stars* are eminent scientists who have been accorded recognition in their discipline, who are visible in their community, who possess great talent, who are highly productive achievers of excellence, and who usually choose careers that give them a great deal of freedom and personal independence (Merton, 1968). In particular, they are individuals who are involved in many aspects of the practice of science. Once they become members of distinguished scientific organisations (e.g. the Royal Society), elite researchers rise quickly to positions of prominence and are called upon to participate in many activities (i.e. hold office, preside over meetings, chair special interest groups, etc.). They are intimately involved in the network communication system of their profession by serving as editors and referees of journals (Crane, 1967). Their expertise attracts many requests to share their knowledge by acting as guest lecturers or keynote speakers. All of these dimensions of academic involvement are a form of service of a scientifically useful nature (Shilling & Bernard, 1964).

4. Data

Several steps have been carried out to build the final sample of individual researchers whose visibility we will measure to test our hypotheses. Preliminarily, biotechnology publications have been selected from the core biotechnology database created by Glänzel et al. (2003) for Belgian disclosures between 1992 and 2000.

It is worth noting that our preliminary dataset included patents applied for at the European Patent Office but none of the sampled patents in industry and government had been cited up to 2004. The absence of forward citation could have occurred for two reasons. Either, the patented technology might have been so applied that it was located in the frontier of knowledge, or other organisations might not have been able to absorb the patented technology. Thus, our preliminary data gathering was restricted to four types of documents, namely: articles, letters, notes and reviews, because they have a reference list or bibliography.

Furthermore, the preliminary publications come from industry, government and academia. Specifically, the publications were retrieved from the following subject categories of Thomson Scientific's *Web of Science*: biochemical research methods, biochemistry and molecular biology, biophysics, biotechnology and applied microbiology, cell biology, developmental biology, genetics and heredity, microbiology and plant sciences.

For identifying MTA-related publications in our preliminary dataset, a survey was done. Thus, representatives from the institutional affiliations distinguished whether or not their publications had used materials received through MTAs. After carrying out this preliminary distinction, the publications that used MTAs were taken into account for identifying MTA year and authors in the final sample that was built to carry out our study.

Fig. 1. Publication timeline of an author that used an MTA.

The year of MTA-related publication was used as a proxy for MTA year because, in fact, we were not able to determine when the MTA was signed due to confidentiality clauses inherent of this type of contract. Consequently, MTA year refers to the publication year of the research project that handled external materials formalised in an MTA. It is of interest to note that a content analysis of representative MTAs in the survey was not possible because of the confidentiality clauses. This is why, it cannot be determined how many MTAs explicitly required that receivers should have acknowledged providers in relevant publications, or whether receivers should have not mentioned providers at all, irrespective of reason.

Receivers were listed from the set of MTA-related publications as they appear in the by-line. The receivers identified the provider either in the acknowledgments section, in the main text or in the reference list of the publication. The role of supplier was thus identifiable in the scientific publication. In one case, the provider was not indicated as such in the publication but appeared as a co-author.

As we examine the visibility of individual researchers who used MTAs, we see that the length of a scientist's career is calculated from the year of the first publication of this author recorded in the Web of Science up to 2004 inclusive. In point of fact, we backtracked an author's publications up to the year of his or her first publication. In other words, the production of an author comprises the publications recorded in the Web of Science during his or her career up to 2004.

Graphically, the timeline of events per author is shown as Fig. 1. Pre-MTA refers to the period of time lapsed between the year of first publication done and the proxied MTA year inclusive. Post-MTA denotes a period of time lapsed between the proxied MTA year up to 2004 inclusive. The length of the period of time represents researcher's seniority. Then, publications were allotted before and after a MTA year. A control group was also needed. As these researchers did not use MTAs, no distinction among variables before and after MTA was needed.

Then, the final dataset was compiled by retrieving information concerning publications of researchers in the treatment and control group in all languages in journals recorded in the three databases of the Web of Science (viz. natural sciences, social sciences, arts and humanities). All publications for each author were collected up to 2004 inclusive by using the four steps refinement feature – last name, first initial, middle initial; supplementary initials; research field; institutional affiliation – upgraded by the Web of Science in July 2006 to reduce the homonym bias. The total citation window ran from the year of publication up to the end of 2004. Our study involved a total of 5194 publications and 68,874 citations according to the *Science Citation Index*.

