Research Communication Costs in Australia, Emerging Opportunities and Benefits

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Summary

The environment in which research is being conducted and disseminated is undergoing profound change, with new technologies offering new opportunities, changing research practices demanding new capabilities, and increased focus on research performance. Nevertheless, despite billions of dollars being spent by governments on R&D each year, relatively little policy attention has yet been paid to the dissemination of the results of that research through scholarly publishing.

A key question facing us today is, are there new opportunities and new models for scholarly communication that could enhance the dissemination of research findings and, thereby, maximise the economic and social returns to public investment in R&D? By exploring the costs involved in scholarly communication activities and some of the potential benefits available through emerging scholarly communication alternatives, this study contributes to helping us answer this question.

The study provides background information, which is intended to provide a basis for improved management of, and access to, research information, outputs and infrastructure so that they are discoverable, accessible and shareable. It also provides activity costing estimates for a range of core activities within the higher education sector that may prove useful in the management of institutional budgets and priorities.

Costs of scholarly communication

Chapter 3 explores the activities and costs associated with scholarly communication, using a systems perspective. It suggests that scholarly communication costs include:

- *Research* – the costs associated with the research that enables the production of the article, monograph or other composition, its writing and preparation, submission and revision, and related editorial and peer review activities;
- *Publishing* – the costs associated with acquisition of content, editing and production, marketing and sales, and distribution and access;
- *Research infrastructure (distribution)* – the costs associated with access to research findings, including library infrastructure and activities, the provision of equipment and the network infrastructure for access; and
- *Research infrastructure (funding and management)* – the costs associated with research funding, research management and the evaluation of research activities.

An Australian cost model

An extensive literature review provided the foundation for the development of a model of the costs associated with these activities in Australia. The model was refined through local data collection and a series of interviews with local stakeholders. Inevitably, a number of simplifying assumptions must be made in the construction of such a model,

and the preliminary costings outlined should be taken as no more than a first approximation, intended to scope local activities rather than provide detailed costings.

Scholarly communication system costs

Research communication costs are significant. Summing the estimated costs associated with core scholarly communication activities in Australian higher education (*including higher education related ARC and NHMRC research grant application and review, reading for those higher education staff producing HERDC compliant publications, writing HERDC publications, related peer review and editorial activities, and related publishing costs*) gives an approximate estimate of overall system costs of between AUD 2.6 billion and AUD 4.6 billion (mean AUD 3.6 billion) per year (Table A1). Nationally, these costs amount to around 30% of total higher education revenues and expenditures.

Table A1 Costing estimates for Australian higher education, circa 2004 (AUD per annum)

Activity, Content & Infrastructure Costs	*Lower Bound*	*Upper Bound*	*Mean*
Reading (Published Staff)	2,036,200,000	3,423,700,000	2,698,700,000
Reading (Academic Staff)	3,507,900,000	5,898,300,000	4,649,300,000
Writing (HERDC compliant publications only)	325,400,000	604,100,000	480,100,000
Peer Review (Scaled to HERDC)	39,900,000	177,800,000	100,200,000
Editorial activities (Scaled to published staff)	13,300,000	59,400,000	33,100,000
Editorial board activities (Scaled to published staff)	1,700,000	5,800,000	3,500,000
Preparing Grant Applications (ARC & NHMRC)	77,500,000	143,900,000	114,400,000
Reviewing Grant Applications (ARC & NHMRC)	9,800,000	35,100,000	21,700,000
Publisher Costs (Scaled to HERDC)	104,100,000	190,500,000	147,700,000
Library Acquisition costs (CAUL)	..	..	181,900,000
Library non-Acquisition costs (CAUL)	..	..	316,800,000
Acquisition Cost per Serial Title (CAUL)	..	..	76
Implied acquisition cost per Article (Estimated)	..	..	< 1
Cost per download (Sample of CAUL subscriptions)	1.24	10.11	4.49
Acquisition Cost per non-serial item (CAUL)	..	..	60
Research Management costs (Estimated)	..	..	36,800,000
ICT Infrastructure (Estimated Total Expenditure)	806,900,000	1,344,800,000	1,075,900,000
Scholarly communication system costs	*2,607,900,000*	*4,640,400,000*	*3,599,500,000*

Note: All costings relate to Australian higher education. Upper and lower bounds are set, primarily, by academic salary ranges. National total includes core publishing related activities only.
Source: CSES project model, Author's analysis.

Research costs

Costs associated with research activities are based on those found in the literature, with activity times translated into costs using the AVCC guide to full cost recovery for (non-laboratory) contract research activities. They include full staff salary and on-costs, as well as overhead costs.

Writing (≈AUD 480 million pa): In Australian higher education institutions it is estimated that it costs around AUD 480 million per year to write those publications counted in the Higher Education Research Data Collection (HERDC) alone. No account is taken of the cost of producing other outputs, publications that do not qualify for inclusion or those rejected by publishers.

Peer review (≈AUD 120 million pa): Assuming that journal and monograph related peer review activities scale to peer reviewed publication, it is estimated that in Australian higher education they cost around AUD 100 million a year. It is further estimated that peer review of higher education related ARC and NHMRC grant applications costs a further AUD 20 million or more, bringing the total costs of peer review activities in Australian higher education to around AUD 120 million a year. No account is taken of other peer reviewing activities relating to other grants or those associated with other outputs.

Editorial activities (≈AUD 37 million pa): Based on an extensive international survey, it is estimated that in Australian higher education editorial activities relating to scholarly journals alone cost around AUD 37 million a year. No account is taken of other editorial activities (*e.g.* internal working papers, contract research reports, etc.) or of activities relating to books.

Reading (≈AUD 4,650 million pa): Based on extensive international surveys, it is estimated that reading by academic staff in higher education may cost around AUD 4.6 billion a year. Of which, reading by those staff who are actively publishing (*i.e.* approximating reading in order to write) may cost around AUD 2.7 billion a year.

Publishing costs (≈AUD 150 million pa)

Publishing costs are based on a wide ranging review of studies of the costs associated with publishing, supplemented by consultation with senior publishing industry executives. It is estimated that publisher costs relating to those Australian higher education publications reported in the HERDC alone amount to almost AUD 150 million a year. No account is taken of the cost of producing other outputs or publications that do not qualify for inclusion in the HERDC collection.

Research infrastructure costs

Research infrastructure costs include those associated with access to findings, including library infrastructure and information acquisition, the provision of equipment and the network infrastructure for access, as well as costs associated with research funding, management and evaluation.

Library acquisition costs (≈AUD 182 million pa)

Those research libraries reporting to The Council of Australian University Librarians (CAUL) reported total expenditure of almost AUD 500 million during 2004, of which AUD 182 million was spent on content acquisition – AUD 125 million on serials, and AUD 56 million on non-serial items. In 2004, total acquisition expenditures amounted to around AUD 5,180 per FTE academic staff. On a per item basis, subscriptions to serials titles cost an average AUD 76 each, while non-serial items cost an average AUD 60.

Based on averages derived from an analysis of almost 5,000 journal titles, the implied cost of providing higher education access per article was less than AUD 1. The cost per download for a sample of seven of the larger publishers' packages subscribed to through CAUL during 2005 ranged from a low of AUD 1.24 to a high of AUD 10.11 (weighted mean AUD 3.60, unweighted mean AUD 4.49).

Institutional Repositories (≈AUD 2 to 10 million pa)

A wide range of repository establishment and operational costs are reported, due to the range of content, scope and functionality offered and varying practices regarding the inclusion of overhead and 'in-kind' costs.

A review of the literature suggests average repository establishment costs of around AUD 9,000 and annual operating costs ranging from a low of around AUD 4,000 to a high of around AUD 80,000 per year (mean AUD 41,000). Assuming a 5 year depreciation of establishment costs, mean annual costs per archive would be around AUD 42,500, implying that the total costs of operating institutional repositories for all higher education institutions in Australia might be of the order of AUD 2 million a year.

However, it should be noted that canvassing a small number of local examples unveiled annual costs of up to AUD 275,000. These cost levels would suggest that the total cost of operating institutional repositories for all higher education institutions in Australia might be up to AUD 10 million a year at the upper end. Taking account of the policy, advocacy, management and operation of a substantial institutional repository, and fully costing staff time involved, suggests that individual institutions might expect repository costs to be of the order of AUD 200,000 a year.

ICT expenditure in higher education (≈AUD 1 billion pa)

Preliminary findings from CAUDIT's benchmarking study suggest that higher education institutions typically spend between 6% and 10% of their total income on ICTs. This suggests total higher education ICT expenditure of the order of AUD 1 billion in 2004.

Research grants (≈AUD 160 million pa)

It is estimated that the preparation of ARC and NHMRC grant applications in Australian higher education institutions alone cost around AUD 114 million in 2004. External peer review costs associated with such applications are estimated to have been AUD 22 million in higher education alone. ARC and NHMRC agency costs amount to around AUD 25 million. There is insufficient information available to be able to apportion this expenditure between higher education and other institutions, and no account is taken of other research granting agencies and activities.

University research office operations (≈AUD 35 million pa)

There is no central reporting of the activities of university research offices comparable to that of libraries and IT services. Moreover, structures and activities vary widely, with some research offices operating centrally while others are more diffuse (*e.g.* decentralised data collection done within departments and faculties). Hence, it has not been possible to estimate the costs involved with any accuracy. Nevertheless, based upon the extrapolation of three diverse cases on an FTE staff basis, Australian higher education research offices' annual operating expenditures would be of the order of AUD 35 million.

Institutional costs

In most cases it is possible to disaggregate these costings to individual higher education institutions. However, it should be noted that these disaggregated data are substantially less reliable. They are at best indicative, and should be taken as no more than an approximate guide.

Tables 3.5 and 3.6 (see body of this report) present estimated annual scholarly communication related activity, content access and infrastructure costings for individual higher education institutions in Australia. They show, for example, that:

- Writing HERDC publications costs some AUD 40 million a year at The University of Melbourne, compared with less than AUD 1 million at the University of the Sunshine Coast;
- Peer review of such publications may cost more than AUD 8 million a year at The University of Melbourne, Sydney University and University of Queensland, compared with AUD 320,000 at Charles Darwin University, AUD 250,000 at Bond University and less than AUD 200,000 at the University of the Sunshine Coast;
- Library acquisition expenditures exceeded AUD 14 million at Monash University in 2004, but were less that AUD 3 million at Victoria University (with differences in reporting likely accounting for a part of the difference); and
- 'Author-pays' publishing might cost the University of Sydney more than AUD 4.5 million, compared with less than AUD 1 million at no fewer than 22 universities (were it to be adopted for all HERDC compliant journal publications).

Benefits of enhanced access

Chapter 4 builds on a review of the literature discussing the potential benefits of emerging open access scholarly communication models, and seeks to quantify some of those benefits.

Enhanced access opportunities

Perhaps the most important potential benefit of open access is enhanced access to, and greater use of, research findings, which would, in turn, increase the efficiency of R&D as it builds upon previous research. There is also significant potential for open access to expand the use and application of research findings to a much wider range of users, well beyond the core research institutions that have had access to the subscription-based literature.

Focusing on higher education, Getz (2005, pp11-12) noted three important dimensions of benefit: broader industry, government and society impacts; educational impacts; and the potential for greater integration of publications and other the digital objects that are increasingly the outputs of research (*e.g.* numeric data sets, software algorithms, animations, sound and video files). Kircz (2005) explored the 'dis-benefits' of the subscription publishing system, noting that the published literature was not, as often described, the record of science – at least, not the full record. Firstly, because of timing, it is "*the full stop after the fact*", with current discussion in many fields already based on pre-prints and other communications mechanisms (*e.g.* discussion lists, web logs, etc.). Secondly, because of selectivity in publishing, it is "*only a trophy cabinet*", with little reporting in the formal journal literature of failed experiments or trial and error tests.

Identifying the benefits that might be measured

The dimensions of potentially measurable benefits from enhanced access include those relating to research, industry and government, and the wider community.

Research

The most immediate benefits of open access would be likely to accrue within research, wherein the dimensions of potential benefit include:

- Speed of access speeding up the research and discovery process, increasing returns to investment in R&D and, potentially, reducing the time/cost involved for a given outcome, and increasing the rate of accumulation of the stock of knowledge;
- Improved access leading to less duplicative research, saving duplicative R&D expenditure and improving the efficiency of R&D;
- Faster access leading to better informed research, reducing the pursuit of blind alleys, saving R&D expenditure and improving the efficiency of R&D;
- Wider access providing enhanced opportunities for multi-disciplinary research, inter-institutional and inter-sectoral collaborations;
- Wider access enabling researchers to study their context more broadly, potentially leading to increased opportunities for, and rates of, application and commercialisation; and

- Improved access leading to improved education outcomes, enabling a given education spend to produce a higher level of educational attainment (at least at the post secondary level), leading to an improvement in the quality of the ‘stock’ of researchers and research users.

Industry and government

Given relative levels of access under the subscription publishing system, it is possible that greater potential benefits lie in enhanced access for industry and government, wherein the dimensions of potential benefits include:

- The potential for wider access to both accelerate and widen opportunities for adoption and commercialisation of research findings, thereby increasing returns on public investment in R&D and on private investment in commercialisation related activities;
- The potential for much wider access for GPs/nurses, teachers/students, small firms in consulting, engineering, architecture, design, law, electronics/ICTs, biotechnology, nanotechnology, etc., who currently have limited access, with a positive impact on quality of services and, possibly, productivity in those sectors of the economy; and
- The potential for the emergence of new industries based upon the open access content – there are examples of new industries built on publicly accessible data (*e.g.* weather derivatives based on meteorological data), and there are potential futures for publishers to become value adding services providers overlaying open access content (*e.g.* peer review services, bibliometrics and webometrics for research evaluation, etc.). In turn, these might enhance research evaluation and lead to better focused R&D expenditures.

Impacts might be felt more in particular sectors (*e.g.* knowledge intensive services, biotechnology, etc.). Impacts in such areas as management and economic consulting and engineering might be significant, raising the quality of advice to the benefit of clients across the economy. There may also be significant impacts in policy development, through better informed policy debate and enhanced access to information underpinning policy decisions.

One important dimension might be the potential for greater access for small and medium sized firms (SMEs), enabling SMEs to do more research internally, increasing the share of R&D undertaken by SMEs, and increasing the share of R&D done in industries and countries that include a relatively high share of SMEs (*e.g.* Australia).

