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Abstract

It is a common perception that European public-funded research fails to commercialize their discoveries, in contrast to the perceived success of their American counterparts. This resulted in policies aimed at improving the commercialization of European publicly-funded research, including the establishment of Technology Transfer Offices (TTOs). Recent surveys on the activities of these TTOs show that although European public-funded research lags behind the United States in patent applications and grants, they produce more start-ups, and have comparable results for the number of licenses executed. Steps to improve the international comparability of TTO surveys could provide useful new indicators for policy development. However, this will also require indicators for knowledge transfer through informal 'open science' methods."

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1. Introduction

Over the past decade, innovation policy in many OECD countries has stressed the need to improve the commercialization of research results from 'public science' institutions such as universities and government research institutes. Within Europe, this policy focus is partly due to a perception that Europe has failed to benefit from its substantial investments in public research, in contrast to the American experience, where university research results are believed to lie behind the creation of several globally competitive firms and blockbuster products ranging from pharmaceuticals to computer hardware and software. Another measure of American success in commercializing public science is the substantial licensing income that universities such as Stanford, Columbia, MIT and the University of Florida have earned from patenting their inventions.

The policy discussion in Europe frequently refers to a 'European Paradox' of high public expenditure on research with few visible commercial benefits. A long-standing explanation for the paradox is a failure of public science institutes in Europe to actively commercialize their discoveries (EC, 1995). The causes of this failure have been linked in policy documents to a wide range of factors, including a lack of entrepreneurial spirit among scientists, barriers to the ability of public sector scientists to move to the private sector on a temporary basis to develop their discoveries, and to poor intellectual property rights for university inventions. Alternative explanations of the European Paradox, based on differences in the commercial potential of public research conducted in Europe versus the United States (Dosi et al, 2005), have not attracted much attention in the policy community.

European governments have responded to the European Paradox by introducing policies to promote commercialization, such as university courses on entrepreneurship for future academics, and a range of other programmes to encourage technology transfer by promoting formal contractual relationships between the business sector and public science. These include subsidies for the establishment of technology transfer offices (TTOs) at universities, changes in IPR regulations to encourage universities to patent and license inventions, and requirements for universities to obtain a higher share of their research funding from the private sector (Callan and Cervantes, 2006).

To date, there are very few national or internationally comparable indicators within Europe for evaluating the success of policies to promote the commercialization of public science. Internationally comparable indicators would be particularly useful for determining if a "failure of commercialization" is the cause of the European Paradox, or if other possible factors should receive more attention.

Potential indicators of relevance to the commercialisation of research by public science institutions range from citations to the scientific literature in business patents to the economic impacts of public science in terms of employment or value-added. Economic impact indicators are the most useful of all measures, but they are difficult to obtain and generally suffer from long lag times between public investment and outcomes. Consequently, they are not very useful for assessing the short and medium term effects of policies to encourage commercialisation.

Indicators of value to policy must be capable of measuring the commercial potential of public science results or, preferably, the current use of the outputs of public science by firms. As Figure 1 illustrates, firms acquire these outputs through two main pathways: freely available "open science" accessed by reading journal articles, attending academic conferences, or informal contacts between researchers in academia and business, and through formal relationships such as contract research or licensing. With the exception of citations to scientific articles in patents (Jaffe et al, 1993; Malo and Geuna, 2000)[2], the use of open science by firms to develop innovations rarely leaves a visible trace that can be readily identified and measured. Innovation surveys, such as the CIS in Europe, obtain data on the subjective value of public science to firms, but do not separate access to research findings through open science from access through formal relationships.

Formal relationships between firms and public science leave visible traces such as licensing or contract agreements that are more easily measured than open science. These traces are also directly relevant to current policies to encourage academic entrepreneurship and to permit public science institutes to obtain intellectual property rights (IPR) for discoveries with commercial potential. Another advantage is that indicators for the commercial potential of public science discoveries (invention disclosures and patenting), plus indicators for the use of public science outputs by firms (licensing and start-up establishments), can be obtained from a comparatively small number of technology transfer offices (TTOs) that serve public science institutions, rather than needing to survey a large number of firms about their use of the results of public science[3].

Insert figure 1 here.

Data on the commercialization of public science have been collected on a consistent basis from the 1990s for two countries, the United States and Canada. The Association of University Technology Managers (AUTM) has collected data on American TTOs since 1991 and on an annual basis since 1996, with the most recent results available for fiscal year 2004 (AUTM,

[2] This method is not entirely accurate because the cited research is often included by the patent examiner rather than by the patent applicant. In addition, a cited paper can be included to build a patent claim, without the cited research contributing to the invention.

2005). Statistics Canada first surveyed Canadian universities in 1998 and on an annual basis since 2003, with complete results available for 2004 (Read, 2005; Read, 2006). Similar data are available for Australia for 2000, 2001 and 2002 for universities and other public research institutes (Commonwealth of Australia, 2004). All of these surveys collect data on both the commercial potential of public science and the use by firms of public science outputs.

A main challenge for producing comparable indicators is to find a relevant denominator to normalize outputs from public science systems that vary enormously in size. There are two potential options, the number of researchers and the number of research expenditures, but the latter is more widely available.

Relevant data for Europe on the commercialization of public science have not been available until recently. Between 2001 and 2002, the OECD ran a multi-country survey of the technology transfer activities of universities and government research institutes in thirteen OECD countries, including eight in Europe (OECD 2002; OECD 2003), but inter-country comparisons were severely hampered by a lack of good denominators such as R&D expenditures or the number of researchers[4]. The ProTon study for fiscal year 2004 obtained relevant output data from 172 European public science institutes (Conesa et al, 2004), but did not provide results for a denominator[5].