Computationally, we calculated h-indices for each researcher of the treatment and control group, i.e. the MTA and non-MTA group respectively. Despite the fact that some researchers in the sample had retired by 2004, the h-index remains useful as a measure of cumulative achievement.

Only for the treatment group, i.e. those researchers that used MTAs, we computed also h-indices before and after the MTA year. To do so, publications were counted: (i) from the first year that the researcher has published up to the end of the proxied MTA year for the pre-MTA period; (ii) from the proxied MTA year to end of 2004 for the post-MTA period.

While other studies used a fixed citation window (i.e. a shorter period of time after the publication year to measure recent performance), we counted citations: (i) from the year of publication to the end of the proxied MTA year for the pre-MTA period; (ii) from the proxied MTA year to end of 2004 for the post-MTA period.

In the treatment group or MTA group, all documents were multi-authored. Thus, scientists with high h-indices achieved mostly through publications with many co-authors would be treated overly favourably by their h-indices. As we found large differences in the number of co-authors for each paper in our final dataset, we used a factor Ω to capture co-authorship in order to compare different individuals. This factor can be specified as follows:

$$\Omega = \frac{1}{P_i} \sum \frac{1}{A_j},$$

where P_i represents total number of publications of each author i and A_i stands for the number of authors of each paper j of author i. The absence of co-authors is expressed as $\Omega = 1$. The total inverse omega was then computed before and after the MTA year.

Table 1
Group statistics between MTA and non-MTA group

	MTA	N	Mean	S.D.	S.E.M.
c	1	70	983.91	1420.679	169.804
	0	69	416.38	855.337	102.970
Ω	1	70	0.223132	0.0915903	0.0109471
	0	69	0.173786	0.1218933	0.0146742
h	1	70	13.14	9.993	1.194
	0	69	6.59	7.009	0.844
t	1	70	18.51	10.796	1.290
	0	69	12.16	5.677	0.683

The variables for the sampled researchers (MTA and non-MTA group) were grouped according to certain features, such as the use of an MTA in the period 1992–2000, the role-played in the MTA and the sector of activity when they used an MTA. Group membership was assumed to be mutually exclusive (i.e. no case belongs to more than one group) and collectively exhaustive (i.e. all cases are members of a group). Regarding the coding scheme for the qualitative data, we dichotomized the levels such that $k-1$ zero–one dummy variables were created for each variable having k-levels instead of assigning numerical values to the levels of variables. When a researcher had more than one institutional affiliation in the publication we chose the first one listed by the author in order to obtain exclusive sectoral dedication.

In our group variables, 'MTA' is a dummy that equals 1 if the researcher used an MTA in the period 1992–2000, otherwise it equals 0; 'provider' is a dummy variable that equals 1 if the researcher is a provider, otherwise it equals 0; 'academia' is a dummy variable that equals 1 if the researcher is in academia, otherwise it equals 0; 'government' is a dummy variable that equals 1 if the researcher is in government, otherwise it equals 0. It should be pointed out that it is not necessary to include a dummy variable referring to 'industry' because we have three institutional sectors and only two dummies are needed: 'academia' and 'government'. Consequently, the group 'industry' is often called the omitted group or reference group taken into account by the 0 in 'academia' or 'government'.

The quantitative variables employed in the analysis were: c for all citations obtained by each sampled researcher up to 2004; Ω for the omega factor of each researcher up to 2004; h for the h-index scored by each sampled researcher up to 2004; t for the seniority of each sampled researcher. The descriptive statistics are shown in Table 1.

5. Methodology

As the overall aim is to assess whether MTAs might have had an impact on visibility of researchers, the construct visibility was operationalised using h-indices and citations counts. The first empirical strategy was to carry out a one-way analysis of variance to test the null hypothesis that the visibility of the typical researcher that used MTAs (treatment) is equal to that of the one who did not (control).

The second last empirical strategy was to detect which variables discriminated best among MTA providers and MTA receivers using the dummy variables 'academia' and 'government', and the following quantitative variables: 't pre-MTA' for the time length (in years) up to the MTA year inclusive; 't post-MTA' for the time length (in years) after the MTA year up to 2004; '$1/\Omega$ pre-MTA' for co-authorship up to the MTA year inclusive; '$1/\Omega$ post-MTA' for co-authorship after the MTA year up to 2004; 'h pre-MTA' for the h-index up to the MTA year inclusive; 'h post-MTA' for the h-index after the MTA year up to 2004; 'c pre-MTA' for the citations up to the MTA year inclusive; 'c post-MTA' for the citations after the MTA year up to 2004. The descriptive statistics are shown in Table 2.