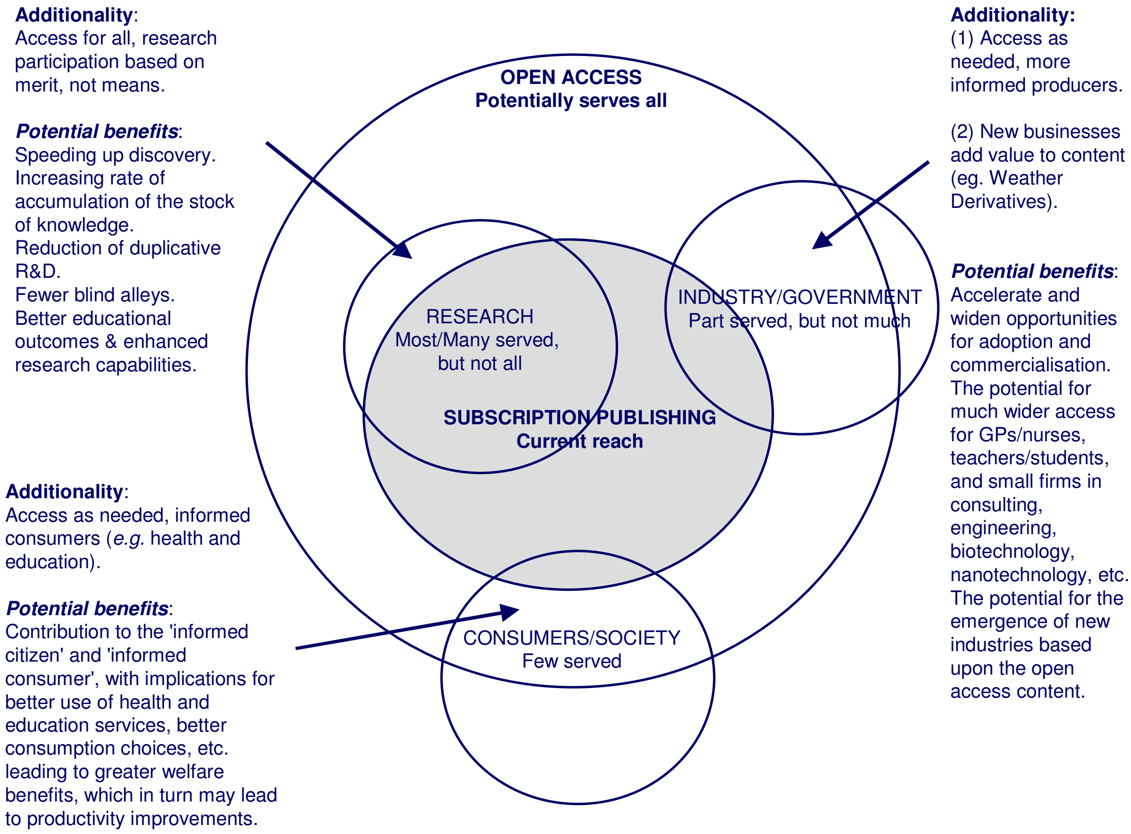
The wider community

In relation to the wider community, the dimensions of potential benefit include the potential contribution of open access to the ‘informed citizen’ and ‘informed consumer’, with implications for better use of health and education services, better consumption choices, etc. leading to greater welfare benefits, better health, etc., which in turn may lead to economy-wide productivity improvements.

An impacts framework

These dimensions of impact are represented in Figure A1, which shows the potential expanded coverage and access available through open access. In these three spheres of activity, subscription publishing has served: most but not all research institutions; some but not many industry and government users; and few consumers. The additionality and some of the potential benefits of enhanced access are also shown.

Figure A1 Impact framework: Subscription versus open access publishing



Source: Author's Analysis.

Quantifying some of the benefits

There are many difficulties involved in attempting to quantify benefits and compare costs and benefits. Nevertheless, it is possible to gain some sense of the possible scale of potential impacts by developing impact scenarios focusing on the aggregate measure of social returns to investment in R&D, and a modified growth model introducing access and efficiency variables into calculating the returns to R&D.

Estimating the benefits of a one-off increase in accessibility and efficiency

Using a simple Solow-Swan growth model to explore the returns to R&D, we note that the standard approach makes some key assumptions. In particular, it is assumed that:

- All R&D generates knowledge that is useful in economic or social terms (*efficiency of R&D*);
- All knowledge is accessible to all firms or other entities that could make productive use of it (*accessibility of knowledge*); and
- All types of knowledge are equally substitutable across firms (*substitutability*).

A good deal of work has been done to address the fact that the substitutability assumption is not realistic, as particular types of knowledge are often specialised to particular industries and applications. Much less has been done on the other two assumptions (*i.e.* efficiency and accessibility). We introduce 'accessibility' and 'efficiency' as negative variables into the standard model to take account of real world access and efficiency limitations.

Table A2 Potential annual benefits of enhanced/open access, circa 2003

Research sector	*Expenditure AUDm*	*Social returns*	*Increase in accessibility & efficiency*	*Annual impact AUDm*	*Benefit/cost ratio*
Gross expenditure on R&D	12,250	50%	5%	628	214
Government expenditure on R&D	5,438	25%	5%	139	47
Public sector R&D	5,912	25%	5%	151	51
Higher education R&D	3,430	25%	5%	88	30
ARC funded research (NCGP)	481	25%	5%	12	4.1
NHMRC funded research	350	25%	5%	9	3.1

Note: Benefit/cost ratios are calculated over 20 years for a full system of institutional repositories in Australia costing AUD 10 million a year and achieving a 100% self-archiving compliance.
Source: CSES project model, Author's analysis.

Estimating the benefits of a one-off increase in accessibility and efficiency (*e.g.* because of a move to open access), we find that if accessibility and efficiency are constant over the estimation period but then show a one-off increase, then, to a close approximation, the return to R&D will increase by the same percentage increase as that in the accessibility and efficiency parameters. Assuming that the increase in both parameters is the same, that the change to open access has no *net* impact on the rates of accumulation and obsolescence of the stock of knowledge, and that the information are discoverable, we find that:

- With *public sector R&D expenditure* at AUD 5,912 million and a 25% rate of social return to R&D, a 5% increase in accessibility and efficiency would be worth AUD 150 million a year;
- With *higher education R&D expenditure* at AUD 3,430 million and a 25% rate of social return to R&D, a 5% increase in accessibility and efficiency would be worth AUD 88 million a year; and

- With *ARC administered funding* (competitive grants) at AUD 480 million and a 25% rate of social return to R&D, a 5% increase in accessibility and efficiency would be worth AUD 12 million a year (Table A2).

Note that these are recurring annual gains from the effect on one year's R&D. Assuming that the change is permanent they can be converted to growth rate effects.

Comparing costs and benefits

It is possible to express these impacts as benefit/cost ratios by focusing on a limited range of costs that relate to a change from the current position to open access to public sector and/or higher education research via a national system of institutional repositories. Thus we are comparing the estimated additional incremental cost of open access institutional repositories in Australian higher education with the potential additional incremental benefits from moving to open access to Australian higher education research. No other changes are taken into account.

Expressing these impacts as a benefit/cost ratio we find that, over 20 years, a full system of institutional repositories in Australia costing AUD 10 million a year and achieving a 100% self-archiving compliance would show:

- A benefit/cost ratio of 51 for the modelled impacts of open access to public sector research (*i.e.* the benefits are 51 times greater than the costs);
- A benefit/cost ratio of 30 for the modelled impacts of open access to higher education research; and
- A benefit/cost ratio of 4.1 for the modelled impacts of open access to ARC competitive grants funded research (Table A2).

Obviously, there is unlikely to be 100% open access to all public sector research, because of commercial limitations, confidentiality and non-compliance. Nevertheless, whether applied across the board or to sector specific research findings it appears that there may be substantial benefits to be gained from increasing access to research findings. While it is difficult to calculate the quantum of those benefits with any certainty, these simple preliminary estimates of the potential impact of open access on social returns to R&D suggest that a move towards more open access may represent a substantial cost-benefit advantage.

Emerging opportunities and futures

Three of the four main functions of scholarly communication (*i.e.* registration, certification and dissemination) have been integrated in traditional scholarly publishing. The common thread in the literature on possible futures is the expectation of a fragmentation of these activities.

In the immediate future, we may see open access repositories and 'author-pays' open access journals as complementary elements in an evolving system, wherein repositories provide registration, awareness and archiving, and 'author-pays' journals provide the certification (primarily through peer review).

In the mid term, it is likely that such a system might evolve further, with more focused and specialised services providers emerging and a rationalisation of overlapping activities, which would lead to a more cost effective and efficient system. In the 'born digital' environment, cost savings could be made by stopping production of journals (and, perhaps, research monographs) in print form, and replacing them with overlay journals and services (*e.g.* peer review, branding and quality control services) and institutional e-presses, which depend upon the open access archives and repositories for distribution.

In the longer term, the evolution of the scholarly communication system may involve the dissolution of existing and emergence of new combinations of objects, activities and responsibilities – such as, for example, the decline of commercial publisher control over peer reviewed journal titles and the rise of open access subject archives and institutional repositories populated by free-standing digital objects of all kinds, with quality control based around career review, online user commentary and more formalised but diffuse review processes, and impacts measured as hits, downloads, citations and links, which better reflect the use and impact of the work than do citations alone.

Whatever the future, the emerging system should take account of new and emerging research practices. As Van de Sompel, *et al.* (2005) put it, "…dramatic changes in the nature of scholarly research require corresponding fundamental changes in scholarly communication. Scholars deserve an innately digital scholarly communication system that is able to capture the digital scholarly record, make it accessible, and preserve it over time… the future scholarly communication system should closely resemble – and be intertwined with – the scholarly endeavour itself, rather than being its after-thought or annex."

Conclusions and recommendations

There are new opportunities and new models for scholarly communication that can enhance the communication and dissemination of research findings to all potential users and, thereby, increase the economic and social returns to investment in R&D. Open access is, perhaps, the most important.

From a policy perspective, the question is how to enable the current system to evolve towards such a future. Setting the goals and using points of policy leverage to facilitate the transition are the keys.

Setting the goals

This report provides a basis for a re-examination of individual and institutional scholarly communication behaviours, and the ways in which both can be reorganised and streamlined. The study findings inform and support existing initiatives (*e.g.* the Research Quality Framework, National Collaborative Research Infrastructure Strategy and the Australian Research Information Infrastructure Committee), which are based upon a desire to ensure accessibility to, and dissemination of, research results. Through these initiatives an opportunity exists to increase the returns on our investment in research by enhancing access to it.

This study reveals a growing global open access publishing movement in the research sector. It is driven by two major factors. Firstly, a widespread sense that publicly funded research should be accessible to the public. Secondly, that the accessibility of such research is a major factor in the distribution and impact of that research and, thereby, in maximising the return on our investment in it. The cost-benefit analysis undertaken for this study reveals substantial potential benefits from more open access.

Accessibility to research information can be facilitated through the development of a national system of institutional or enterprise-based repositories to support the new modes of enquiry and research. All Australian higher education and research institutions should be encouraged to develop enterprise-wide digital repositories for the storage, preservation, curation, access, registration and management of their intellectual property. The ability to access all Australian research through institutional repositories will not only make it available, but will also facilitate its management and increase the impact of Australian research.

Realising the benefits of enhanced access depends upon appropriate infrastructure and incentives, to ensure:

- Widespread adoption of open access strategies by universities, research funding bodies and government agencies;
- 'Hard or soft mandated' deposit of research output at the national, funder and/or institutional levels;
- Fully integrated institutional repositories or relevant subject-based archives based upon open access standards; and
- Fully developed links between content 'publishing' and research management, reporting and evaluation.

In this context, there is a need to support further work towards understanding how best, and most cost-effectively, to support the research process and the research infrastructure to maximise Australian research dissemination and impact.

Points of leverage

Research evaluation is the primary point of leverage, influencing strongly the scholarly communication and dissemination choices of researchers and their institutions. A related secondary point of leverage is funding, and the conditions funding bodies put upon it.

To attain the goal of accessibility it will be essential to ensure that funding and grant assessment, research evaluation and reward take account of emerging possibilities and opportunities, and build in open access options. As Willinsky (2006, pxii) put it: "A commitment to the value and quality of research carries with it a responsibility to extend the circulation of such work as far as possible and ideally to all who are interested in it and all who might profit by it."

Inter alia, this means:

- Ensuring that the Research Quality Framework supports and encourages the development of new, more open scholarly communication mechanisms, rather than encouraging a retreat by researchers to conventional publication forms and media, and a reliance by evaluators upon traditional publication metrics (*e.g.* by ensuring dissemination and impact are an integral part of evaluation);
- Encouraging funding agencies (*e.g.* ARC, NHMRC, etc.) to mandate that the results of their supported research be made available in open access archives or repositories;
- Encouraging universities and research institutions to support the development of new, more open scholarly communication mechanisms, through, for example, the development of hard or soft open access mandates for their supported research; and
- Supporting an advocacy program to raise awareness and inform all stakeholders about the potential benefits of more open scholarly communication alternatives, and provide leadership in such areas as copyright (*e.g.* by encouraging use of creative commons licensing).

In the light of the global nature of research, Australia can also contribute through international activities. This might, for example, include working at the international level to encourage open access through international fora (*e.g.* OECD, CODATA, etc.), exploring the possibility of further building upon open access to data initiatives (*e.g.* the OECD Declaration on Open Access, and The Global Information Commons for Science Initiative), and participating in international work exploring the impacts of enhanced access to research.

1 Introduction

The environment in which research is being conducted and disseminated is undergoing profound change, with new technologies offering new opportunities, changing research practices demanding new capabilities, and increased focus on research performance and the commercialisation of findings. Nevertheless, despite billions of dollars being spent by governments on R&D each year, relatively little policy attention has yet been paid to the dissemination of the results of that research through scholarly publishing.

A key question facing us today is, are there new opportunities and new models for scholarly communication that could enhance the dissemination of research findings and, thereby, maximise the economic and social returns to public investment in R&D? By exploring the costs involved in scholarly communication activities and some of the potential benefits available through emerging scholarly communication alternatives, this study contributes to helping us answer this question.

The study provides background information, which is intended to provide a basis for improved management of, and access to, research information, outputs and infrastructure so that they are discoverable, accessible and shareable. It also provides activity costing estimates for a range of core activities within the higher education sector that may prove useful in the management of institutional budgets and priorities.

1.1 Scholarly communication in context

In his introduction to open access, Bailey (2006) wrote: "Conventional fee-based publishing models fragment worldwide scholarly journal literature into numerous digital enclaves protected by various security systems that limit access to licensed users. What would global scholarship be like if its journal literature were freely available to all, regardless of whether the researcher worked at Harvard or a small liberal arts college, or he/she was in the United States or Zambia? What would it be like if, rather than being entangled in restrictive licenses that limited its use, journal literature was under a license that permitted any use as long as certain common-sense conditions were met?"