Three recent surveys provide European data that are comparable to the AUTM, Australian and Canadian surveys. Two studies provide results for the UK (UNICO, 2005; HEFCE, 2006)[6] while the third provides results for public science institutes across Europe (Arundel and Bordoy, 2006).

In this paper we use the results of these six surveys to explore the possibilities and problems for developing internationally comparable output indicators for the commercialization of public science. The main purpose of the analysis is to illustrate what could be done, at relatively low cost, to fill an important gap in internationally comparable innovation indicators. This paper builds on preliminary work in several of these surveys to develop comparable indicators based on outputs per unit of R&D expenditures, but we provide a deeper analysis of the problems in using this approach to construct comparable indicators and suggest several solutions. We also identify additional survey questions that could provide valuable complementary information.

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[3] The distinction between commercial potential and actual use indicators is in line with the one described in Hawkins et al. (2006) between output and outcome indicators.

[4] The OECD study used the number of patents or licenses obtained per TTO, but this is unlikely to produce comparable indicators because of large differences in the number of researchers or research expenditures per public science institute.

[5] The study collected data on the number of academics per institution but did not provide these data in a usable form.

[6] In addition, a 2002 survey in the UK collected similar data for about 50 universities (Chapple et al 2005, Lockett and Wright, 2005)

2. Data sources and methodology

All surveys collect data on research expenditures and on three output indicators for the commercial potential of public science discoveries (invention disclosures, patent applications and patent grants) and on three indicators for the use of public science by firms (licenses executed, start-ups established, and gross license revenue).

In the spring of 2006, on behalf of the European ASTP, we conducted a survey of ASTP members representing public sector institutions such as universities, academic hospitals, and government or non-profit research institutes (Arundel and Bordoy, 2006). The survey response rate was 59%, with 101 replies from respondents that met the survey eligibility criteria. The respondents were based in 22 European countries.[7] Seventy-four of the eligible respondents handled the technology transfer activities of a university while 27 represented government research institutes or hospitals.

The ASTP membership represents approximately 19% of an estimated 1,000 public science institutes (universities and government research organisations combined) in the European union (Conesa et al, 2004), with survey responses available for approximately 10% of them.[8]

The United States has an estimated 2,500 universities, but many are liberal arts colleges that are unlikely to develop patentable discoveries. Limited to universities that offer science and engineering (S&E), 1,521 offer bachelors degrees in S&E, 826 offer Masters level degrees in S&E, and 345 offer Doctorate level degrees in S&E (NSF, 2006). The fiscal 2004 AUTM survey obtained responses from 33 research institutes, most of which are hospitals, and from 164 universities, or a minimum of 11% of American universities that offer science and engineering degrees (using bachelor level granting institutions).

The 197 AUTM respondents included 96 of the top 100 American research universities. According to the AUTM report, these universities accounted for 87% of federal and industry-financed research expenditures by American universities (the study does not report data for state sponsored research).

The ASTP and AUTM surveys are limited to a self-selected group of association members, whereas the other four surveys were sent to almost all members of their target population of universities, research hospitals or other public research institutes.

[7] Ten or more valid responses were received from Denmark, the Netherlands and the United Kingdom, while between five and nine valid responses were obtained from Belgium, Finland, France, Germany, Greece, and Switzerland.

[8] The ASTP survey obtained responses from 11% of all universities in seven countries where precise data on the number of universities are available: Italy, Spain, Switzerland, Norway, Portugal, the United Kingdom and the Netherlands.

The Canadian survey by Statistics Canada was sent to all members of the Association of Universities and Colleges of Canada (AUCC), which covers most universities granting a Bachelors level degree or higher, and to all known research hospitals. The survey response rate was 83% for universities and 63% for the hospitals. Results were obtained for 73 universities and 24 hospitals.

The UNICO survey for the UK appears to have been sent to all degree granting universities and major government research institutes. Although 44% of the target population did not respond, the study notes that responses were received from 47 of the top 50 UK universities in terms of research income for 2004. No final breakdown is given of the number of responses from universities versus other types of public institutions. The second UK survey (HEFCE, 2006) was only sent to universities and obtained responses from all of its target population for academic year 2003/04.

2.1 Comparability issues

Several differences in the design of the six surveys could reduce comparability. These include differences in the target populations, the questionnaires, and in the treatment of item non-response.

Target populations

International comparability will be maximized if each study receives responses from all universities, all government research institutes, and all hospitals. This would prevent possible biases that could occur by preferentially surveying or obtaining a higher response rate from research-intensive institutions that are likely to perform better on the output indicators than second or third-tier institutions. The UK HEFCE survey for 2003/04 comes closest to this goal by obtaining results for all universities, followed by the Statistics Canada results for universities. In contrast, the ASTP and AUTM survey results are likely to be biased towards institutes with above average performance, although an evaluation of the respondent institutions suggests that the ASTP survey is less biased in this respect than the AUTM survey (Arundel and Bordoy, 2006).

Another difference in the survey populations that will influence comparability is the proportion of non-university institutes in the respondent samples, which accounts for between zero and 44% of the responses. These differences matter because of variations in performance by type of institution and by country. In the ASTP sample, non-university institutes out-perform universities on patent applications, patent grants, licenses executed and license income. Performance differences by the type of institution were also found in the OECD study (OECD, 2003). In contrast, there is very little difference in the performance of universities and other

research institutes in the AUTM sample. One option is to limit the results to universities, but the relevance of this approach depends on the role of non-university institutions in national public research efforts. Only providing results for universities would fail to capture the commercialisation of public science in countries, such as Australia, that invest heavily in government research institutes. To avoid these problems, we provide results for all public science institutes combined and for universities only.