6. Results

First, the one-way analysis of variance tested the null hypothesis that the visibility of the typical researcher who used MTA is equal to that of the one who did not. As the results were found to be significant (Table 3) using the above procedure, it implies that the means differ more than would be expected by chance alone. In terms of the above

Table 2
Group statistics

Provider	Variables	Mean	S.D.	N
0	Academia	0.568966	0.4995461	58
	Government	0.155172	0.3652312	58
	t pre-MTA	11.206897	9.1895414	58
	t post-MTA	6.017241	3.6152279	58
	$1/\Omega$ pre-MTA	4.746461	2.0028993	58
	$1/\Omega$ post-MTA	5.083801	2.0851841	58
	h pre-MTA	6.965517	7.8337227	58
	h post-MTA	7.275862	6.6088540	58
	c pre-MTA	685.120690	1203.8892395	58
	c post-MTA	368.793103	564.9490199	58
1	Academia	0.333333	0.4923660	12
	Government	0.666667	0.4923660	12
	t pre-MTA	17.166667	9.0937874	12
	t post-MTA	7.583333	2.3143164	12
	$1/\Omega$ pre-MTA	2.881189	1.4832684	12
	$1/\Omega$ post-MTA	5.228183	1.8923709	12
	h pre-MTA	6.083333	5.7597085	12
	h post-MTA	7.583333	6.6532061	12
	c pre-MTA	329.166667	391.2397157	12
	c post-MTA	316.416667	514.7335513	12

technique, it would mean that MTA-users were more visible (in terms of h and c) than non-MTA-users, controlling for seniority and co-authorship. Having the same seniority, typical researchers who used MTAs were more visible in the majority of cases. Having similar Ω structure, typical researchers who used MTAs were more visible in the majority of cases.

The results of the discriminant analysis are shown in Table 4. Both the dummy ‘government’ and the variable ‘$1/\Omega$ pre-MTA’ were found to be significant discriminant factors between MTA providers and MTA receivers.

All in all, in the sample those researchers involved with MTAs were more visible compared to those who did not use MTAs. Nonetheless, MTA providers and MTA receivers could not be differentiated in terms of visibility but by research sector and co-authorship before MTA. An interpretation and explanation of these results follows in the next section.

Table 3
Analysis of variance

MTA and non-MTA-users	Sum of squares	d.f.	Mean square	F	Significance
h					
Between groups	1490.172	1	1490.172	19.954	0.000
Within groups	10231.209	137	74.680		
Total	11721.381	138			
c					
Between groups	11192353.448	1	11192353.448	8.112	0.005
Within groups	189013597.689	137	1379661.297		
Total	200205951.137	138			
t					
Between groups	1403.282	1	1403.282	18.788	0.000
Within groups	10232.732	137	74.691		
Total	11636.014	138			
Ω					
Between groups	0.085	1	0.085	7.296	0.008
Within groups	1.589	137	0.012		
Total	1.674	138			

Table 4
Step-wise statistics for dummy variables: variable entered (maximum number of steps is 20; minimum partial F to enter is 3.84; maximum partial F to remove is 2.71; F-level, tolerance, or VIN insufficient for further computation)

Step	Entered	Wilks' lambda							
		Statistic	d.f.1	d.f.2	d.f.3	Exact F			
						Statistic	d.f.1	d.f.2	Significance
1	Government	0.798	1	1	68.000	17.224	1	68.000	0.000
2	$1/\Omega$ pre-MTA	0.738	2	1	68.000	11.895	2	67.000	0.000

At each step, the variable that minimizes the overall Wilks' lambda is entered.