The existing system of scholarly publishing evolved over many years to serve the needs of disciplinary research in specialist institutions in a print-based environment. But the scholarly information environment is now undergoing profound change, as a result of new technologies allowing new modes of research dissemination, changing research practices and needs, increased focus on research performance and the application and commercialisation of findings (Houghton *et al.* 2003; Houghton 2004; Houghton *et al.* 2004).

Van de Sompel *et al.* (2004) suggested that: "The manner in which scholarly research is conducted is changing rapidly. This is most evident in Science and Engineering, but similar revolutionary trends are becoming apparent across disciplines. Improvements in computing and network technologies, digital data capture techniques, and powerful data mining techniques enable research practices that are highly collaborative, network-based, and data-intensive. These dramatic changes in the nature of scholarly research require corresponding fundamental changes in scholarly communication. Scholars deserve an innately digital scholarly communication system that is able to capture the digital scholarly record, make it accessible, and preserve it over time."

The existing scholarly publishing system no longer serves well the needs of researchers for uninhibited access to the research findings of others, or the needs of their funders for cost effective dissemination of findings in order to maximise the economic and social benefits from their investment in R&D. It is not about journal prices and the difficulties faced by arts and humanities scholars in publishing monographs *per se*, but about access, permission to use and the emergence of new opportunities to communicate, coordinate, integrate and preserve the full range of digital objects that are now increasingly the everyday outputs of research activities.

1.2 Layout of this report

Chapter 2 presents a brief review of recent developments and emerging business models in scholarly publishing.

Chapter 3 explores the activities and costs associated with scholarly communication. A review of the literature (Appendix I) provides the foundation for the development of a 'cost model' of the estimated costs of scholarly communication in higher education institutions in Australia.

Chapter 4 notes that it is always more difficult to estimate the potential benefits than it is to estimate the costs involved, but for the sake of informed policy discussion it is important that we begin to put some 'ball park' figures on the benefits side of the equation. Analysis builds on a review of the literature discussing the benefits of enhanced access (Appendix II) to identify and quantify some of those benefits.

Chapter 5 concludes the analysis with a brief exploration of possible scholarly communication futures. It draws on the literature to suggest possible evolutionary pathways in order to shed light on key points of policy leverage and how change might be affected.

Appendix I presents an extensive review of the literature on scholarly communication costs. This review provides the foundation for the development of the Australian cost model presented in Chapter 3.

Appendix II presents a review of the literature on the potential benefits of open access. This review provides the foundation for the analysis of impacts and benefits presented in Chapter 4.

2 Emerging Business Models

This section builds on previous work looking at scholarly communication and the scholarly publishing models that have emerged over recent years (Houghton 2005b). It suggests that online access and distribution change cost structures.

Characteristically, content products have high first copy costs and low subsequent copy or marginal costs of production. Nevertheless, when content is printed, packaged and distributed through a wholesale-retail distribution channel there remain significant costs in the production and distribution of copies. Making the same content available online reduces these producers' costs dramatically, with no physical (re)production and distribution activities and no inventory required. New investment in the producers' technical infrastructure is frequently required, but the long-term impact of online distribution tends to be to increase first copy costs, reduce marginal cost of production to near zero and shift the distribution of costs towards fixed costs. Current and emerging content business models can be seen as responses to these changed economic characteristics brought about by online distribution and access.

The major recent and emerging models for scholarly communication and access include:

- *The 'Big Deal'* – where institutional subscribers pay for access to online aggregations of titles through consortial or site licensing arrangements;
- *'Author-pays' publishing* – where authors, their employing or funding organizations contribute to the costs of publication; and
- *Open Access archives and repositories* – where organizations support institutional repositories and/or subject archives.

There are also a number of hybrids, such as delayed open access (where journals allow open access after a period during which they are accessible to subscribers only), and open choice (where authors can choose to pay author fees and make their works open access, or not to pay and make their works subscription only), and less widespread alternatives, such as pay-per-view.

2.1 The 'Big Deal'

The 'Big Deal' is a highly developed form of bundling. Bakos and Brynjolfsson (2000, p117) suggested that the internet had radically changed the economics of distribution and opened up new possibilities. Goods that were previously aggregated to save transaction or distribution costs may be disaggregated (*e.g.* newspapers), but new aggregations may emerge to exploit the potential of bundling for profit maximisation. Near zero marginal cost favours bundling from the producers' side, the more so where advertising and marketing costs can be significantly reduced by aggregating consumers, and some analysts have extended the logic of bundling beyond the content itself to subscription (*i.e.* bundling over time) and site licensing (*i.e.* bundling users) (Bakos and

Brynjolfsson 1999; Bakos, Brynjolfsson and Lichtman 1999; Bakos and Brynjolfsson 2000).

Table 2.1 Advantages and disadvantages of the 'Big Deal'

Advantages	*Disadvantages*
Improved access, with access to more titles – which suits researchers in emerging interdisciplinary areas and tends to lead to higher use.	Tends to lock libraries into the major bundles and makes it more difficult to cancel titles.
Reduces the per title and per article costs to users of the overall package.	Tends to reduce substitutability, and may reduce price elasticity of demand.
Can increase budgetary certainty for research libraries through multi-year deals with fixed price increases agreed up-front.	Tends to squeeze out smaller publishers who cannot offer access to large bundles (*i.e.* becomes competition between publishers rather than titles).
Can increase access through consortial deals, especially for those previously poorly served.	May influence impact factors in favour of titles within the bundle and strengthen the position of the major publishers.
	Because publishers try to build up the bundle and price it, rather than individual titles, there is less pressure to axe low demand titles. As a result, aggregate fixed (first copy) costs increase.
	Access may sometimes be more restrictive than that for print subscriptions (*e.g.* access for walk-in library users may be cut by either publisher or library logon requirements).
	Concern over access to previously subscribed to back issues if subscription is terminated (*i.e.* cut off from everything, not just new issues).
	Concern over long-term archival integrity.

Source: Houghton, J.W. (2005) *Digital Delivery of Content: Scientific Publishing*, OECD, Paris. Available http://www.oecd.org/dataoecd/42/12/35393145.pdf accessed September 2005.

While much progress has been made in developing the 'Big Deals' in response to customer demands, there remain concerns relating to the mechanics, economic and scholarly outcomes of major bundled subscriptions and site licensing deals (Frazier 2001; Gatten and Sanville 2004; CESTMJP 2004, p22; Hahn 2006) (Table 2.1). Amongst them have been concerns over access and permissions.

2.2 Open access

A recent development to have gained considerable momentum is open access, principally in the forms of 'author-pays' publishing supported by grants and donations, author charges or other kinds of cost recovery, *and* open access archives and repositories.[1]

Definitions of open access vary. The Public Library of Science suggested that an open access publication is one that meets the following two conditions:

- The authors and copyright holders grant to all users a free, irrevocable, worldwide, perpetual right of access to, and a license to copy, use, distribute, transmit and display the work publicly and to make and distribute derivative works, in any digital medium for any responsible purpose, subject to proper attribution of authorship, as well as the right to make small numbers of printed copies for their personal use, and
- A complete version of the work and all supplemental materials, including a copy of the permission as stated above, in a suitable standard electronic format, is deposited immediately upon initial publication in at least one online repository that is supported by an academic institution, scholarly society, government agency or other well-established organization that seeks to enable open access, unrestricted distribution, interoperability and long-term archiving (PLoS 2004).

The key element of open access is that the material is made available freely and openly, without charge or usage restrictions, to anyone with internet access. Open access need not be limited to scholarly publications. It can apply to any born digital works (*e.g.* research databases and analytical objects) or to older works (*e.g.* public-domain literature and cultural-heritage objects, digitalised later in life).[2] The primary focus is royalty-free products (*i.e.* products which the author gives away).

'Author-pays' publishing

In the *'author-pays' publishing* model, the costs of peer review and the production of journals are met from donations and/or institutional support, or wholly or in part by charging authors a per article or per page fee for publication, submission or some combination of both. Currently, relatively few open access journals are entirely, literally, author pays, with many using donations, bequests, institutional support, priced add-ons or auxiliary services to support publication.

Among the major 'author-pays' open access publishing initiatives are:

- The Public Library of Science (PLoS) – which is a non-profit organization of scientists and physicians that seeks to make the world's scientific and medical literature a public resource. It began in October 2000 with a call to make scientific and medical literature available, on an open access basis, after a delay (typically of six months) for material published in subscription journals. In 2001, PLoS launched its own open access journals using the 'author-pays' model. Author fees for the publication of an article in a PLoS open access journal are USD 1,500, and all articles published are deposited in an open access archive (*e.g.* PubMed Central). PLoS also operates an institutional membership scheme for author fees, in which author fees are waived for authors employed by member institutions (www.plos.org).

- BioMed Central – which lists more than 100 open access journals covering all areas of biology and medicine. BioMed Central is an independent publisher that makes all the original research articles in its journals immediately and permanently available online without charge or any other barriers to access. All research articles and most other content in BioMed Central's journals are peer-reviewed. Authors retain copyright over their work. Open access is supported by article processing charges levied on authors. The majority of BioMed Central journals charge a flat fee of USD 550 for each accepted manuscript, but the leading journals in the stable charge up to USD 1,680. A number of major institutional funders have announced their willingness to cover BioMed Central and other open access publishing charges within their research grants, and no direct article charges are levied if the submitting author's institution is a BioMed Central member. As at January 2006, BioMed Central had 503 institutional members in 37 countries (www.biomedcentral.com).

Table 2.2 Advantages and disadvantages of 'author-pays' publishing

Advantages	*Disadvantages*
Increases access to the findings of research, thereby increasing social returns from investment in research.	May lead to inequality of access, with publishing based on means rather than merit.
Costs should be lower than subscription-based models, due to lack of need for licensing, subscription management, and access control.	May not work for the humanities, arts and social sciences, where research funding is more limited.
Scales publication to research funding and activity, rather than research library budgets (*i.e.* better matches demand and supply).	May make it more difficult to establish a new journal, thereby reducing the number of titles over time and making it difficult for new areas of scholarship to find an outlet.
Journals compete for authors rather than subscribers, so likely to increase substitutability between titles.	May create a disincentive to publish, thereby reducing the impact of R&D and the return on R&D spending.
	May have a detrimental impact on institutional and society publishers, who have used subscription revenues to subsidise other activities.
	May raise quality concerns due to economic pressure to lower rejection rates to control costs.
	Will shift the costs of publishing, and may lead to organisations and countries that are major producers of scientific and scholarly works paying more in author charges than they would for subscription fees in a reader pays system.
	May create a free rider problem, with open access for previously paying users in the private sector (*e.g.* pharmaceutical firms).

Source: Houghton, J.W. (2005) *Digital Delivery of Content: Scientific Publishing*, OECD, Paris. Available http://www.oecd.org/dataoecd/42/12/35393145.pdf accessed September 2005.

There are many others adopting and/or experimenting with open access and various forms of 'author-pays' journal publishing, including: the Institute of Physics Publishing, Oxford University Press, The Company of Biologists, National Academy of Science, The American Physiological Society, Entomological Society of America, The American Institute of Physics and the large commercial publishers Springer and Blackwells. Lund University's Directory of Open Access Journals listed 2,158 titles and 92,812 articles in April 2006 (www.doaj.org), and Highwire Press hosted 926 peer reviewed open access journals, with free access to almost 1.3 million full text articles (http://highwire.stanford.edu/).

Open access archives and repositories

Open access *archives* are typically subject or discipline based, offering open and free access to pre-print and/or post-print papers in a particular discipline or subject area. Open access *repositories* are typically institutionally based, offering the same level of open and free access to the work and outputs of particular institutions (*e.g.* a university or research institute). Both rely upon authors and/or their employing institutions depositing material onto the archive/repository (*i.e.* 'self-archiving').[3]

Subject-based archives have been available for a number of years. Some are subject to oversight by a group of experts (*e.g.* arXiv). They can cater for both pre-prints (*i.e.* articles that have been submitted for publication, but not yet accepted) and post-prints (*i.e.* articles that have been accepted for publication and/or published), with the balance between pre-prints and post-prints depending upon the focus and policy of the individual archive.

Perhaps the leading and best known example is the Ginsparg Archive (arXiv.org), which is a pre-print and post-print service in the fields of physics, mathematics, non-linear science, computer science and quantitative biology. Established in August 1991, arXiv had received 362,334 submissions by April 2006. The contents of arXiv conform to Cornell University's academic standards, with an advisory board and subject experts overseeing its operation. According to Hickerson (2004), a combination of "heuristic screening mechanisms, scientists acting as moderators for various fields, and endorsement procedures contribute to ensuring that submissions to the arXiv are of refereeable quality". There were more than 20 million full text downloads from arXiv during 2002 (Hickerson 2004). Other examples of subject archives include: CogPrints (cogprints.ecs.soton.ac.uk), E-BioSci (www.e-biosci.org), and RePEC (repec.org).

Institutional repositories operate in much the same way as subject archives, but they are associated with an organization (*e.g.* a university or research institute) rather than a subject area or discipline. Examples include the CERN Document Server (cds.cern.ch), which in early 2006 had over 800,000 bibliographic records, including 360,000 full text documents of interest to people working in particle physics and related areas. It covers pre-prints, articles, books, journals, photographs, etc. According to the 2004 PALS report, there were over 200 Institutional Repositories in the world at that time, mainly populated with unpublished material (HCSTC 2004b, p27).

Institutional repositories operate by voluntary or mandated deposit of the works of institutional employees either before publication (pre-print) or, more commonly, afterwards (post-print). A crucial element in the success of repositories is the existence of metadata management and access standards ensuring harvestability, and the widespread availability of open source software systems for their operation and management. The Open Archives Initiative (OAI), which was developed to promote the use of standards that facilitate the dissemination of content, has played a major role.[4] There are now a number of OAI-compliant software systems available as freeware that enable open access through author and/or institutional archiving (*e.g.* EPrints, DSpace, CDSware, Fedora, etc.) (Buckholtz *et al*. 2003, p2; OSI 2004). The OAI searcher, OAIster, listed more than 7 million records from 610 institutions in March 2006 (http://oaister.umdl.umich.edu/o/oaister/).