TTO coverage of activities

In countries such as Italy where patent rights are held by the inventor, the TTO may not be aware of all patents linked to a university invention. The PATVAL study, based on a patent database analysis of university patents between 1992 and 1997 in the Netherlands, the UK, Spain, Germany, France and Italy, found that well over half of patents with a university inventor were not owned by the university (Verspagen, 2006). This is one argument for tracing university patents through TTOs rather than patent databases, since TTOs can assist with the patenting of inventions that are not owned by the university. Furthermore, as European TTOs develop expertise over the time, the share of university patenting that they are aware of is likely to increase. The ASTP study asks TTOs managers to estimate the percentage of all patent applications by researchers at their affiliated institution that were handled by their office in 2006 (Arundel and Bordoy, 2006). On average, 91% of patent applications were handled by TTOs.

Variable definitions

International comparability will be affected by different definitions of both outputs and research expenditures.

A problem with the output measures is differences in how patent grants are counted. The AUTM study is limited to patents granted by the USPTO. This is likely to account for almost all patenting among the respondents, since very few patent applications are likely to be made only outside of the United States. Conversely, some patent applications by European public science institutes are only made outside of the home country (Arundel and Bordoy, 2002; OECD, 2003). For this reason, the ASTP study limits the definition of patent grants to 'technically unique patents" to prevent multiple counting of an invention that is patented in more than one jurisdiction[9]. This should improve comparability with the AUTM results.

[9] The ASTP survey asked respondents to give the number of 'technically unique patents that were granted to your institution". A technically unique patent grant was defined in the question as "for one invention only. A patent for the same invention in two or more countries is one technically unique patent". 'Logical data and outlier checks, followed up by telephone calls, showed that the definition of a patent grant in the ASTP questionnaire was misunderstood by a few respondents who gave the total number of patents that were granted in all jurisdictions, rather than the number of technically unique patents. This led to substantial over reporting of patent grants, which was corrected using information collected in the follow-up.

The number of patent grants reported in the Australian, Canadian and both UK studies does not exclude multiple counting of granted patents for the same invention. In the Canadian and UNICO studies the same invention can be counted up to three times (in the domestic country, the United States, and all other countries combined), with the data suggesting substantial multiple counting. In the Australian study, patents can be counted in both Australia and the United States. To improve comparability, we limit the counts to the region or country with the largest number of patent grants. This is the United States for Canada, the UK for the UNICO and the HEFCE studies, and Australia for the Australian study. This will result in an underestimate of the true number of patent grants for these countries.

The problem with multiple patent counts does not occur for patent applications in the AUTM, Canadian, ASTP and UNICO studies as all four surveys limit them to priority applications. However, the Australian study includes both applications in Australia and in the United States, and the HEFCE study provides the total number of patent applications and the number of those applied abroad, which does not prevent double counts. The Australian results are limited to Australian applications and the HEFCE results given below subtract the number of foreign applications from the total.

Most of the surveys count all types of license agreements and license income from all types of IPR, for example from patents, material transfer agreements, copyright, etc. Conversely the AUTM survey excludes license income from software and biological material end-user licenses under $1000 and income received from material transfer agreements.

Differences in the definition of research expenditures will have a significant impact on comparability because this statistic is the denominator for all indicators. Table 1 summarizes the different definitions in use and estimates if the definition will over or under estimate research expenditures compared to the AUTM study for the United States. An overestimate of research expenditures compared to the AUTM study will reduce the number of outputs per unit of research expenditures and therefore underestimate relative performance compared to the United States. Relative performance with the AUTM is likely to be underestimated for Europe, the HEFCE study, and for Australia, and overestimated for Canada.

Insert table 1 here.

Treatment of missing values

The comparability of standardized performance indicators based on outputs per unit of research expenditures depends on how each study manages missing values, due to a reporting institution not answering a specific output question such as the number of patents granted in the relevant year. This can be a serious issue. In the ASTP survey, the share of missing values for the output

questions varied from a low of 18% for the number of start-ups to a high of 45% for the amount of license income earned. We adjust for missing values in the calculation of standardized performance indicators for the ASTP study by excluding respondents that did not answer both the output question and the question on total research expenditures.

Missing values could have been less of a problem in the other five studies, but it is impossible to know since none provide the percentage of missing values for specific questions. The Canadian survey notes that some missing values are imputed, but provides no other details. From the count data given in the Australian study, it appears that there either were no missing values (highly unlikely) or that all missing values were imputed.

We calculate standardized performance indicators for Canada, Australia, the United States and the UK by dividing the total reported outputs by the total reported research expenditure. This will underestimate performance if the research expenditure data are complete but some respondents do not report specific outputs, or overestimate performance if the output data are complete but some expenditure data are missing. Furthermore, missing data for either research expenditures or outputs for a small number of major respondent institutions can distort the results, since the distribution of both outputs and expenditures is highly skewed in all five surveys. As an example, failing to account for missing values in the ASTP survey for Europe, for instance by using the aggregated research results in Table 2 to calculate the indicators, would increase European performance by between 25% and 72%, depending on the output variable. This highlights the importance of adequately accounting for missing data.

Insert table 2 here.

3. Results

Table 2 summarizes the main results of each of the six surveys. All financial data are given in US dollar purchasing power parities (PPP$), using OECD data on PPPs for Canada, Australia and each European country for the relevant year.

Figure 2 gives five standardized performance indicators per 100 million US PPP$ of research expenditures from five surveys that include both universities and other types of public research institutes. The results for Europe and Australia (except for patent applications are limited to respondents that reported both research expenditures and each output, whereas the other performance indicators can be calculated from the aggregated data in Table 1.