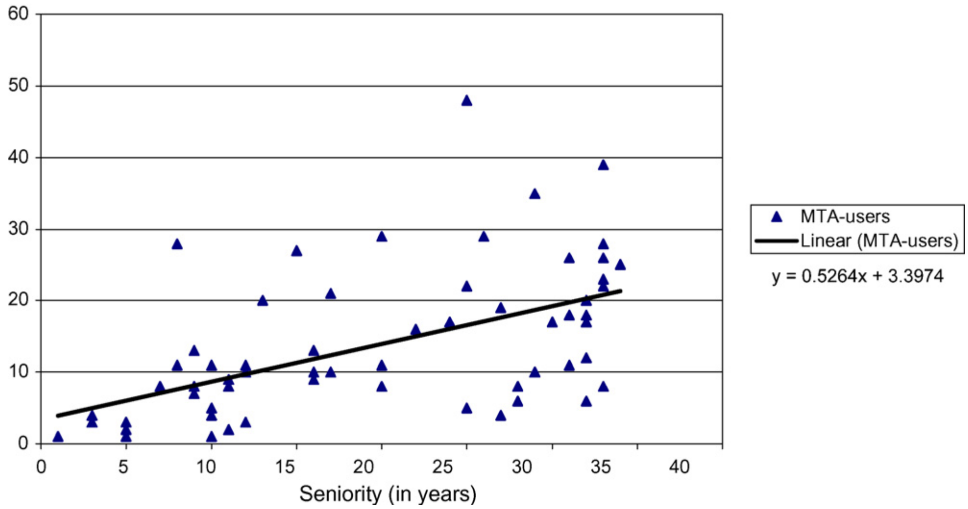

Fig. 2. Plot visibility in terms of seniority for MTA-users.

7. Discussion

As seniority and co-authorship have a positive relationship with visibility, their effects have been controlled by comparing the visibility of researchers of same t or similar *inverse omega*. In this respect, the visibility h in terms of seniority t for MTA-users has an intercept of 3.3974 and a slope of 0.5264 (as shown in Fig. 2) and for non-MTA-users the intercept is −2.4645 and the slope is 0.7450 (as shown in Fig. 3). The visibility h in terms of inverse omega, for MTA-users has an intercept of 24.1553 and a slope of −2.1601 and for non-MTA-users the intercept is 7.9004 and the slope is −0.1535.

If we compare 'h pre-MTA' in terms of 't pre-MTA', 'h post-MTA' in terms of 't post-MTA', h of those who did not used MTAs in terms of t, we obtain an intercept of 0.4589 and a slope of 0.5197 for the pre-MTA visibility, an intercept of −0.2711 and a slope of 1.2090 for the post-MTA visibility, and an intercept of −2.4645 and a slope of 0.7450 for the non-MTA visibility. Accordingly, the slope of the curve 'h post-MTA' for the researchers who used MTAs was steeper vis-à-vis that of 'h pre-MTA' for the same group of researchers.

In an effort to determine if the sample in analysis of variance was biased, we have chosen to perform the two-sample Kolmogorov–Smirnov test (Table 5). This is a general test that detects differences in both the locations (or central tendencies) and the shapes of distributions. The probability of the Kolmogorov–Smirnov Z statistic falls well below 0.05. By that standard, the distributions are significantly different from each other. From Table 5, we can conclude that the significance of the difference between the two distributions is due only to their different locations on the scale, and not to any differences in shape.

For assessing the validity of the discriminant analysis, the total sample was randomly divided into an analysis sample consisting of around 70% of the entire sample (50 observations) and a holdout sample of around 30% (20 observations). Since the holdout sample was small, it is possible that there might be a good deal of variability simply due to the reduced

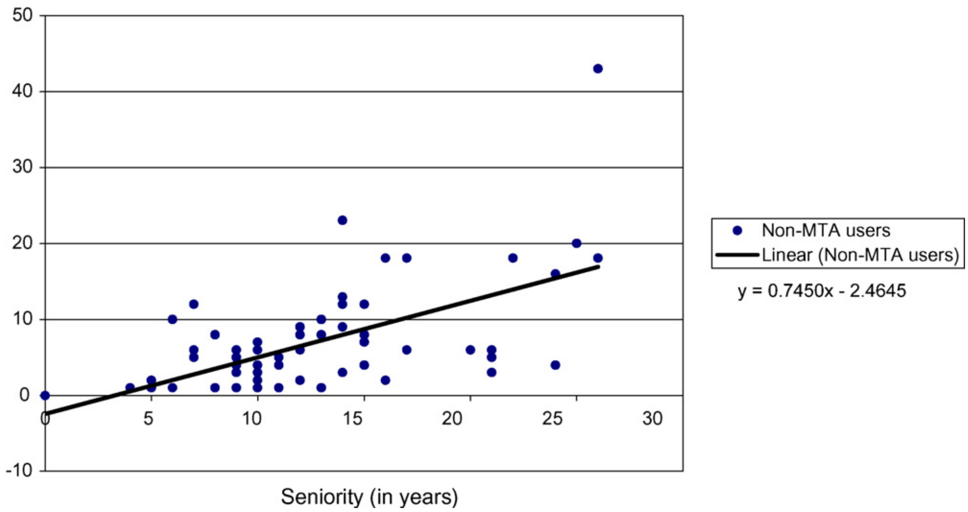

Fig. 3. Plot visibility in terms of seniority for non-MTA-users.