Table 2.3 Advantages and disadvantages of open access archives and repositories

Advantages	*Disadvantages*
Access free and open to all, maximising the dissemination of research findings and thereby social welfare benefits from R&D spending.	Control over quality and posting may vary from archive to archive and institution to institution.
Speed of dissemination is greater than subscription-based or open access publishing. May help to overcome the publishing bias towards publication of successful findings.	Concern over the handling of copyright for archives/repositories and publishing (*e.g.* possible limitations on posting published material and potential IP conflicts).
May contribute to the creation of a more complete record of scholarship (*e.g.* institutional repositories recording the institutions' entire output).	Potential lack of market segmentation for authors and access control over their works.
Because of the availability of OAI standards and guidelines and a number of open source / freeware software systems archives and repositories could be a relatively low-cost alternative.	Relatively low rates of posting to most institutional repositories to date (*i.e.* population issue).
Potential for repositories to integrate with e-science data repositories and a range of other forms of digital objects, and thereby provide enhanced support for collaborative and inter-disciplinary research.	
Potential to contribute to enhanced measurement, and greater quality and ease of research assessment at both institutional and/or individual levels.	

Source: Houghton, J.W. (2005) *Digital Delivery of Content: Scientific Publishing*, OECD, Paris. Available http://www.oecd.org/dataoecd/42/12/35393145.pdf accessed September 2005.

One of the most important features of institutional repositories is that they can host a range of objects, including pre-print and post-print articles *and* a wide range of other digital objects (*e.g.* monographs, technical reports, laboratory and field notes, data, analytical software, audio, video and image files). As the nature and practice of research changes, with greater capabilities for automated data collection and increased emphasis on data manipulation, mining and analysis, the flexibility that institutional repositories provide in hosting and enabling the use of such digital objects is an important strength, and is one of the ways in which they go beyond traditional scientific publishing in the facilitation of both research and its dissemination. Open access repositories are also better adapted to the needs of inter-disciplinary and collaborative research (Lynch 2003) and have the potential to readily integrate with e-science data repositories, thereby allowing dissemination to be built into the e-science infrastructure.

Box 2.1 Institutional repositories

Repositories began with man's first storing and protection of artefacts and information succeeded by the formalization of those efforts through libraries and museums. In 1988, Peter Drucker's *Harvard Business Review* article "The Coming of the New Organization" declared that an organization's knowledge was its most important asset, and to manage that asset well was to ensure the organization's success. Thus began the knowledge management movement of the 1990's that reached beyond book and article "containers" and placed value on all knowledge explicit and tacit, in datasets and graphics, in e-mails and sketches. By 2000, it was becoming easier for individuals and groups to create and disseminate content, using desktop tools and networking, which challenged universities to coordinate, share, and preserve its digital assets.

In 2002, two seminal events occurred when the Massachusetts Institute of Technology (MIT) collaborated with Hewlett-Packard Corporation to launch an open-source institutional repository entitled Dspace, and the Scholarly Publishing and Academic Resources Coalition (SPARC) published '*The Case for IRs: A SPARC Position Paper*'. From DSpace emerged a new strategy for universities to capture their creativity and research, as well as pose an alternative to the high-costs of scholarly communication. In 2003, with funding from The Andrew W. Mellon Foundation and other sources, MIT's DSpace was replicated and the software released under an open source arrangement, greatly lowering cost and expediting development.

Source: McLendon, W. (2005) *Institutional Repositories*, A White Paper for the UNC-Chapel Hill Scholarly Communications Convocation, January 2005, pp1-2.

3 Costs of Scholarly Communication

This section explores the activities and costs associated with scholarly communication. It uses a systems perspective to frame a review of the literature on the costs involved in the entire scholarly communication value chain (See Appendix I for the literature review). This provides the foundation for the development of a 'cost model' that presents estimated scholarly communication costs for higher education institutions in Australia.

3.1 The scholarly communication system

A review of the literature relating to the costs of scholarly publishing and access reveals two distinct approaches, with the majority of writers focusing upon the publishing process and discussing the functions and costs involved, while others explore the wider context, seeing publishing as a part of a system of knowledge creation and dissemination.

Publishing itself is a multifaceted activity, involving a wide range of activities and performing a number of key functions. Following a long tradition, Crow (2005) suggested that the main functions of scholarly communication are: registration (establishing intellectual priority); certification (certifying the quality and validity of the research); dissemination/awareness (assuring accessibility of the research to others); and preservation (preserving the research for future use). Traditionally, publishers have performed all of these functions except archiving, which has been performed by libraries and archives.

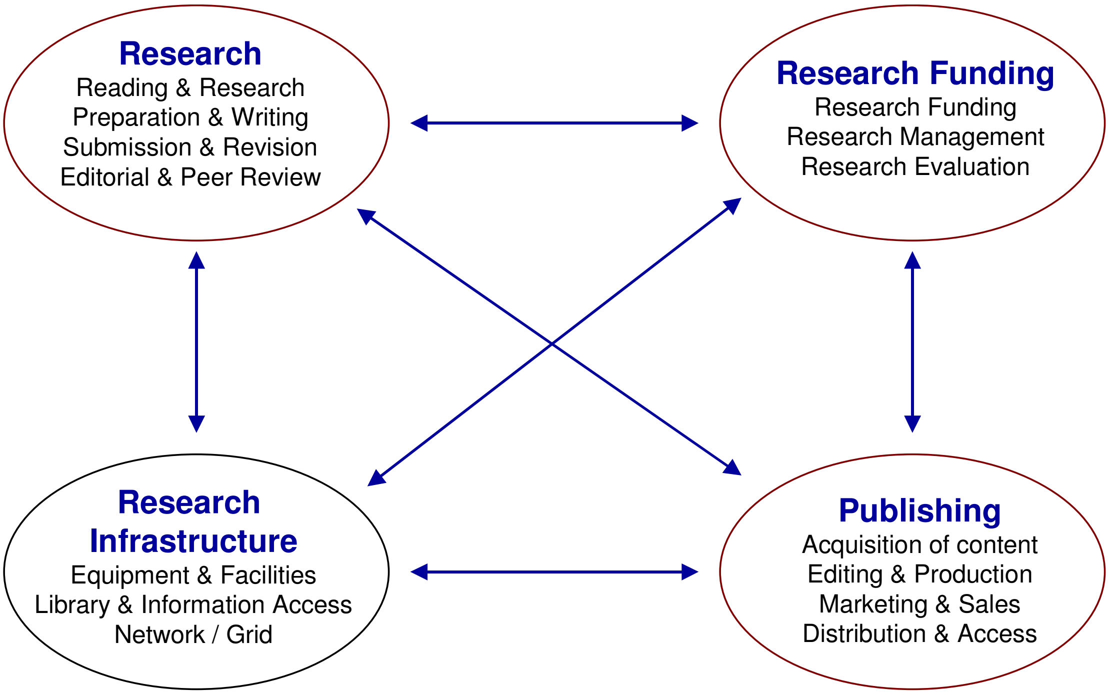
The emergence of the web and of open access archives and repositories has provided the foundations for a disaggregation of these functions and the emergence of a layered system, consisting of a content layer and a services layer. At the same time, publishing has become more integrated into research and both it and research are becoming more integrated into other activities across innovation systems, with knowledge production becoming more diffuse, and invention, innovation and diffusion increasingly iterative and interdependent. Moreover, publishing is increasingly used for non-communicative purposes (*e.g.* research evaluation and accreditation of individuals and institutions).

As result, however detailed, analyses that focus on publishing activities alone are unlikely to reflect the system wide costs or benefits involved. Cost models must include the activities related to publishing *and* those related to system functions, including such things as research evaluation, the promotion and marketing of education and research institutions, and investment in, and the operation of, supporting research infrastructure (Figure 3.1). Scholarly communication costs, therefore, include:

- *Research* – the costs associated with the research that enables the production of the article, monograph or other composition, its writing and preparation, submission and revision, and editorial and peer review activities;

- *Publishing* – the costs associated with acquisition of content, editing and production, marketing and sales, and distribution and access;
- R*esearch infrastructure (distribution)* – the costs associated with access to findings, including library infrastructure and activities (*e.g.* acquisition/accession, shelving, archiving, etc.), the provision of equipment for access (*e.g.* desktop computers), and the network infrastructure for access (*e.g.* high bandwidth research networks and e-science grid computing facilities); and
- *Research infrastructure (funding and management)* – the costs associated with research funding, research management and the evaluation of research activities.

Figure 3.1 Scholarly publishing activities and costs



Source: Author's Analysis.

3.2 Scholarly communication costs in Australia

An extensive literature review (See Appendix I) informed the development of a model of the costs associated with various scholarly communication activities in Australia, with the activity costs and times cited in the literature used as the basis for calculation of equivalents for Australia. These have been supplemented and refined through local data collection and a series of interviews with local stakeholders. Inevitably, a number of simplifying assumptions must be made in the construction of such a model and these preliminary costing should be taken as no more than a first approximation, intended to scope local activities rather than provide detailed costings.

Research costs

Costs associated with research activities are based on those found in the literature. Activity times are translated into costs using the AVCC guide to full cost recovery for non-laboratory contract research activities, and they include full staff salary and on-costs as well as overhead costs. Results are presented as a total for the activities in Australian higher education and on a per item basis, and they refer to the most recent year (typically 2004, or the most recent year reported in the particular data collection concerned). Key assumptions are explained in the accompanying boxes.

Table 3.1 Activity costing estimates for Australian higher education, circa 2003-04 (AUD per annum)

Annual Activity Costs	*Lower Bound*	*Upper Bound*	*Mean / Higher Education*
Reading (Published Staff)	2,036,200,000	3,423,700,000	2,698,700,000
Reading (Academic Staff)	3,507,900,000	5,898,300,000	4,649,300,000
Writing (HERDC compliant publications only)	325,400,000	604,100,000	480,100,000
Peer Review (Scaled to HERDC)	39,900,000	177,800,000	100,200,000
Editorial activities (Scaled to published staff)	13,300,000	59,400,000	33,100,000
Editorial board activities (Scaled to published staff)	1,700,000	5,800,000	3,500,000
Preparing Grant Applications (ARC & NHMRC)	77,500,000	143,900,000	114,400,000
Reviewing Grant Applications (ARC & NHMRC)	9,800,000	35,100,000	21,700,000
Publisher Costs (Scaled to HERDC)	104,100,000	190,500,000	147,700,000
Scholarly communication system costs	*2,607,900,000*	*4,640,400,000*	*3,599,500,000*

Note: All costings relate to Australian higher education. Total system costs include core scholarly communication activities only.
Source: CSES project model, Author's analysis.

Writing (≈AUD 480 million pa)

Nationally, in higher education institutions it is estimated that it costs around AUD 480 million per year to write those publications counted in the Higher Education Research Data Collection (HERDC) alone – of which AUD 355 million would relate to refereed journal articles and conference papers, AUD 85 million to research monographs and AUD 40 million to book chapters. No account is taken of the cost of producing other outputs, publications that do not qualify for inclusion in the HERDC collection or those rejected for publication.

It is further estimated that the preparation of ARC and NHMRC grant applications by higher education institutions in Australia costs around AUD 114 million a year in researcher time alone. No account is taken of other grant application and tendering activities.

On a per item basis it is estimated that in Australian higher education institutions it costs around AUD 13,000 to write a refereed journal article, conference paper or book chapter, and around AUD 150,000 to write a research monograph.

Box 3.1 Key assumptions in research costings

Researcher costs are based on the AVCC guide to full cost recovery for contract research and approximate full costing (AVCC 1996). The salary range used is $50,000 to $110,000 plus oncosts (52%) and overheads (92% of salary and oncosts), following the AVCC guide. Overhead costs are averaged and distributed across the range. An hourly rate is calculated on the basis of 'official' work time, at 230 working days per year and 7.5 hours per day.

Staff producing publications is the number of staff 'generating publications' reported in the most recent *Research and Research Training Management Reports* (typically 2002 or 2003). Total academic staff includes those counted as teaching only, research only and research and teaching staff in 2004. Estimates of the number of academics involved in peer review, editorial broad and editorial activities are based on an international survey of more than 5,500 active authors, which is confirmed by a more focused German study.

Time to produce an article is derived from the literature review (based primarily upon US surveys). Time to produce a monograph is assumed to be 12 times that to produce an article, based on average chapter counts and lengths, and has been confirmed in industry consultations.

Time to review an article is derived from the literature review (based primarily upon US surveys). Time to review a monograph is assumed to be 4 times that to review an article, based on industry consultations. It is also assumed that there are 2 to 3 external peer reviewers, based on both the literature review and publishing industry consultations (median 2.5 per article and 2.25 per monograph).

Time spent reading an article and the number read per year are derived from the literature review (based primarily upon US surveys). Times spent reading other materials are based on page count equivalents (at 1 hour per 20 pages).

Times spent on editorial activities are derived from the literature review and publishing industry consultations. It is assumed that editors spend 10 to 30 days per year on editorial activities and editorial board members spend ½ to 1 day per year. Activity and costs are scaled to publishing.

Publication data are taken from HERDC reporting and are unweighted counts averaged over two years (2002-2003). While this may introduce some minor double counting in relation to collaboration, for the purposes used here it is a reasonable approximation.

Peer review load is assumed to scale to production (*i.e.* if we publish 2.9% of the world's papers we peer review 2.9%, with inflow and outflow of international reviewing cancelling each other out). For journal articles it is assumed that 40% of manuscripts are rejected, of which 75% are re-submitted elsewhere. For monographs, chapters and refereed conference papers it is assumed that 20% of manuscripts are rejected on first review, of which 1/2 are re-submitted elsewhere.

Preparation of grant applications costs are based on the number of ARC and NHMRC applications, assuming that each takes a similar time to prepare as does a journal article. Counts include all ARC applications and the NHMRC grants for which a university is the administering institution (excluding affiliated hospitals and specialist centres). The commencing 2004 round is used in both cases.

Review of grant applications costs is based on the number of ARC and NHMRC application reviews, that there are 3-6 external reviewers for ARC (median 4) and 2-5 for NHMRC (median 3), and that reviews take a similar time to conduct as peer review of a journal article (confirmed with both agencies). There is a further assumption that we do overseas reviews in proportion to the overseas reviewing done for us (with international reviewing cancelling out). The higher education load is estimated as all ARC assessments and scaled to that proportion of NHMRC grants that go to universities.

Peer review (≈AUD 120 million pa)

Assuming that peer review activities scale to HERDC compliant publication (*i.e.* peer reviewed publication), it is estimated that peer review activities in higher education cost around AUD 100 million a year – of which perhaps AUD 90 million would relate to the peer review of journal articles and conference papers, AUD 6.5 million to book chapters and AUD 4.5 million to research monographs. No account is taken of reviewing other outputs.

It is further estimated that peer review of higher education related ARC and NHMRC grant applications costs a further AUD 22 million, bringing the total costs of peer review activities in Australian higher education to some AUD 120 million a year. No account is taken of other peer reviewing activities relating to other grants.