Insert figure 2 here.

As noted above, the indicators in Figure 2 are unlikely to be fully comparable, due to differences in the target population, the definition of each output and of R&D expenditures, and differences in the treatment of missing values. With this caveat, the United States is the performance leader for only one indicator, patent grants, and Canada leads on patent applications. The UK leads for the other three indicators, but we suspect that this might be due to a lack of adjustment for missing values. If the UK is excluded, Europe leads on licenses executed and start-up establishments.

A sixth performance indicator is gross annual license revenue as a percentage of total annual research expenditures. This indicator should be of particular interest in countries where a policy goal is to increase non-governmental funding of university research, since some license revenue is often returned to the institute to fund research. The share of license revenue as a percentage of reported research expenditures is 1.0% for the UK[10], 1.01% for Canada, 1.2% for Australia, 3.0% for Europe (ASTP), and 3.5% for the United States. In all cases license revenue is a meager source of funding for research, particularly since part of license revenue often goes to the inventor, while another part is used to cover TTO expenses.

Figure 3 gives results for universities only[11], which are similar to those in Figure 2 for all institutes combined[12]. The United States leads on patent grants and Canada is the performance leader for patent applications. The UK leads for invention disclosures, licenses executed[13] and, together with Europe, for start-ups. The UK performs much better for patent grants and patent applications when only universities are considered. However, this result could be due to multiple patent counts in the HEFCE study. Of note, European performance on start-ups increases from 1.6 per 100 million US PPP$ for all institutes to 2.8 for only universities. For universities, the share of license revenue as a percentage of reported research expenditures is 1.1% for the UK, 1% for Canada, 1.7% for Australia, 1.2% for Europe (ASTP), and 2.9% for the United States.

Insert figure 3 here.

Table 3 shows the relative performance of Europe, the UK, Australia and Canada compared to the AUTM results for the US (AUTM equals 1), for all institutes combined and for universities only. The only indicator for which the relative performance changes from above or below 1 is the number of licenses executed. In this case, Europe outperforms the US when all institutes are

[10] The figure of 1% is obtained from page 29 of the UNICO report. Using the aggregate data in Table 1 for the UK gives a rate of 1.6%, which suggests that the rate given in the UNICO study is adjusted for non-response for reported license revenues.
[11] The results for Canada were provided in a special tabulation by Cathy Read from Statistics Canada. Comparable data were only available for invention disclosures, patent applications and licenses executed.
[12] The results for Australia for universities only are not adjusted for missing values.
[13] According to the HEFCE report, about half of the licenses executed correspond to only two institutions.

considered but performs below the US for universities only. All countries except Australia and Canada have a higher performance than the US on start-ups. The highest relative performance to the US is also observed for this indicator: 3.1 and 2.5 for the UK for all institutes and for universities only, respectively, and 2.4 for Europe for universities only.

Insert table 3 here.

4. Discussion

The six performance indicators given above include three indicators for the potential commercialization of public science, invention disclosures, patent applications, and patent grants; and three indicators for the actual use of public science discoveries by the business sector: licenses executed, start-up establishments, and license revenue.

The value to policy of the three commercial potential indicators is not very high because they do not measure the actual uptake of public science results by firms. Their main value to policy is to determine the factors that increase the efficiency with which public institutions (primarily through their affiliated TTOs) transfer knowledge to the business sector. This requires econometric analysis of data at the level of each institution, which requires access to such data. This information is reported in the AUTM study for many of the respondents and has been extensively analyzed. Phan and Siegel (2006) provide a thorough review of this literature and find, not surprisingly, that efficient knowledge transfer depends on the characteristics of the institution, such as its research focus, the incentive structure, and organizational characteristics of the TTO[14]. Of this group, the most valuable indicator is for patent grants, particularly if combined with additional questions on licensing practices, as discussed below.

The three indicators for the use of public science by firms are inherently more valuable for policy because they are closer to measuring the commercialization of public science results[15]. A comparison of national performance on these three indicators is consequently of greater interest than a comparison of performance on patent applications or patent grants. Although subject to many problems of comparability, the Table 3 summary of the results intriguingly shows that the United States is the leader on indicators for commercial potential, particularly patent grants, but that its relative performance is more mixed for the three indicators for the use of public science by firms, particularly for the number of licenses executed and the number of start-up establishments.

[14] Based on a comparative case study of several Canadian universities, Mc. Daniel (2006) concludes that a variety of social factors are positively associated with the university's innovation record. Among other, the university receptivity to organizational innovation, the degree to which networking is encouraged and the connection to the community are cited as the most important ones.

[15] None, however, measure successful commercialization. A start-up can fail, a license can lead to nothing of value, and even license revenue can be earned without the firm bringing an invention to market or making a profit from it.

The results for the three indicators for the use of public science by firms also suggest that we need to take a much more critical look at European assumptions about the causes of the "policy paradox". Europe performs better than the United States on two of the three knowledge transfer indicators (and a close second on the third for license revenue as a share of research expenditures) for all types of public science institutes combined. The marked weakness for European universities for license revenue compared to American universities is partly due to the fact that European TTOs that serve universities are much younger than their American counterparts and have had less time to develop a licensing portfolio. In the ASTP study, older TTOs affiliated to universities earn more license income than younger TTOs[16]. Furthermore, the AUTM sample is likely to contain a higher percentage of the top performing institutes than the ASTP sample, so we would have expected the AUTM sample to have better performance than the ASTP sample on most indicators.