Table 5
Two-sample Kolmogorov–Smirnov test statistics[a]

	c	t	Ω	h
Most extreme differences				
Absolute	0.297	0.357	1.000	0.410
Positive	0.085	0.057	1.000	0.000
Negative	−0.297	−0.357	0.000	−0.410
Kolmogorov–Smirnov Z	1.753	2.102	5.895	2.416
Asymptotic significance (two-tailed)	0.004	0.000	0.000	0.000

[a] Grouping variable: MTA.

number of observations. Therefore, a more conservative test was performed in which the discriminant coefficients were derived using all of the available sample observations (analysis plus hold-out samples).

In Table 6, the classification function coefficients based on absolute magnitudes for both the analysis and total samples are given. It is worth noting that there are no sign reversals when the same variables were entered by the stepwise. The tabulation clearly indicates that for the dummy variables 'provider' there is no discrepancy in the number of discriminant factors between the analysis and total sample. Accordingly, those researchers that were affiliated to governmental or industrial research laboratories might be differentiated as providers or receivers. In any case, co-authorship before MTAs also worked well as a discriminating factor between providers and receivers.

It is worthy pointing out that the t-test deals with the problems associated with inference based on small samples. An extension of the two-sample t-test is the one-way analysis of variance for a quantitative dependent variable by a single factor (independent) variable. Analysis of variance is used to test the hypothesis that several means are equal. That said, it should be clear that, if the means for a variable are significantly different in different groups, then we could say that this variable discriminates between the groups. In other words, in addition to determining that differences

Table 6
Classification function coefficients

Group	Discriminant	Analysis sample (ca. 70%)		Complete sample (100%)	
		0	1	0	1
Provider	Government	1.641	4.149	1.708	4.869
	$1/\Omega$ pre-MTA	1.403	0.943	1.312	0.877

Fisher's linear discriminant functions.

exist among the means, it is interesting also to know which means differ from each other. Therefore the basic idea underlying discriminant function analysis is to determine whether groups differ with regard to the mean of a variable. Discriminant analysis may act as a univariate regression and is also related to analysis of variance (Wesolowsky, 1976). The relationship to analysis of variance is such that discriminant analysis may be considered as a multivariate version of analysis of variance.

Upon becoming involved in MTAs, it was hypothesised at the outset that the visibility of providers would be higher than that of receivers. Being a provider was deemed to be a leverage factor for acquiring scientific leadership and gaining greater visibility than a receiver simply because the provider could be recompensed with more citations. That was not the case. The creation of research materials that are requested by peers did not generate significant differences in visibility in our sample. We could not reject the null hypothesis that the mean *h*-index or citation after MTA was the same between providers and receivers. For that reason, we looked for other factors that could characterise the role of provider and receiver through a discriminant analysis.

Some studies have looked beyond researchers' organisational affiliation and have shown that other orientations come into play, in interaction with the organisational setting. Cotgrove and Box (1970) revealed that the interplay between scientific roles and identities could be the basis for the development of a topology of scientists that is not tied to the organisational setting.

8. Concluding remarks

A crucial challenge in the literature of science and technology studies is to detect relationships between MTA involvement and researchers' visibility. In this paper, this issue was tackled by exploiting a natural experiment. When carrying out a research project, some materials may not have in-house availability. Thus, investigators have resort to external providers for conducting their research project. To that end, the exchange is formalised through MTAs. In this context, the provider supplied the material; receivers used it and published their results.

Bibliometric data of researchers involved in MTAs was collected and a control group of researchers that did not use them was created. In our study, we were conscious that MTA year is antecedent to the publication year of research results. Usually, there is a difference of more than a year between the MTA year and the publication year. The problem was that we were not able to determine the precise date of the MTA signature due to confidentiality clauses included in the contract itself. That is why we proxied a MTA year as the publication year of research results which used external material received through MTAs.