On a per item basis, it is estimated that in Australian higher education institutions it costs around AUD 1,700 to peer review of each journal article, AUD 1,500 to peer review each refereed conference paper or book chapter, and AUD 6,000 to peer review each research monograph.

Editorial activities (≈AUD 37 million pa)

Based on an extensive international survey of more than 5,500 researchers, it is estimated that Australian higher education editorial activities relating to scholarly journals alone costs perhaps AUD 37 million a year – of which AUD 33 million might relate to editorial activities and AUD 3.5 million to editorial board activities. No account is taken of other editorial activities (*e.g.* internal working papers, contract research reports, etc.) or of activities relating to monographs. The level of payments and/or honoraria received in recompense for these activities is unknown.

Reading (≈AUD 4,650 million pa)

Based on extensive international surveys, it is estimated that reading by higher education staff may cost AUD 4.6 billion a year – of which around AUD 3 billion might relate to books, AUD 865 million to journal articles and AUD 650 million to other research materials (*e.g.* conference papers, technical reports, etc.). Of the total, reading among the sub-set of higher education staff who are actively publishing might cost AUD 2.7 billion.

On a per item basis, it is estimated that in Australian higher education institutions it costs around AUD 130 for each reading of a journal article, refereed conference paper or book chapter, and AUD 1,900 for each reading of a research monograph.

Publishing costs

Publishing costs are based on a wide ranging review of studies of the costs associated with publishing, supplemented by local consultation with senior publishing industry executives. They are presented per item and as a total of those activities for Australia (based on higher education publishing activities).

It is estimated that publisher costs relating to those Australian higher education publications reported in the HERDC alone amount to around AUD 150 million a year – of which AUD 90 million relates to journal articles, almost AUD 35 million to monographs, AUD 17 million to book chapters and around AUD 7 million to other publications (*e.g.* conference papers and proceedings, technical reports, etc.). While no specific costing is given, these publisher costs implicitly include rejected manuscripts and repeat submissions.

Box 3.2 Key assumptions in publishing costings

Per item publishing costs are based on 'consensus' averages taken from a wide ranging literature review. For research monographs estimates are based on the literature review and consultations with senior publishing industry figures.

National and institutional publishing costs are based on the above and HERDC reporting of the number of items produced. Hence, they include no more than a subset of what is actually produced.

On a per item basis, it is estimated that publisher production costs for a journal article average around AUD 4,500, publisher costs per research monograph exceed AUD 60,000 and those for a book chapter around AUD 5,000. There is substantial variation between publishers and by discipline.

Library, access, repository and e-press costs

Library costs are calculated primarily from CAUL library statistics for 2004 (www.caul.edu.au). They reflect the per item and total acquisition and non-acquisition costs of Australian university libraries. These university library and infrastructure costs are a part of higher education overhead costs and are, implicitly, already included within the research related activity costings outlined above.

Box 3.3 Key assumptions in library costings

Library costs are derived primarily from CAUL statistics relating to higher education and to individual institutions. CAUL totals are those of the Australian member institutions. However, some of the consortial deals include non-higher education partners and New Zealand universities. In such cases, calculations, such as cost per download, refer to the consortium administered by CAUL.

Access and usage costs are derived from CAUL statistics and a range of publishing industry sources. Subscription prices paid by individual institutions are often based on their historical print subscription expenditures and vary considerably from one institution to another. Moreover, statistical collections are neither entirely comparable nor complete. As a result, cost per download estimates can be no more than indicative.

Open Access archive and repository costs are based on 'consensus' lower and upper bound estimates taken from an extensive review of the literature, supplemented by local consultations. Counts are derived from e-prints.org surveys and from local case studies.

Table 3.2 Content and infrastructure costing estimates for Australian higher education, circa 2004 (AUD per annum)

Annual Content & Infrastructure Costs	*Lower Bound*	*Upper Bound*	*Mean / Higher Education*
Library Acquisition	..	..	181,900,000
Library non-Acquisition	..	..	316,800,000
Acquisition Cost per Serial Title	..	..	76
Implied acquisition cost per Article	..	..	< 1
Cost per download	1.24	10.11	4.49
Acquisition Cost per non-serial item	..	..	60
Author-Pays Fees for all HERDC articles	13,500,000	80,800,000	47,100,000
Repository/ Archive Costs (Estimated)	2,000,000	10,000,000	6,000,000
Institutional E-press Costs (Estimated per e-press)	525,000	730,000	625,000
Research Management (Estimated)	..	..	36,800,000
ICT Infrastructure (Estimated Total Expenditure)	806,900,000	1,344,800,000	1,075,900,000

Source: CSES project model, Author's analysis.

Content acquisition (AUD 182 million pa)

Those Australian university libraries reporting to CAUL reported total expenditure of almost AUD 500 million during 2004, of which AUD 182 million was spent on content acquisition – AUD 125 million on serials and AUD 56 million on non-serials. In 2004, total acquisition expenditures amounted to around AUD 5,180 per FTE academic staff. On a per item basis, access to serials titles cost an average AUD 76 each, while non-serial items cost an average AUD 60.[5]

Based on averages derived from an analysis of almost 5,000 journal titles, the implied cost of providing higher education access per journal article under CAUL subscriptions was less than AUD 1 (*i.e.* 63 cents). However, it should be noted that this estimate is no more than approximate because not all serial items are journals and some of the articles included within the subscription packages may be open access (*i.e.* free within the bundle).

The cost per download for a sample of seven of the larger publishers' packages subscribed to through CAUL during 2005 ranged from a low of around AUD 1.24 to a high of AUD 10.11 (weighted mean AUD 3.60, unweighted mean AUD 4.49).[6] These compare with the mean costs per download across four major publishers reported from a sample of UK academic research libraries of AUD 3.25 to AUD 7.30 (unweighted mean AUD 5.00) (Woodward and Conyers 2005).[7]

Table 3.3 Implied download costs for CAUL subscription packages, 2005

	Downloads (Full Text, 2005)	*Cost Per Download (AUD)*
Publisher A	172,353	9.02
Publisher B	234,082	10.11
Publisher C	339,282	1.24
Publisher D	555,148	2.07
Publisher E	1,067,069	5.31
Publisher F	1,046,072	1.53
Publisher G	323,543	2.16
Mean of packages		4.49
Weighted mean of downloads		3.60

Note: These publishers account for around half CAUL libraries' serials expenditure. Not all parties to the consortia are Australian higher education institutions.
Source: CAUL.

Non-acquisition (AUD 317 million pa)

Those Australian research libraries reporting to CAUL reported non-acquisition expenditure of AUD 317 million during 2004. While the actual distribution of these expenditures is unknown, the implied non-acquisition costs per content item held was AUD 10. If non-acquisition costs are distributed in proportion to acquisition costs, implied serials handling costs amount to AUD 218 million (AUD 132 per current title held) and implied non-serials handling costs amount to AUD 98 million (AUD 6.12 per item held). It should be noted, however, that library reporting varies in terms of what is included in overheads.

'Author-pays' (≈AUD 47 million pa)

There is a wide range of author fees charged by 'author-pays' journals, with references in the literature and many specific cases ranging from USD 500 to USD 3,000. At the mean of USD 1,750 per published article, 'author-pays' would have cost Australian higher education institutions around AUD 47 million during 2003.

It is impossible to make an 'apples with apples' comparison for costing purposes, but if one assumes that the articles published were randomly distributed across titles, then the comparable subscription costs to CAUL libraries during 2004 was around AUD 12,500 (to provide access to that many articles).

Hypothetically, if everything in the world were 'author-pays' open access and CAUL libraries were to cancel all their subscriptions, there would have been an implied annual saving of the order of AUD 80 million (at 2004 prices, publishing and subscription levels). Even more hypothetically, if Australia adopted 'author-pays' publishing *unilaterally* and CAUL libraries were able to cancel subscriptions to just those articles within the current packages without any change to the implied per article cost within the packages (which, of course, they cannot), then Australia would have been of the order of AUD 45 to 50 million worse off.

Repositories (≈AUD 2 to 10 million pa)

A wide range of repository establishment and operational costs are reported in the literature, due to the wide range of content scope and functionality offered and varying practices regarding the inclusion of overhead and 'in-kind' costs. A review of the literature would suggest average establishment costs of around AUD 9,000 and annual operating costs ranging from a low of AUD 4,000 to a high of AUD 80,000 per year (mean AUD 41,000). Assuming a 5 year depreciation of establishment costs, then on these figures mean annual costs per repository would be around AUD 42,500.

In January 2006, there were 23 Australian open access repositories with around 62,000 records listed by eprints.org. Hence, current estimated costs would be around $1 million per year, implying that the total costs of operating institutional repositories for all higher education institutions in Australia might be of the order of AUD 2 million a year (with substantial variation). On a per item basis, it is estimated that it costs between AUD 18 and AUD 27 (mean AUD 23) to deposit an item on an open access repository if it is done by the author, and probably somewhat less if done by a dedicated member of staff. Nationally, this would imply a cost of some AUD 700,000 a year to deposit (*i.e.* self-archive) those publications reported in the HERDC alone (excluding edited books).

The level of functionality, the extent of advocacy, level of policy engagement, and the extent of integration with a broader range of objects than simple e-prints (*e.g.* monographs), generic digital curation, e-research infrastructure and activities, capture and/or digitisation of historical and cultural collections, learning objects, etc. are all crucial determinants of repository costs. Canvassing a small number of local examples unveiled annual repository costs of up to AUD 275,000 when all expenditures and staff time are included (costed as above). This may include some non-repository activities and undoubtedly includes early phase development costs.

These cost levels would suggest that total costs of operating institutional repositories for all higher education institutions in Australia might be up to AUD 10 million a year at the upper end, although the potential for the followers to learn from the experience of the leaders may reduce this significantly. Nevertheless, taking account of the policy, advocacy, management and operation of a substantial institutional repository, and fully costing staff time involved, suggests that institutions might expect costs to be of the order of AUD 200,000 a year.

E-presses (≈AUD 625,000 each)

The convergence of e-presses and open access archives/repositories is another development which is having a significant impact on scholarly publishing. Institutional repositories can provide a vehicle for institutional e-presses and help to minimise e-press publishing costs.

Information is limited, with few established e-presses operating in Australia, a range of strategies being pursued and a variety of services and scale. Nevertheless, indicatively, the Australian university e-presses studied reported direct staffing costs of around AUD 180,000 to AUD 250,000 a year. Applying the AVCC full cost recovery formula these are equivalent to annual operating costs of AUD 525,000 to AUD 730,000 (mean AUD 625,000 per annum). At these cost levels, per title monograph production costs appear similar to those of traditional print publishers. As in the case of open access archives and repositories, however, downloads appear to significantly exceed the sales of print copies of similar titles.

Research infrastructure and management costs

Research infrastructure and management costs relate to higher education ICT system costs, the management and operation of research funding and grant systems, the operation of institutional research offices for the collection and reporting of research outputs for evaluation, and the research time involved in them. Full costing would also include the operation of granting agencies and bodies.

Box 3.4 Key assumptions in research management costings

As noted, **preparation of grant applications costs** is based on the number of ARC and university-based NHMRC applications, assuming that each takes a similar time to prepare as a journal article.

The **review of grant applications costs** is based on the number of ARC applications and university NHMRC applications, assuming that there are 3-6 reviewers for ARC and 2-5 for NHMRC, and that reviews take a similar time to conduct as peer review of a journal article. There is a further assumption that we do overseas reviews in proportion to the overseas reviewing done for us.

Research offices operation costs are derived from consultations and a small number of local cases, with the national cost estimated based on scaling by research active staff.

ICT infrastructure costs have been estimated from preliminary CAUDIT benchmarking survey results.

ICT expenditure in higher education (≈AUD 1 billion pa)

Preliminary findings from CAUDIT's benchmarking study suggest that higher education institutions typically spend between 6% and 10% of their total income on ICTs (including hardware, software, staff, outsourcing and maintenance). This suggests total higher education ICT expenditure of the order of AUD 1 billion in 2004. There is insufficient information available to be able to apportion this expenditure between research, teaching and administrative activities.[8]

Research grants (≈AUD 160 million pa)

As noted above, it is estimated that the preparation of ARC and NHMRC grant applications in Australian higher education institutions alone cost between AUD 80 and AUD 140 million during 2004 (mean AUD 114 million). External peer review costs associated with such grants are estimated to have been around AUD 20 million in higher education alone.[9] No account is taken of other research grant sources and activities.

ARC and NHMRC agency costs amounted to around AUD 25 million, of which more than AUD 15 million was staff costs. There is insufficient information available to be able to apportion this expenditure between higher education and other institutions. No account is taken of other research granting agencies and activities, or of the monitoring and management thereof.

University research office operations (≈AUD 35 million pa)

There is no central reporting of the activities of university research offices comparable to that of libraries (CAUL) and IT services (CAUDIT). Moreover, structures and activities vary widely, with some research offices operating centrally while others are more diffuse (*e.g.* decentralised data collection done within departments and faculties). Hence, it has not been possible to estimate the costs involved with any accuracy.

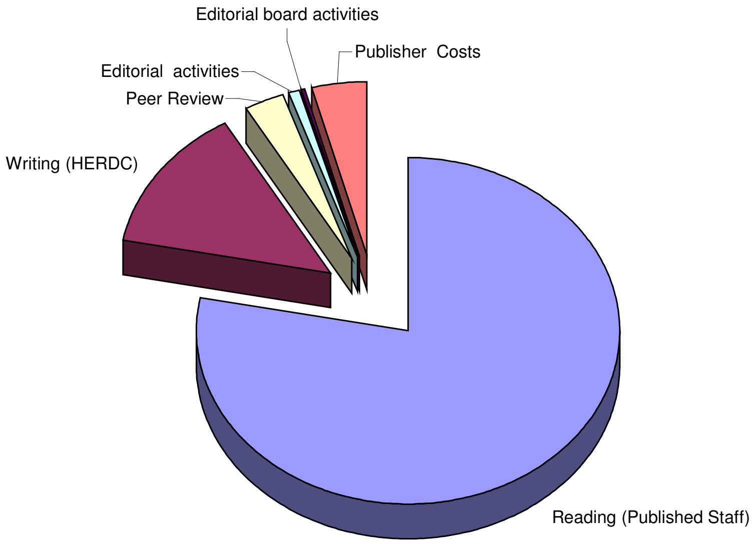
Nevertheless, based on the extrapolation of three diverse cases on an FTE staff basis, Australian higher education research office annual operating expenditures may be of the order of AUD 35 million, employing perhaps 350 staff. There is insufficient information to be able to apportion this expenditure between research reporting and other activities, and no account is taken of the reporting burden at the department and faculty levels.