Some of the differences between the performance indicators for Europe and the United States could be due to differences in incentives or 'environmental' factors. The higher rate of start-up formation in Europe could be due to low royalties for academic inventors. This would provide an incentive for academics to establish a firm to exploit their discovery, as found in a study for the United States (Di Gregorio and Shane, 2003). Whatever the cause, the high rate of start-up formation in Europe suggests that European academics might not be less 'entrepreneurial" than their American counterparts.

4.1 Indicator improvement

The development of internationally comparable indicators for the commercialisation of public science will require the use of standard definitions for output variables and for denominators such as research expenditures, similar target populations and survey coverage, and greater transparency in the treatment of missing values. In addition, to solving these problems, the time causality problem also needs to be addressed. Using research expenditures and outputs for the same year implies that the outputs are directly due to the reported research expenditures. This is not likely to be the case, with many outputs due to research expenditures over several years. This can particularly apply to patent grants, which could be due to research conducted several years previously. One possibility is to construct indicators after using different lag times for research expenditures, but this might be unnecessarily complex. An alternative for the future is to average research expenditures over the previous three years. This is currently only possible for the Canadian and AUTM surveys.

[16] On average, only 13% of the ASTP respondent universities were established before 1990, compared to over half of the American TTOs. The Pearson correlation coefficient for the age of ASTP TTOs in years and PPP$ of license income per PPP$ research expenditures is 0.636 (p=0.000).

The construction of high quality comparable indicators requires a much higher coverage rate than that of the AUTM and ASTP surveys, which is likely to raise serious problems of confidentiality. Many public science institutions with poor performance could be reluctant to respond if they believe that their results will be made publicly available, possibly leading to a reduction in future funding. Yet a failure to include poor performers in surveys will bias the results and reduce their value for policy. The ASTP asked respondents if they agreed to have their results made public, with 75% refusing. This indicates that the issue of confidentiality must be taken seriously in future surveys.

4.2 Other indicators for policy

The six basic indicators given in this paper can be obtained in a one or two page survey questionnaire, based on the questionnaires used in the ASTP and UNICO studies. Since many of the national surveys are much longer, ranging from six pages for the AUTM survey to 13 pages for Canada, there should be room to collect additional data that could be used to construct internationally comparable indicators. We suggest five areas where additional internationally comparable data would be of value to policy[17].

The first area is to collect data on the number of researchers, preferably in units of time devoted to research, to provide an alternative denominator to research expenditures. Units of research time could be more comparable internationally than units of research expenditures, which are affected by how expenditures are defined and by a lack of purchasing power parity (PPP) currency equivalents for research. Furthermore, the ASTP survey found that a higher percentage of respondents could provide the number of researchers (73%) than research expenditures (61%). The higher response rate for the former could be particularly important for surveys that are not compulsory.

The second area is to collect data on *who* licenses public science inventions – firms based within the home country or abroad[18], in order to construct an indicator for the percentage of licenses that are given domestically. This would serve a basic policy interest in encouraging knowledge flows that support domestic economic activity. This question is particularly relevant for exclusive licenses, since the main justification for non-exclusive licenses is to raise funds for the public institute.

Third, the role of non-exclusive licenses is an important policy issue by itself. Although non-exclusive licenses can maximize income for the research organization, they could be less

[17] We ignore issues such as whether or not the TTO is financially self-sufficient, such as if the license and IP costs are fully covered by license revenue. This is primarily a domestic issue, where internationally comparable data are of less value.
[18] Ownership is less relevant. The key issue is if the location of the development of the licensed invention.

effective in transferring knowledge and technology to the business sector than publications that make the results freely available to all. Conversely, exclusive licenses for some inventions could be absolutely necessary for a firm to invest in developing the invention into a commercial product (Colyvas et al, 2000). The disadvantage is that inefficient use of exclusive licensing could slow down technical developments and possible social benefits. Indicators for the share of exclusive licenses, particularly by technology field, would help policy makers determine if the rate of exclusive licensing is above or below the international norm.

Fourth, there is no point in a public science institution applying for IP rights, particularly a patent, if the invention is never licensed. This will only increase costs to the institute and theoretically, albeit under the unlikely assumption that no firm will infringe the patent, prevent firms from using or further developing the patented technology. For this reason it is worthwhile to collect data on the percentage of patents that have ever been licensed in order to track changes over time and benchmark national performance.

Last, non-patented inventions account for a significant share of licensing activity, even though IP policy frequently stresses patents or the need for other strong forms of IP. The OECD study (OECD, 2003) found that approximately half of all licenses did not involve a patent, while the ASTP study found that 40% of license income in both 2004 and 2005 did not involve a patent. In order to keep the role of patents in perspective, it would be worth collecting data on the share of licenses and license income that does not involve patents.

5. Conclusions

This paper shows that it would be possible to obtain internationally comparable indicators for the commercialisation of public science with relatively simple agreement over definitions, improved survey coverage in Europe and the United States, and a few other ‘tweaks’ to current surveys. In addition, the policy relevance could be improved by adding a few additional indicators for who licenses, licensing exclusivity, the share of patents that have ever been licensed, and the share of licenses and license income from patented and non-patented inventions.

It is important not to lose sight of the fact that the visible and easily measurable output of public science institutions, such as patents and licenses, form only part of a large number of activities that can lead to commercialisation and social benefits. As noted earlier, useful knowledge can be transferred from universities to firms through open science methods such as publications, conference presentations, and informal contacts. Two surveys in the early 1990s that were able to differentiate between open science and formal methods of knowledge transfer found that both European and American firms rate open science more highly as a means of obtaining valuable knowledge from public science for their innovative activities than formal methods (Cohen et al. 2002; Arundel and Geuna, 2004). Similar results have been reported from interviews with MIT

staff, which found that patents and licensing are one of the least useful methods of knowledge transfer (Agrawal and Henderson, 2002). In Canada, federal departments and agencies have experimented with other types of indicators that might be possible to collect from TTOs, such as measures of the dissemination of research results to the public (including media coverage, web visits, non-scientific publications) and qualitative measures of how research results are used (Therrien, 2006).