Seniority and co-authorship have a positive relationship with visibility. In the sample, researchers that used MTAs were more visible compared to those who did not use MTAs controlling for seniority and co-authorship. Being an MTA-user might, to some extent, be the reflection of systematic differences in the stratification of science based on visibility. So, the more visible researchers tended to get involved in MTAs, i.e. '*h* pre-MTA' equals 6.81 and '*h* non-MTA' equals 6.59. Consequently, MTAs might not be the cause of having a higher visibility but a higher visibility might have been a driver for being involved in MTAs.

Do material owners attract more requests and thereby do they receive more citations? MTA providers and MTA receivers could not be distinguished in terms of visibility but could be by research sector and co-authorship before MTA. This study shows how difficult it is to discriminate between *h*-indices and other dummies, such as provider, sector, etc.

Additional remarks with implications for citation studies are worth making here. Material receivers identified the provider either in the acknowledgments section, in the main text or in the reference list of the publication. Thereby the role of supplier was identifiable in the scientific publication. In one case, the provider was not indicated as such in the publication but appeared as a co-author in the by-line. A situation only distinguishable by the authors themselves and not by bibliometricians. If academic journals follow the initiative of Yank and Rennie (1999), the roles of authors in the production of articles can be identified.

Apart from that, some providers might have asked receivers not to mention them in publications because that citation could be deemed as prior art for patent purposes. If this was the case, citation counts might not reflect visibility when receivers omit to acknowledge providers upon their requests. Only by taking these comments into account can research on visibility make unequivocal conclusions when vested interests are at stake.

This ex post-study is relevant because it shows the relationship between visibility and MTA. Indeed, those who used MTAs, regardless their role as provider of receivers, continued to be more visible than those who did not used them (first empirical strategy). This might suggest that those researchers who were more visible before using MTAs were more prone to adapt to changes in modes of science imposed by more contractual or privatised practices.

The results of this study demonstrate that the hypothesised influence on decisions to share research materials only when visibility is at stake was not found in the sample. Indeed, providers and receivers could not be distinguished in terms of visibility (second empirical strategy).

As pointed out earlier, material providers could ask their receivers to comply with some requirements to accept the exchange, from omission of acknowledgment – because there is a patent pending – to some form of explicit recognition, such as citations. This study does not aim at assessing the omission of credits. We have only focused on the relationship between material transfer agreements and researchers' visibility measured by *h*-indices or citation counts.

Acknowledgements

We would like to extend our gratitude to *Steunpunt O&O Statistieken* for providing the venue where these ideas were initially discussed and much of the work was done. We are indebted to Bart Thijs, Maria Zúñiga, and Mariëtte Du Plessis for the access to their databases on forward citation of articles; forward citations of patents; biotechnology patents and articles, respectively. We are deeply grateful to Gerard Moulin Romsée for gathering empirical literature. We received valuable observations from Georg Licht and Dirk Czarnitzky at the Workshop on Science–Industry Interaction at the *Zentrum für Europäische Wirtschaftsforschung* in Mannheim in December 2006. We would also like to thank Reinhilde Veugelers, Geertrui Van Overwalle and Geert Duysters for their helpful comments on an earlier version in a seminar held in Leuven in January 2007. We have benefited from suggestions by anonymous referees of the International Society for Scientometrics and Informetrics in January 2007 and the Journal of Informetrics in September 2007. During the edition of the manuscript, we received useful contributions from Nicholas Neill-Fraser, Jean Gilbert, Kristin Blanpain, Wan Li, Wolf Vanpaemel, Bart Ons, Tuan Bui and Tom Howes. We appreciate the assistance generously given by Rebecca Crabbé and Olivier Lescroart. We acknowledge very much the support from the KUL Research Council (GOA AMBiorics), the FWO (G.0499.04), the IWT (GBOU-McKnow-E) and the Belgian Federal Science Policy Office (IUAP P5/22).

References

Adam, M., Carrier, M., & Wilholt, T. (2006). How to serve the customer and still be truthful: Methodological characteristics of applied research. *Science and Public Policy*, *33*, 435–444.

Aksnes, D. (2003). Characteristics of highly cited papers. *Research Evaluation*, *12*, 159–170.

Aksnes, D., & Siversten, G. (2004). The effect of highly cited papers on national citation indicators. *Scientometrics*, *59*, 213–224.

Allison, P., Long, J., & Krauze, T. (1982). Cumulative advantage and inequality in science. *American Sociological Review*, *47*, 615–625.