Total scholarly communication system costs

Clearly, research communication costs are significant. Summing the estimated costs associated with core scholarly communication activities in Australian higher education (*including current higher education related ARC and NHMRC research grant application and review, reading for those higher education staff actively producing HERDC compliant publications, writing HERDC publications, related peer review and editorial activities, and related publishing costs*) gives an approximate estimate of overall system costs of between AUD 2.6 billion and AUD 4.6 billion (mean AUD 3.6 billion) per year (Figure 3.2).[10]

Nationally, these costs amount to around 30% of total higher education revenues and expenditures. Institutions vary, with estimated scholarly communication related costs accounting for 40% or more of total revenues and expenditures for some of the more research intensive universities (*e.g.* University of Queensland and Australian National University), and as little as 10% for others (*e.g.* Southern Cross and Charles Darwin Universities).

Figure 3.2 Scholarly communication system cost shares (per cent)



Source: CSES project model, Author's analysis.

Per item system costs of publications

The cost model created for this project is activity based, but it is possible to turn it around to calculate approximate estimates of system costs per item (*e.g.* the system costs of a journal article or research monograph). However, it should be noted that while production costs are national, reading costs are not – they are per item worldwide reading estimates based on Australian higher education costs. Moreover, they cannot simply be added – as library acquisition costs include publisher costs.

Journal article (production ≈AUD 19,000)

The production of a journal article in Australian higher education institutions is estimated to cost from AUD 12,500 to AUD 25,000 (mean AUD 19,000), depending primarily upon the salary levels of the author(s) and peer reviewers. Of the AUD 19,000, a mean of almost AUD 13,000 might relate to writing, some AUD 4,500 to publisher costs and AUD 1,700 to peer review. Library acquisition and handling costs amount to around AUD 2 per article.

At Australian higher education salary levels, average reading might add AUD 80,000 to AUD 140,000 (mean AUD 118,000), bringing mean system costs per article to an estimated average of AUD 140,000.

Research monograph (production ≈AUD 224,000)

The production of a research monograph in Australian higher education institutions is estimated to cost from AUD 155,000 to AUD 285,000 (mean AUD 224,000), depending primarily upon the salary levels of the author(s) and peer reviewers. Of the mean AUD 224,000, a mean of AUD 154,000 would relate to writing, some AUD 64,000 to publisher costs (per title), and AUD 6,000 to peer review. Library acquisition and handling costs amount to around AUD 65 (per item).

At Australian higher education salary levels, average reading might add AUD 1.2 to AUD 2.2 million (mean AUD 1.7 million), bringing mean system costs per monograph to an estimated AUD 1.9 million worldwide.

Table 3.4 Per item costing estimates for Australian higher education

Item Costs, per item (AUD circa 2004)	*Lower Bound*	*Upper Bound*	*Mean / Higher Education*
Cost of a journal article			
Writing	8,700	16,200	12,900
Peer review	700	2,900	1,700
Publisher related	3,100	6,000	4,500
Library acquisition	0.63	0.63	0.63
Library handling	1.10	1.10	1.10
Per article production	*12,400*	*25,000*	*19,100*
Reading	81,400	141,000	117,900
Publisher share of production costs	25%	24%	24%
Cost of a research monograph			
Writing	104,600	194,100	154,300
Peer review	2,600	11,600	6,100
Publisher related	48,000	78,500	63,800
Library acquisition (per item)	60	60	60
Library handling (per item)	6	6	6
Per monograph production	*155,100*	*284,300*	*224,100*
Reading	1,225,300	2,184,000	1,674,900
Publisher share of production costs	31%	28%	28%
Cost of a book chapter			
Writing	8,700	16,200	12,900
Peer review	700	2,900	1,500
Publisher related	4,000	6,500	5,300
Library acquisition	5	5	5
Library handling	1	1	1
Per chapter production	*13,400*	*25,600*	*19,700*
Reading	81,400	141,000	117,900
Publisher share of production costs	30%	26%	27%

Note: Monograph costs are per title costs, except those relating to library acquisition and handling, which are per unit.
Source: CSES project model, Author's analysis.

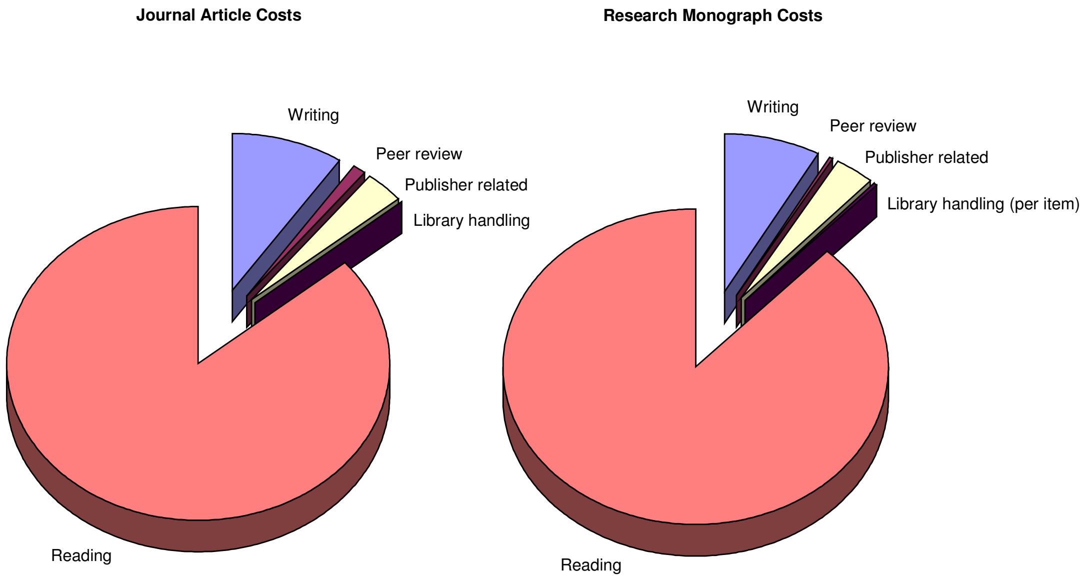
Book chapter (production ≈AUD 19,500)

The production of a book chapter in Australian higher education institutions is estimated to cost from AUD 13,000 to AUD 25,000 depending primarily upon the salary levels of the author(s) and peer reviewers – mean AUD 19,500, of which a mean of almost AUD

13,000 would relate to writing, some AUD 5,300 to publisher costs and AUD 1,500 to peer review.

At Australian higher education salary levels, average reading might add AUD 80,000 to AUD 140,000 (mean AUD 118,000), bringing mean system costs per book chapter to an estimated AUD 138,000 worldwide.

Figure 3.3 Scholarly publishing cost proportions (Higher Education)



Source: CSES project model, Author's analysis.

It is clear that by far the largest share of costs in the scholarly publishing system is researcher time in reading, writing and peer review activities. Library and content access costs are relatively modest.

System costs by institution

In most cases it is possible to derive costings from this model for individual higher education institutions. However, it should be noted that these disaggregated data are substantially less reliable. They are at best indicative, and should be taken as no more than an approximate guide.

The following tables present estimated mean annual scholarly communication related activity, content access and infrastructure costings for all AVCC member higher education institutions in Australia. Overall, they suggest that these research and scholarly publishing activities account for between 10% and 45% of total institutional expenditures, depending upon the research (publishing) intensity of the institution, and for around 30% across higher education nationally.

Box 3.5 Key assumptions in institutional costings

Most assumptions are the same at the institutional and national levels (see above).

Researcher costs are based on the AVCC guide to full cost recovery for contract research and approximate full costing. The salary range used is $50,000 to $110,000 plus oncosts (52%) and overheads (92% of salary and oncosts). An hourly rate is calculated on the basis of 'official' work time, as 230 working days per year and 7.5 hours per day.

Staff producing publications is the number of staff 'generating publications' reported in the most recent *Research and Research Training Management Reports* (typically 2002). Total academic staff includes those counted as teaching only, research only and research and teaching staff in 2004.

Estimates of the number of staff involved in peer review, editorial broad and editorial activities are scaled to the number of staff producing publications and reflects participation in scholarly publishing activities.

Peer review load is assumed to scale to publication, with publication data taken from institutional HERDC reporting as counts averaged over two years 2002-2003.

Preparation of grant applications costs are based on the number of institutional ARC and NHMRC applications in 2004. Counts include grants for which the university is the administering institution, which in some instances will exclude affiliated hospitals and specialist centres. The commencing 2004 round is used in both cases.

Review of grant applications costs are scaled to the number of institutional ARC and NHMRC applications.

Table 3.5 Mean research activity costing estimates for Australian higher education institutions (AUD per annum)

	Reading (Published)	*Reading (Academic)*	*Writing (HERDC)*	*Peer Review*	*Journal Editorial Activities*	*Editorial Board Activities*	*Preparing Grant Applications*	*Reviewing Grant Applications*	*Publisher Costs*
Australian National University	184,520,000	271,620,000	34,320,000	6,470,000	2,260,000	240,000	9,090,000	1,860,000	12,210,000
University of Canberra	26,740,000	44,080,000	3,610,000	630,000	330,000	30,000	310,000	60,000	1,140,000
Charles Sturt University	30,440,000	71,480,000	5,930,000	1,100,000	370,000	40,000	360,000	80,000	1,790,000
Macquarie University	46,060,000	102,320,000	11,760,000	2,280,000	570,000	60,000	2,790,000	580,000	3,760,000
Southern Cross University	4,770,000	35,210,000	2,580,000	530,000	60,000	10,000	400,000	80,000	770,000
University of New England	23,430,000	63,140,000	5,560,000	1,080,000	290,000	30,000	1,070,000	220,000	1,800,000
University of New South Wales	154,870,000	267,120,000	33,250,000	7,170,000	1,900,000	200,000	9,060,000	1,780,000	10,290,000
University of Newcastle	73,070,000	121,380,000	11,420,000	2,460,000	900,000	90,000	3,190,000	640,000	3,290,000
University of Sydney	211,390,000	307,760,000	37,750,000	8,430,000	2,590,000	270,000	11,640,000	2,240,000	12,580,000
University of Technology, Sydney	63,270,000	113,840,000	9,370,000	1,890,000	780,000	80,000	2,030,000	420,000	2,510,000
University of Western Sydney	59,040,000	105,630,000	10,320,000	2,020,000	720,000	80,000	1,240,000	260,000	2,890,000
University of Wollongong	61,550,000	90,410,000	10,450,000	2,160,000	760,000	80,000	2,730,000	560,000	2,840,000
Charles Darwin University	6,350,000	20,910,000	1,420,000	320,000	80,000	10,000	420,000	80,000	490,000
Bond University	7,020,000	..	1,370,000	250,000	90,000	10,000	120,000	20,000	460,000
Central Queensland University	24,750,000	51,760,000	3,460,000	690,000	300,000	30,000	150,000	30,000	800,000
Griffith University	92,660,000	144,280,000	13,130,000	2,690,000	1,140,000	120,000	2,640,000	540,000	3,980,000
James Cook University	25,940,000	77,300,000	5,570,000	1,370,000	320,000	30,000	900,000	180,000	1,700,000
Queensland University of Technology	91,470,000	133,560,000	13,270,000	2,770,000	1,120,000	120,000	2,450,000	500,000	3,310,000
University of Queensland	275,190,000	335,290,000	36,790,000	8,250,000	3,380,000	360,000	11,250,000	2,200,000	11,870,000
University of Southern Queensland	17,870,000	58,240,000	2,120,000	470,000	220,000	20,000	360,000	80,000	530,000
University of the Sunshine Coast	5,030,000	13,370,000	950,000	190,000	60,000	10,000	30,000	10,000	290,000
Flinders University of South Australia	52,950,000	86,170,000	9,500,000	2,100,000	650,000	70,000	1,860,000	350,000	3,240,000
University of Adelaide	75,580,000	161,090,000	18,550,000	4,330,000	930,000	100,000	5,750,000	1,090,000	6,050,000
University of South Australia	59,960,000	119,130,000	10,440,000	2,140,000	740,000	80,000	2,700,000	560,000	2,520,000
University of Tasmania	67,240,000	89,880,000	9,620,000	2,060,000	830,000	90,000	2,550,000	520,000	3,030,000
Deakin University	77,170,000	112,380,000	10,990,000	2,340,000	950,000	100,000	2,000,000	420,000	2,920,000
La Trobe University	57,580,000	137,270,000	12,590,000	2,350,000	710,000	70,000	2,170,000	440,000	4,240,000
Monash University	211,920,000	321,130,000	35,330,000	7,320,000	2,600,000	270,000	7,270,000	1,400,000	10,570,000

Cont'd.

	Reading (Published)	*Reading (Academic)*	*Writing (HERDC)*	*Peer Review*	*Journal Editorial Activities*	*Editorial Board Activities*	*Preparing Grant Applications*	*Reviewing Grant Applications*	*Publisher Costs*
RMIT University	65,790,000	141,240,000	11,530,000	2,190,000	810,000	90,000	2,020,000	420,000	2,760,000
Swinburne University of Technology	36,800,000	60,490,000	5,200,000	1,060,000	450,000	50,000	1,290,000	270,000	1,250,000
University of Ballarat	13,370,000	26,210,000	2,400,000	430,000	160,000	20,000	370,000	80,000	720,000
University of Melbourne	158,180,000	333,440,000	41,410,000	8,720,000	1,940,000	210,000	13,880,000	2,610,000	13,530,000
Victoria University of Technology	34,810,000	74,130,000	7,340,000	1,340,000	430,000	50,000	630,000	130,000	2,080,000
Curtin University of Technology	88,950,000	136,470,000	9,030,000	1,890,000	1,090,000	120,000	2,090,000	420,000	2,440,000
Edith Cowan University	31,110,000	71,480,000	7,570,000	1,420,000	380,000	40,000	710,000	150,000	1,810,000
Murdoch University	43,680,000	64,070,000	7,200,000	1,420,000	540,000	60,000	1,140,000	240,000	2,320,000
University of Western Australia	117,940,000	178,430,000	20,730,000	4,580,000	1,450,000	150,000	6,130,000	1,170,000	6,760,000
Australian Catholic University	12,440,000	46,990,000	3,570,000	560,000	150,000	20,000	350,000	70,000	1,180,000
Total Higher Education	2,698,730,000	4,649,310,000	480,140,000	100,210,000	33,110,000	3,500,000	114,410,000	21,720,000	147,730,000

Note: .. not data.
Source: CSES project model, Author’s analysis.