There is a serious danger that only providing indicators for formal methods of transferring knowledge could encourage the policy community to promote formal methods at the expense of open science. Phan and Siegel (2006) refer to an unpublished study in the United States by Markman, Gianiodis and Phan that found that an increase in professional activities by TTOs leads to a fall in informal or 'bypassing' linkages between academics and firms. They also report that bypassing activities were "associated with more valuable discoveries and heightened entrepreneurial activities". This suggests that the policy community needs to find the optimum balance between promoting formal technology transfer methods based on IPR and licensing and the informal methods of open science. In this respect, it would be worth developing better comparable indicators for the role of open science in the innovative activities of firms. This cannot be done through surveys of TTOs, but would require a survey of firms themselves. The European Community Innovation Survey (CIS) can provide relevant indicators, such as the percentage of firms that give a high importance to knowledge obtained from public research organisations. These types of indicators would need to be given equal billing with indicators of formal knowledge transfer activities. Perhaps we might find that the cause of any "European paradox" is not due to the formal transfer of public science discoveries to firms, where European performance appears to be acceptable, but to problems with the system of open science.

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Captions / titles of the figures and tables:

Figure 1: Transfer of public science results

Table 1: Definition of research expenditures

Table 2: Aggregate data for each survey

Figure 2: All institutes: Performance indicators for the commercialization of public science: numbers per 100 million US PPP$ research expenditures

Figure 3: Universities only: Performance indicators for the commercialization of public science: numbers per 100 million US PPP$ research expenditures

Table 3: Relative performance (AUTM=1) for all institutes and universities only

Figure 1

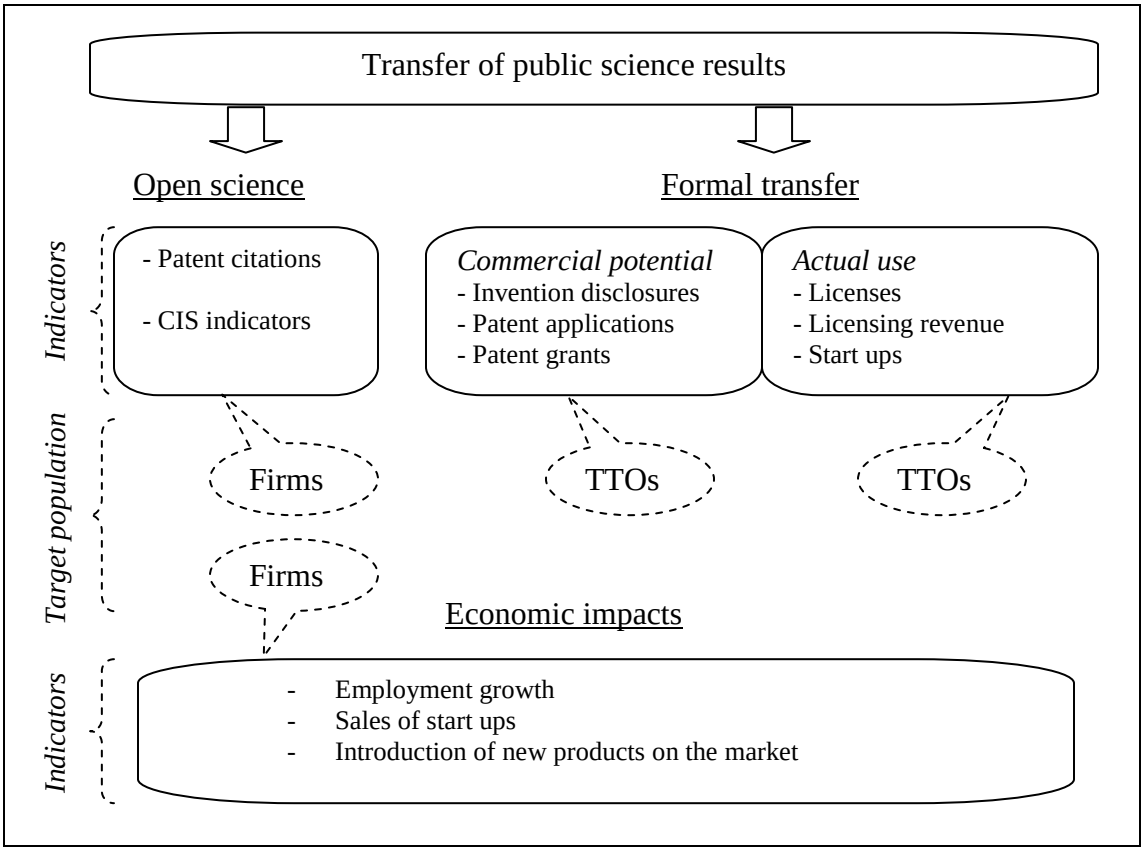

Transfer of public science results
Open science
Formal transfer
Indicators
- Patent citations
- CIS indicators
Commercial potential
- Invention disclosures
- Patent applications
- Patent grants
Actual use
- Licenses
- Licensing revenue
- Start ups
Target population
Firms
TTOs
TTOs
Firms
Economic impacts
Indicators
- Employment growth
- Sales of start ups
- Introduction of new products on the market

Table 1.