Avery, R. (1960). Enculturation in industrial research. *Transactions on Engineering Management*, *7*, 20–24.

Bailyn, L. (1985). Autonomy in the industrial R&D lab. *Human Resource Management*, *24*, 129–146.

Ball, P. (2005). Index aims for fair ranking of scientists. *Nature*, *436*, 900.

Barnes, S. (1971). Making out in industrial research. *Science Studies*, *1*, 157–175.

Bornmann, L., & Daniel, H. (2005). Does the *h*-index for ranking of scientists really work? *Scientometrics*, *65*, 391–392.

Braun, T., & Glänzel, W. (2000). Chemistry research in Eastern Central Europe (1992–1997): Facts and figures on publication output and citation impact for 13 countries. *Scientometrics*, *49*, 187–214.

Burrell, Q. (2007). Hirsch's *h*-index: A stochastic model. *Journal of Informetrics*, *1*, 16–25.

Callon, M. (1997). Actor-network theory: The market test. In *Actor network and after workshop*. UK: Centre for Social Theory and Technology, Keele University.

Campbell, E., Clarridge, B., Gokhale, M., Birenbaum, L., Hilgartner, S., Holtzman, N., et al. (2002). Data withholding in academic genetics: Evidence from a national survey. *Journal of the American Medical Association*, *287*, 473–480.

Cole, S., & Cole, J. (1967). Scientific output and recognition: A study in the operation of the reward system in science. *American Sociological Review*, *32*, 377–390.

Cole, S., & Cole, J. (1974). Social stratification in science. *American Journal of Physics*, *42*, 923–924.

Cotgrove, S., & Box, S. (1970). *Science, industry and society*. New York, NY: Barnes and Noble.

Crane, D. (1967). The gatekeepers of science: Some factors affecting the selection of articles for scientific journals. *American Sociology Review*, *32*, 195–201.

Crawford, E. (1998). Nobel: Always the winners, never the losers. *Science*, *282*, 1256–1257.

Dasgupta, P., & David, P. (1994). Toward a new economics of science. *Research Policy*, *23*, 487–521.

Debackere, K., & Rappa, M. (1994). Technological communities and the diffusion of knowledge: A replication and validation. *R&D Management*, *24*, 355–371.

Eisenberg, R. (1989). Patents and the progress of science: Exclusive rights and experimental use. *University of Chicago Law Review*, *56*, 1017–1086.

Ellis, N. (1972). The occupation of science. In B. Barnes (Ed.), *Sociology of science*. Baltimore, MD: Penguin Books.

Enzing, C., van der Giessen, A., & Kern, S. (2004). Commercialisation of biotechnology: Do dedicated public policies matter? *Science and Public Policy*, *31*, 371–383.

Evans, J. (2005). Stratification in knowledge production: Author prestige and the influence of an American academic debate. *Poetics*, *33*, 111–133.

Finkenstaedt, T., & Fries, M. (1978). Zur Forschungsmessung in den Geisteswissenschaften. *Ad Acta*, *3*, 110–164.

Garfield, E. (1963). Citation indexes in sociological and historical research. *American Documentation*, *14*, 289–291.

Garfield, E. (1970). Citation indexing for studying science. *Nature*, *227*, 669–671.

Garfield, E., & Welljams-Dorof, A. (1992). Of Nobel class: A citation perspective on high impact research authors. *Theoretical Medicine and Bioethics*, *13*, 117–135.

Glänzel, W. (2000). Science in Scandinavia: A bibliometric approach. *Scientometrics*, *48*, 121–150.

Glänzel, W., Meyer, M., Schlemmer, B., Du Plessis, M., Thijs, B., Magerman, T., et al. (2003). *Biotechnology: An analysis based on publications and patents*. Leuven: Steunpunt O&O Statistieken.

Hagstrom, W. (1965). *The scientific community*. New York, NY: Basic Books.

Hirsch, J. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences*, *102*, 16569–16572.

Kidd, C. (1965). Basic research: Description versus definition. In N. Kaplan (Ed.), *Science and society*. Chicago, IL: Rand McNally.

Kostoff, R. (1998). The use and misuse of citation analysis in research evaluation: Comments on theories of citation. *Scientometrics*, *43*, 27–43.

Latour, B. (1993). *We have never been modern*. London, UK: Harvester Wheatsheaf.