Table 3.6 Mean infrastructure and management activity costing estimates for Australian higher education institutions (AUD per annum)

	Library Acquisition Expenditure	Library non-Acquisition Expenditure	Access cost per serial title	Implied access cost per article	Implied Author-Pays Fees	Repository/ Archive Costs	*Estimated* Research Office Expenditure	*Estimated* ICT Expenditure
Australian National University	7,310,000	8,080,000	100	0.83	3,110,000	..	..	..
University of Canberra	1,320,000	3,130,000	20	0.16	260,000	..	..	..
Charles Sturt University	2,290,000	5,600,000	66	0.55	460,000	..	..	..
Macquarie University	5,150,000	9,740,000	98	0.82	1,050,000	..	..	..
Southern Cross University	1,250,000	2,910,000	31	0.25	250,000	..	..	..
University of New England	2,410,000	3,500,000	57	0.47	500,000	..	..	..
University of New South Wales	10,870,000	12,560,000	124	1.03	3,510,000	..	..	..
University of Newcastle	6,130,000	6,320,000	74	0.62	1,170,000	..	..	..
University of Sydney	10,920,000	18,850,000	121	1.00	4,500,000	..	..	..
University of Technology, Sydney	6,850,000	10,820,000	99	0.82	770,000	..	..	..
University of Western Sydney	7,610,000	10,610,000	70	0.58	830,000	..	..	..
University of Wollongong	4,080,000	5,360,000	108	0.90	870,000	..	..	..
Charles Darwin University	1,240,000	2,910,000	27	0.22	170,000	..	..	..
Bond University	1,080,000	1,970,000	18	0.15	110,000	..	..	..
Central Queensland University	1,940,000	5,320,000	29	0.24	220,000	..	..	..
Griffith University	5,720,000	7,520,000	79	0.66	1,220,000	..	..	..
James Cook University	3,510,000	3,710,000	91	0.75	740,000	..	..	..
Queensland University of Technology	3,570,000	9,600,000	41	0.34	1,120,000	..	..	..
University of Queensland	13,870,000	14,860,000	158	1.31	4,290,000	..	..	..
University of Southern Queensland	2,060,000	3,040,000	48	0.40	190,000	..	..	..
University of the Sunshine Coast	1,100,000	1,130,000	22	0.18	80,000	..	..	..
Flinders University of South Australia	3,220,000	4,880,000	97	0.80	1,150,000	..	..	..
University of Adelaide	5,330,000	8,030,000	72	0.60	2,370,000	..	..	..
University of South Australia	1,550,000	9,370,000	23	0.19	840,000	..	..	..
University of Tasmania	3,620,000	5,150,000	52	0.43	1,040,000	..	..	..
Deakin University	5,650,000	22,410,000	43	0.35	1,010,000	..	..	..

Cont'd.

	Library Acquisition Expenditure	Library non-Acquisition Expenditure	Access cost per serial title	Implied access cost per article	Implied Author-Pays Fees	Repository/ Archive Costs	*Estimated* Research Office Expenditure	*Estimated* ICT Expenditure
La Trobe University	6,120,000	10,370,000	141	1.17	1,100,000	..	..	..
Monash University	14,590,000	30,850,000	119	0.99	3,360,000	..	..	..
RMIT University	5,350,000	11,480,000	65	0.54	730,000	..	..	..
Swinburne University of Technology	1,930,000	4,640,000	31	0.26	420,000	..	..	..
University of Ballarat	1,420,000	1,670,000	35	0.29	170,000	..	..	..
University of Melbourne	10,860,000	17,600,000	121	1.00	4,380,000	..	..	..
Victoria University of Technology	2,620,000	7,430,000	21	0.18	490,000	..	..	..
Curtin University of Technology	4,980,000	9,210,000	109	0.90	790,000	..	..	..
Edith Cowan University	2,350,000	4,890,000	63	0.52	480,000	..	..	..
Murdoch University	2,940,000	4,870,000	50	0.41	660,000	..	..	..
University of Western Australia	6,420,000	9,170,000	117	0.97	2,390,000	..	..	..
Australian Catholic University	1,470,000	4,950,000	79	0.65	220,000	..	..	..
Total Higher Education	181,910,000	316,790,000	76	0.63	47,110,000	..	36,810,000	1,075,870,000

Note: .. insufficient data for estimation.
Source: CSES project model, Author's analysis.

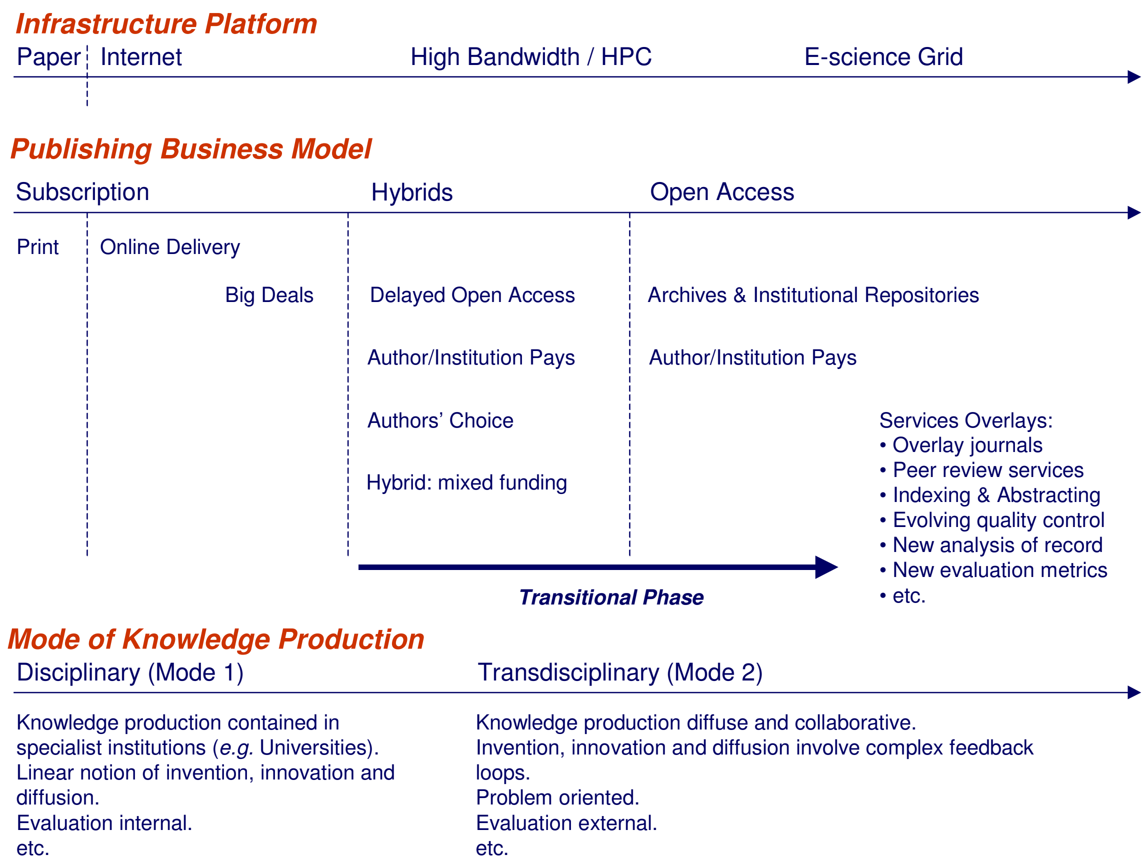
4 Benefits of Enhanced Access

There has been extensive discussion of publishing costs in the literature, but to date less attention has been paid to the potential benefits of the various emerging models for scholarly communication. It is always more difficult to estimate the benefits than it is to estimate the costs involved, but for the sake of informed policy discussion it is important that we begin to put some 'ball park' figures on the benefits side of the equation. This section builds upon a review of the literature discussing the benefits of enhanced access (See Appendix II for the literature review), and seeks to quantify some of those benefits.

4.1 Identifying the benefits that might be measured

To measure the potential benefits of emerging more open access scholarly publishing models it is necessary to identify the possible dimensions of benefits that might be measured and the methodologies that might be used to calculate impacts/benefits.

Figure 4.1 Evolution of scholarly communication



Source: Author's Analysis.

What states are being compared?

To estimate the scope and scale of potential benefits one must establish a starting point. With such rapid change, doing so is far from simple. Nevertheless, it seems plausible to assume that we can compare subscription publishing and the 'Big Deal' circa 2004 (when it was still the dominant mode of scholarly publishing), with a hypothetical open access system in which all publicly funded research findings are immediately available open access (*e.g.* a worldwide system of fully functioning and populated federated repositories), with a continuum between that includes delayed open access, author choice and 'author-pays' models. Figure 4.1 represents this continuum, highlighting the relationships between changes in publishing business models, the information technology environment, changing research practices and modes of knowledge production – with the ICT infrastructure enabling, and changing research practices demanding new scholarly communication capabilities and mechanisms.

What are the possible dimensions of benefit?

The dimensions of potentially measurable benefits include impacts relating to research use, industry and government use, and use by the wider community.

Research

The most immediate benefits of enhanced and/or open access would be likely to accrue within research, wherein the dimensions of potential benefit include:

- Speed of access speeding up the research and discovery process, increasing returns to investment in R&D and, potentially, reducing the time/cost involved for a given outcome, and increasing the rate of accumulation of the stock of knowledge;
- Improved access leading to less duplicative research, saving duplicative R&D expenditure and improving the efficiency of R&D;
- Faster access leading to better informed research, reducing the pursuit of blind alleys, saving R&D expenditure and improving the efficiency of R&D;
- Wider access providing enhanced opportunities for multi-disciplinary research, inter-institutional and inter-sectoral collaborations;
- Wider access enabling researchers to study their context more broadly, potentially leading to increased opportunities for, and rates of, application/commercialisation; and
- Improved access leading to improved education outcomes, enabling a given education spend to produce a higher level of educational attainment (at least at the post secondary level), leading to an improvement in the quality of the 'stock' of researchers and research users.

Industry and government

Given relative levels of access under the subscription publishing system, it is possible that greater potential benefits lie in enhanced access for industry and government, wherein the dimensions of potential benefit include:

- The potential for wider access to both accelerate and widen opportunities for adoption and commercialisation of research findings, thereby increasing returns on public investment in R&D and on private investment in the commercialisation related activities;
- The potential for much wider access than the subscription publishing system gives for GPs/nurses, teachers/students, small firms in consulting, engineering, architecture, design, electronics, software, biotechnology, nanotechnology, etc., who currently have little or no access, with a positive impact on quality of services and, possibly, productivity in those sectors of the economy; and
- The potential for the emergence of new industries based upon the open access content – there are examples of new industries built on publicly accessible data (*e.g.* weather derivatives based on meteorological data), and there are potential futures for publishers to become value adding services providers overlaying open access content (*e.g.* peer review services, bibliometrics and webometrics for research evaluation, etc.). In turn, these might enhance research evaluation and lead to better focused R&D expenditures.

Impacts might be felt more in particular sectors (*e.g.* knowledge intensive services, biotechnology, etc.). Impacts in such areas as management and economic consulting and engineering might be significant, raising the quality of advice to the benefit of clients across the economy. There may also be significant impacts in policy development, through better informed policy debate and enhanced access to information underpinning policy decisions. One important dimension might be the potential for greater access for small and medium sized firms (SMEs), enabling SMEs to do more research internally, increasing the share of R&D undertaken by SMEs, and increasing the share of R&D done in industries and countries that include a relatively high share of SMEs (*e.g.* Australia).

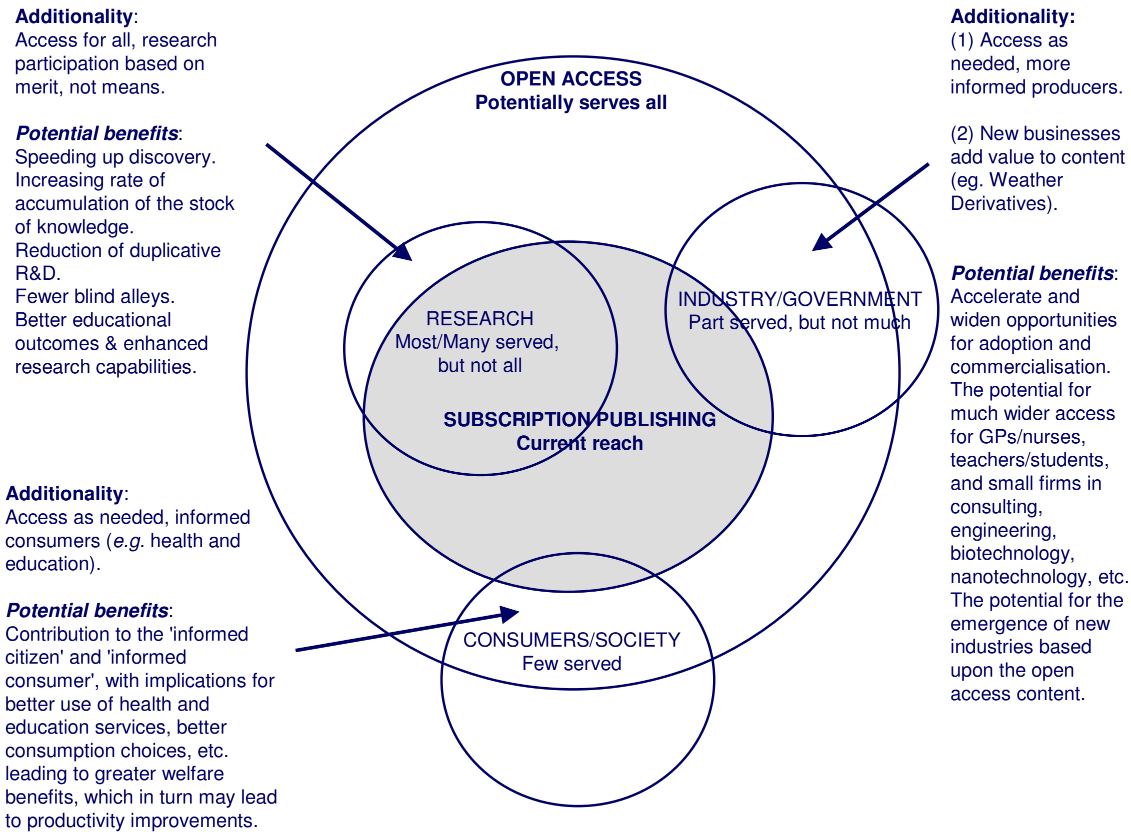
The wider community

In relation to the wider community, the dimensions of potential benefit include the potential contribution of open access to the 'informed citizen' and 'informed consumer', with implications for better use of health and education services, better consumption choices, etc. leading to greater welfare benefits, better health, etc., which in turn may lead to productivity improvements.