	Definition	Compared to AUTM
United States (AUTM)	Federal and industry sponsored research	-
Europe (ASTP)	Total research expenditures	Overestimate
Canada	Sponsored research at universities: conducted under contract with the government, Canadian business, Canadian organizations, foreign governments, foreign businesses, and other foreign organizations. It specifically excludes research funded by several major federal granting sources. No data for hospitals.	Underestimate
UK (UNICO)	Not given, but noted from other sources. Estimated here from reported 'research income' per £ license income.	Unknown
UK (HEFCE)	"Total research grants and contracts" including "aggregate research funding from OST research councils; UK charitable income; UK central government; local, health and hospital authorities; UK industry, commerce; public corporations; EU sources, and other overseas income".	Overestimate Also includes block grants that can be used for either teaching or research.
Australia	All research and experimental development expenditures, using the Frascati definition, including capital and labour costs.	Overestimate

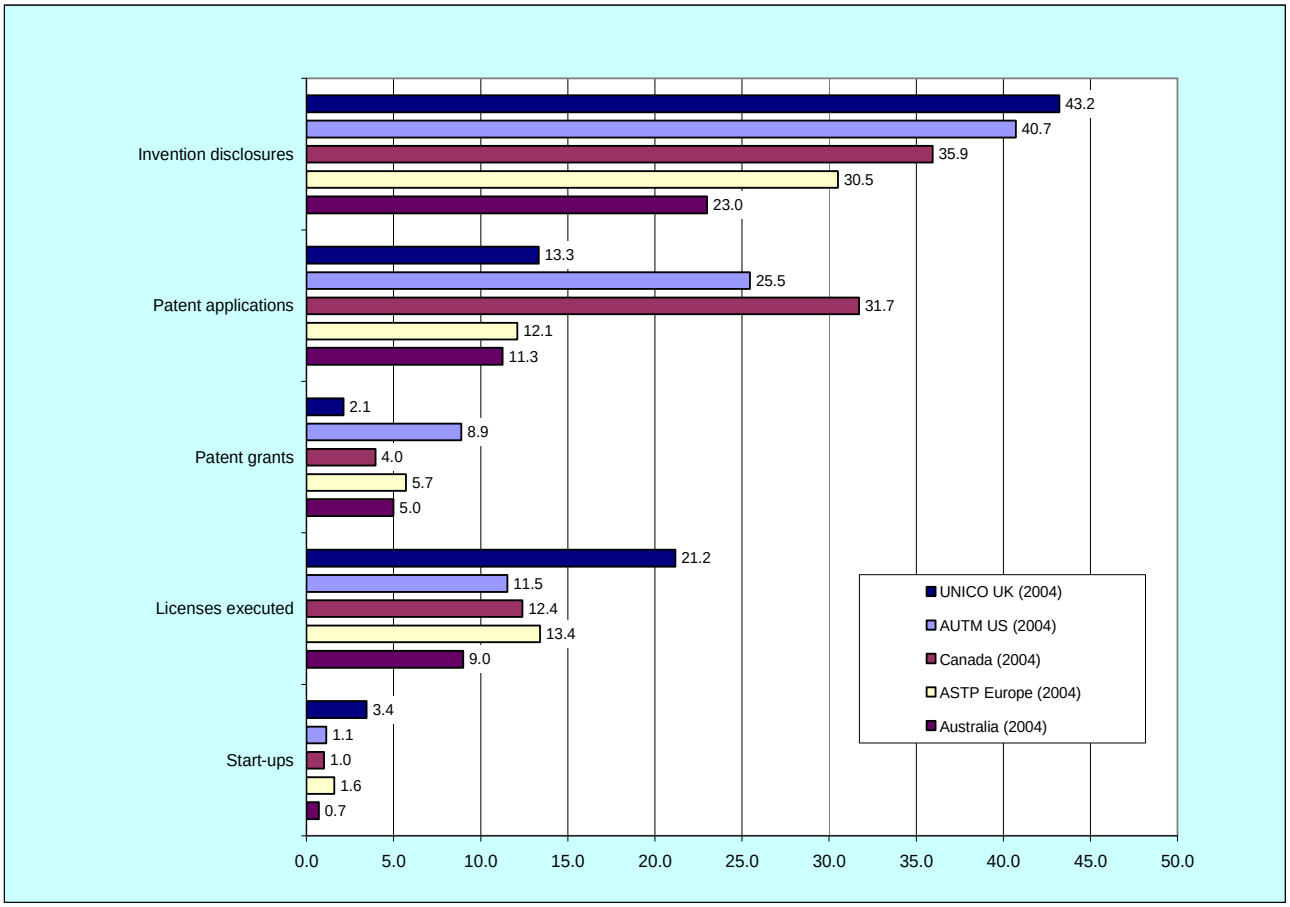
Table 2.

	UK-UNICO	UK-HEFCE	Canada	US (AUTM)	Europe (ASTP)	Australia
Fiscal year	2004	2004	2004	2004	2004	2004
Total reporting institutes	106	162	97	197	101	70
- of which universities	100 (94%)	162 (100%)	73 (75%)	164 (83%)	74 (73%)	39 (56%)
Survey response rate	56%	100%	69%	65%	59%	89%
Output indicators (total reported)						
Invention disclosures	2,871	3,029	1,432	16,792	3,481	961
Priority patent applications	885	884	1,264	13,792	1,616	450
Patent grants	141	183	158	3,667	320	492
Licenses executed	1,406	2,154	494	4,758	1,338	383
Start ups	229	167	40*	462	213	31
License income (million US PPP$)	65.2	61.79	41.1	1,434.3	190.8	48.2
Research expenditures (million US PPP$)	4,062	5,872	4,054	41,244	9,699	4,192

Sources: Arundel and Bordoy, 2006; AUTM, 2005; Read, 2005; UNICO, 2005, Commonwealth of Australia, 2007, HEFCE, 2006.