Leydesdorff, L. (1998). Theories of citation. *Scientometrics*, *43*, 5–25.

Leydesdorff, L., & Etzkowitz, H. (1998). The triple helix as a model for innovation studies. *Science and Public Policy*, *25*, 195–203.

Mauss, M. (1967). *The gift: Forms and functions of exchange in archaic societies*. New York, NY: Norton and Co.

McMillan, G., & Deeds, D. (1998). The role of reputation in the recruitment of scientists. *R&D Management*, *28*, pp. 299–278.

Merton, R. (1968). The Matthew effect in science. *Science*, *159*, 59.

Merton, R. (1973). *The sociology of science: Theoretical and empirical investigations*. Chicago, IL: University of Chicago Press.

Moed, H. (2000). Bibliometric indicators reflect publication and management strategies. *Scientometrics*, *47*, 323–346.

Mora-Valentin, E. (2002). A theoretical review of co-operative relationships between firms and universities. *Science and Public Policy*, *29*, 37–46.

Peritz, B. (1992). On the objectives of citation analysis: Problems of theory and method. *Journal of the American Society for Information Science*, *43*, 448–451.

Rodriguez, V. (2005). Material transfer agreements: Open science vs. proprietary claims. *Nature Biotechnology*, *23*, 489–491.

Rodriguez, V. (2007a). Material transfer agreements: When technology managers collide. *BNA's Patent, Trademark and Copyright Journal*, *73*, 305–308.

Rodriguez, V. (2007b). Merton and Ziman's modes of science: The case of material transfer agreements. *Science and Public Policy*, *34*, 355–363.

Rodriguez, V. (2008). Governance of material transfer agreements. *Technology in Society*, 30, in press.

Rodriguez, V., & Debackere, K. (2007). Strategies for satisfying the need of research materials. *Les Nouvelles* September, 529–533.

Rodriguez, V., Janssens, F., Debackere, K., & De Moor, B. (2007a). Do material transfer agreements affect the choice of research agendas? The case of biotechnology in Belgium. *Scientometrics*, *71*, 239–269.

Rodriguez, V., Janssens, F., Debackere, K., & De Moor, B. (2007b). Material transfer agreements and collaborative publication activity: The case of a biotechnology network. *Research Evaluation*, *16*, 123–136.

Rousseau, R. (2007). The influence of missing publications on the Hirsch index. *Journal of Informetrics*, *1*, 2–7.

Shilling, C., & Bernard, J. (1964). *Informal communication among bioscientists*. Washington, DC: George Washington University.

Van Raan, A. (2006). Comparison of the Hirsch-index with standard bibliometric indicators and with peer judgement for 147 chemistry research groups. *Scientometrics*, *67*, 491–502.

Walsh, J., Arora, A., & Cohen, W. (2003). Research tool patenting and licensing and biomedical innovation. In W. Cohen & S. Merrill (Eds.), *Patents in the knowledge-based economy*. Washington, DC: National Academies Press.

Walsh, J., Cho, C., & Cohen, W. (2005). Patents, material transfers, and access to research inputs in biomedical research: Final report to the National Academy of Sciences' Committee Intellectual Property Rights in Genomic and Protein-Related Inventions. Chicago, IL: University of Illinois at Chicago.

Walsh, J., Cohen, W., & Cho, C. (2007). Where excludability matters: Material versus intellectual property in academic biomedical research. *Research Policy*, *36*, 1184–1203.

Wesolowsky, G. (1976). *Multiple regression and analysis of variance*. New York, NY: John Wiley & Sons.

Yank, V., & Rennie, D. (1999). Disclosure of researcher contributions: A study of original research articles in the Lancet. *Annals of Internal Medicine*, *130*, 661–670.

Zuckerman, H. (1967). Nobel laureates in science: Patterns of productivity, collaboration, and authorship. *American Sociological Review*, *32*, 391–403.

Zuckerman, H. (1996). *Scientific elite: Nobel laureates in the United States*. New Brunswick, NJ: Transaction Publishers.

Zucker, L., & Darby, M. (1996). Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry. *Proceedings of the National Academy of Sciences of the United States of America*, *93*, 12709–12716.

Zucker, L., & Darby, M. (2001). Capturing technological opportunity via Japan's star scientists: Evidence from Japanese firm's biotech patents and products. *Journal of Technology Transfer*, *26*, 37–58.