(*) Results for start ups are from 2003.

Figure 2



Notes: To prevent multiple counts of patents for the same invention, patent grants for the UK are limited to reported UK patents, for Canada to reported US patents, and for Australia to reported Australian patents.

Figure 3

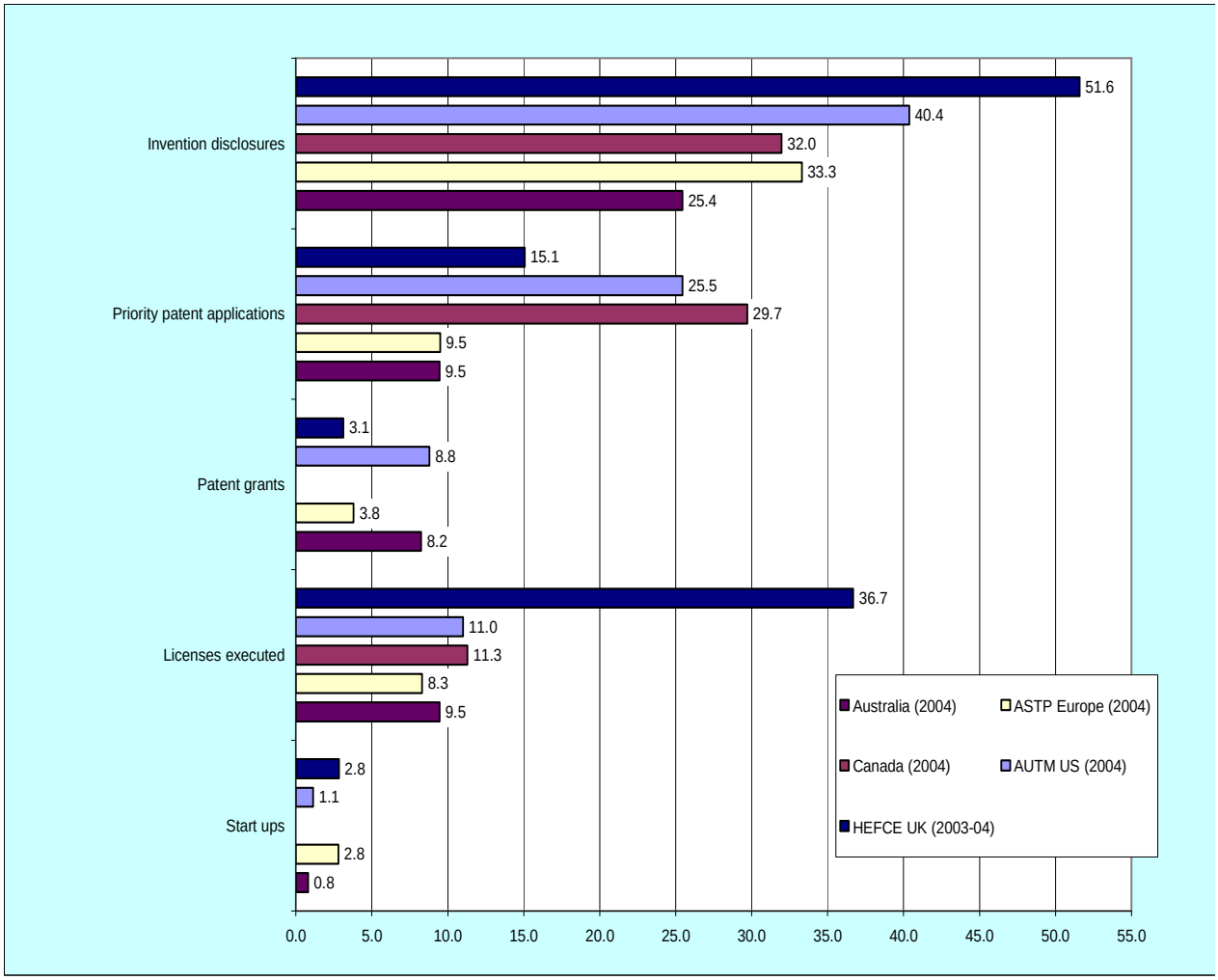

Invention disclosures
Priority patent applications
Patent grants
Licenses executed
Start ups
51.6
40.4
32.0
33.3
25.4
15.1
25.5
29.7
9.5
9.5
3.1
8.8
3.8
8.2
36.7
11.0
11.3
8.3
9.5
2.8
1.1
2.8
0.8
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
Australia (2004)
ASTP Europe (2004)
Canada (2004)
AUTM US (2004)
HEFCE UK (2003-04)

Table 3.

	ASTP-Europe		UK		Australia		Canada	
	All institutes	Univ. only	All[1] institutes	Univ. only[2]	All institutes	Univ. only	All institutes	Univ. only[4]
Commercial potential indicators								
Invention disclosures	0.7	0.8	1.1	1.3	0.6	0.6	0.9	0.8
Patent applications	0.5	0.4	0.5	0.6	-	0.4	1.2	1.2
Patent grants	0.6	0.4	0.2	0.4	0.6	0.9	1.1	-
Use indicators								
Licenses executed	1.2	0.8	1.8	3.3	0.8	0.9	1.1	1.0
Start-ups	1.4	2.4	3.1	2.5	0.6	0.7	0.9	-
License revenue[3]	0.9	0.4	0.3	0.4	0.3	0.3	0.3	0.3

1: UNICO study

2: HEFCE study

3: Relative performance for license revenue as a share of reported research expenditures

4: Source: Special tabulation provided by Cathy Read from Statistics Canada

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