An impacts framework

These dimensions of impact are represented in Figure 4.2. It shows the potential expanded coverage and access available through open access. In the three spheres of activity identified, subscription publishing has served: most but not all research institutions; some but not many industry and government users; and few consumers. The additionality and some of the potential benefits of expanded access are also shown.

Figure 4.2 Impact framework: Subscription versus open access publishing



Source: Author's Analysis.

The mixes and extent of these potential benefits will depend upon many factors. For example, the internet is thought to have a range of potential impacts on information providers and users, from democratisation and wider participation, through reinforcement of existing centres and nodes, to a 'winner takes all' concentration (Schroeder, *et al.* 2005). To what extent these patterns may emerge in e-science and be played out across various fields of research is as yet unclear. So too is the extent to which such patterns might affect the quantity and quality of research done and accessed by potential users.

4.2 Quantifying some of the benefits

With such a range of potential benefits the task of fully exploring the impacts of enhanced/open access is beyond the scope of this project. Nevertheless, it is possible to gain some sense of the scale of potential impacts by developing impact scenarios focusing on the aggregate measure of social returns to investment in R&D, and developing a modified growth model which introduces 'access' and 'efficiency' variables into calculating the returns to R&D.

Increasing social returns to R&D

There have been many studies exploring the economic growth impacts of R&D – useful reviews of this literature include Industry Commission (1995), Dowrick (2003) and Allen Consulting Group (2005). The Science and Innovation Mapping Taskforce (2003, pp45-49) also presented a brief review of the literature and a summary of the mechanisms by which R&D contributes to economic growth. Studies have focused on firm level, industry level and economy wide returns on investment in R&D, with the former exploring the private returns and the latter social returns. The advantages of using social returns are the inclusion of a wide range of impacts and mechanisms, and the relative simplicity of using such an aggregate.

Box 4.1 Returns to investment in R&D

Estimates of private returns to firms' own investment in R&D still produce varying figures, but there is an emerging consensus that gross returns in the range between 20% and 30% are both common and plausible. Taking account of risk-premia required to finance commercial R&D and taking account of depreciation rates on R&D capital, the net private return on R&D investment appears to be broadly comparable with the return on investment in physical capital.

Microeconomic studies confirm the existence of significant spillovers of knowledge from the firms that perform the R&D to other firms and industries. Taking account of measured spillovers typically raises the estimated gross rate of return on business investment into the range between 30% and 40%. But authors warn that these are likely to be underestimates of the true social rate of return because the microeconomic studies do not usually cover all of the sectors of the economy.

Macroeconomic studies, which by definition cover all sectors of the economy, do indeed find significantly higher returns to R&D in OECD countries, with estimates ranging from 50 % to over 100 %. Macroeconomic studies that distinguish between public and private sector R&D and allow for longer lags for the latter to affect productivity, find that public sector R&D contributes significantly to productivity, albeit less strongly than private sector R&D.

Source: Dowrick, S. (2003) *A Review of the Evidence on Science, R&D and Productivity*, Department of Education, Science and Training, Canberra, p16.

The Federation of Australian Scientific and Technological Societies (FASTS) stated that "There have been a number of studies over the last six to ten years which, in a number of major OECD countries, have shown that the return on investment in R&D is of the level of 25-30% direct return (to the individual firm). Then there is an additional rate of return, which is another 25% on top of that, to raise it to the order of 50-60% return. That is known as a "social rate of return" whereby the indirect benefits of that research, which perhaps were not even envisaged by the original researcher, are captured by other people and turned into new products and new technologies (HORSCOSI 2003, p65). Hence, a conservative consensus from the literature is that the (national) social return on investment in R&D is 50% (of which around half are private returns).

Research impacts scenario (≈AUD 245 million pa)

The dimensions of benefit of open access for researchers outlined above can be expressed in various ways. Reductions in duplicative research and the pursuit of 'blind alleys' can be expressed as expenditure savings (or increases, assuming no substitution at the margin). Duplication, and the pursuit of blind alleys that may be known but not widely published (*e.g.* tendency not to publish negative or inconclusive results) may account for 1% or 2% of current research activity. With gross expenditure on R&D (GERD) in Australia of AUD 12,250 million in 2002-03 (ABS 2004), a 1% per annum saving through the reduction of duplicative research activity and the pursuit of 'blind alleys' (effectively a 1% per annum R&D expenditure increase) would effectively increase R&D spending by AUD 122 million per annum (in constant prices). Using a conservative 50% social returns figure, a 1% 'saving' from open access would increase social returns by more than AUD 60 million each year.

Impacts relating to the speed and breadth of access in the conduct of research, increasing efficiency and quality can be expressed as improvements in the effectiveness of R&D spending or increased return on investment. As a result of such impacts, social returns to R&D might rise by 3% (to 51.5%) – a very conservative assumption given the finding that open access journal articles are cited 50% to 250% more than subscription articles (Harnad 2005). With estimated social returns of the order of AUD 6,370 million, the potential impact of open access to Australian research would increase returns by around AUD 186 million each year (in constant prices). Again, the impact would be lagged, hence somewhat lower in net present value terms. Hence, total research related impacts might be worth AUD 245 million a year (in constant prices). Again, the impact would be lagged, hence somewhat lower in net present value terms.

Industry and government impacts scenario (≈AUD 190 million pa)

Given relative levels of access under the subscription publishing system it is likely that greater potential benefits lie in enhanced access for industry and government, with open access both accelerating and widening opportunities for the adoption and commercialisation of research findings. As noted, this might be particularly important for small firms (SMEs) in knowledge intensive manufacturing and services industries and for countries with a relatively large share of small firms (*e.g.* Australia).[11] Conservatively, given the potential scope of enhanced access, social returns to R&D might rise by a further 3% (to 53%). With estimated social returns of the order of AUD 6,560 million, the potential impact of open access to Australian research would increase returns by around AUD 190 million a year (in constant prices). Again, the impact would be lagged, hence somewhat lower in net present value terms.

The second dimension of industry and government impact of 'research use' might be the emergence of new industries based upon open access content – in the same way that industries have emerged based on open access to data. While it is impossible to second guess such developments, it is likely that there is considerable potential for the emergence of value adding service providers overlaying open access content (*e.g.* abstracting, indexing, peer review, bibliometrics, access systems, archiving, access and delivery services). It seems reasonable to assume that the immediate *net* impacts of open access would be neutral (involving both the decline of some existing and emergence of new publishing industry activities), and may well be positive in the longer term.

Consumer and society impacts scenario (≈AUD 195 million pa)

Research serves much wider social goals than the simply economic (*e.g.* health and quality of life, environmental quality and sustainability, and a range of social goals, such as freedom from crime, political and human rights, etc.). In relation to these wider social goals, the dimensions of potential impact include the potential contribution of open access to the 'informed citizen' and 'informed consumer', with implications for better use of health and education services, better consumption choices, etc. leading to greater welfare benefits, better health outcomes and healthcare expenditure savings, etc. In turn, these may have partly quantifiable economic impacts.

For example, a recent study commissioned by the Australian Society for Medical Research, found that annual economic rates of return to Australian health R&D through direct and indirect savings were up to AUD 5 for every AUD 1 spent on R&D (*i.e.* a 400% return on investment). By 1999, the annual gains of better and longer life relative to 1960 were worth AUD 264 billion per annum, of which AUD 142 billion was due to greater longevity (Access Economics 2003). Highlighting the links between research and health outcomes, Hatfield *et al.* (2000) suggested that:

> *Changes in survival rates in the immediate aftermath of acute events – heart attacks and strokes – are almost entirely a result of new technology, which puts a lower bound on the likely benefits from medical research at 20% of the reduction in mortality… Another 13% is tied to new drug therapies that reduce blood cholesterol. Thus roughly one-third of the total gain is apparently the result of medical research that led to new drugs and treatment protocols. However, some fraction of the credit for the other two-thirds also should go to research since gains attributed to public policy and individual behaviour depend on research-driven information.* (Hatfield *et al.* 2000, p8).

Access Economics (2003, p72) suggested that "rates of return to health R&D in Australia are exceptional, with annual rates of return between 1 and 5 times R&D expenditures (2.4 times in the 1999 base case)… Future R&D gains, even relatively small, have potentially stunning impacts. Reducing intentional and unintentional injuries by 30% would save over AUD 370 billion, greater than Australia's total net foreign debt. R&D that reduced deaths from cancer by one fifth would be worth AUD 184 billion to Australians, more than total forecast Commonwealth spending in the current fiscal year. Reducing cardiovascular events by 15% would be worth AUD 34 billion – exceeding our total federal health budget."

These studies demonstrate the enormous potential of enhanced/open access to the findings of health research to contribute of improved health and welfare outcomes. The example of Getz (2005) of a sevenfold increase in use of the MedLine Index upon shifting to open access, combined with the 30% use by non-professionals clearly suggests that there can be significant impact that is not realised with the access constraints imposed under the subscription publishing system.

When combined with impacts from the other areas of environmental and social research and education it is clear that the potential impacts are substantial. If they raised the social rate of return on Australian R&D by a very conservative 3% (to 54.6%), they would contribute a further AUD 195 million each year – bringing the total potential benefits to around AUD 635 million each year (in constant prices), with the impact lagged hence somewhat lower in net present value terms.

Publicly funded and conducted research

These estimates are based on Australia's gross expenditure on R&D (GERD). Were open access to apply to publicly funded research only the potential increases in social returns would be somewhat lower.

Reviewing a range of prior studies Dowrick (2003) reported mixed findings on the question of productivity and growth impact differences between public and private sector R&D. He concluded that macroeconomic studies find social returns to R&D in OECD countries ranging from 50% to over 100%, while those that distinguish between public and private sector R&D and allowing for longer lags for the latter to affect productivity, find that public sector R&D contributes significantly to productivity, albeit less strongly than private sector R&D. In the absence of specific studies of returns on publicly funded research, it seems reasonable to follow reported proportions and use 25% for estimated social returns from publicly funded and/or conducted R&D.

Publicly funded research impacts scenario (≈AUD 140 million pa)

By sector of funding, *government expenditure on R&D* (GovERD) amounted to AUD 5,438 million during 2002-03 (ABS 2004). Using all the same assumptions as the analysis above with the lower 25% returns to investment estimate, the potential benefits of open access would be: research impacts AUD 55 million per annum; industry and government use impacts AUD 42 million per annum; and community and wider social impacts AUD 44 million per annum – bringing the total potential benefits of open access to publicly funded Australian research to AUD 141 million per annum (in constant prices), with the impact lagged hence somewhat lower in net present value terms.

Public sector research impacts scenario (≈AUD 150 million pa)

Were open access to apply only to the results of *research conducted in public institutions* (*i.e.* government laboratories and higher education) then, using the same assumptions, the potential benefits of open access would be: research impacts AUD 60 million per annum; industry and government impacts AUD 46 million per annum; and community and wider social impacts AUD 48 million per annum – bringing the total potential benefits of open access to research conducted in Australian government and higher education institutions to almost AUD 153 million per annum (in constant prices), with the impact lagged hence somewhat lower in net present value terms.

Higher education research impacts scenario (≈AUD 90 million pa)

Were open access to apply only to the results of *research conducted in Australian higher education institutions* then, using the same assumptions, the potential benefits of open access would be: research impacts AUD 35 million per annum; industry and government impacts AUD 27 million per annum; and community and wider social impacts AUD 28 million per annum – bringing the total potential benefits of open access to research conducted in Australian higher education institutions to around AUD 89 million per annum (in constant prices), with the impact lagged hence somewhat lower in net present value terms.

Australian Research Council impacts scenario (≈AUD 12 million pa)

Were open access to apply only to ARC administered funding (NCGP) at 2004-05 levels then, using the same assumptions, the potential benefits of open access would be: research impacts AUD 5 million per annum; industry and government impacts AUD 4 million per annum; and community and wider social impacts AUD 4 million per annum – bringing the total potential benefits of open access to ARC administered funding R&D to around AUD 12 million per annum (in constant prices), with the impact lagged hence somewhat lower in net present value terms.

National Health & Medical Research Council impacts scenario (≈AUD 9 million pa)

Were open access to apply only to NHMRC grant expenditure at 2004 levels then, using the same assumptions, the potential benefits of open access would be: research impacts AUD 4 million per annum; industry and government impacts AUD 3 million per annum; and community and wider social impacts AUD 3 million per annum – bringing the total potential benefits of open access to NHMRC grant funded R&D to around AUD 9 million per annum (in constant prices), with the impact lagged hence somewhat lower in net present value terms.

A modified growth model

In this section we estimate the impacts of enhanced access using a modified growth model to explore returns to R&D. There is a vast literature estimating the rate of return to R&D, with much of it based upon the framework of the standard neo-classical growth model. A characteristic finding of that literature is that the rate of return to R&D is high (in the region of 30-60% per annum, and higher in some cases). Coe and Helpman (1993) and Jones and Williams (1998) have also shown that similar results arise from an endogenous growth model.

Returns to R&D in a simple growth model

In the basic Solow-Swan growth model, the key elements are a production function:

(1) $$Y = A^{\eta} K^{\beta} L^{\alpha}$$

where A is an index of technology, K is the capital stock and L is the supply of labour, where both K and L are taken to be fully employed by virtue of the competitive markets assumption, and an accumulation equation:

$$(2) \qquad \dot{K} = sY - \delta K,$$

where $\dot{K}$ is the net investment or the change in the net capital stock, equal to gross investment less depreciation, and δ is a constant depreciation rate. Substituting (1) into (2) gives

$$(3) \qquad \dot{K} = sA^{\eta} K^{\beta} L^{\alpha} - \delta K .$$

From (3) it is possible to determine the conditions for steady state growth in the capital stock.

Re-arranging, taking logarithms, differentiating with respect to time and imposing the condition that for steady state growth:

$$d/dt(\ln \dot{K}/K) = 0$$

gives:

$$(4) \qquad \dot{K}/K = \frac{\eta}{1-\beta} \dot{A}/A + \frac{\alpha}{1-\beta} \dot{L}/L$$

where $\dot{K}/K = \dot{C}/C = \dot{Y}/Y$, is the single constant steady state rate of growth of capital stock, consumption and output, respectively.

The main features of the Solow-Swan model are readily apparent from equation (4). Firstly, if technology and labour supply are fixed, the steady state growth rate is zero. That is, there is no endogenous growth in the model, growth being driven in the steady state by change in the exogenous variables. Secondly, if one of technology and population show positive growth then the steady state growth rate of the economy is proportional to the growth rate in that variable; if both rates are positive the economy's growth rate is a weighted average of the two. Thirdly, the steady state growth rate does not depend on either the level of savings or of investment in the economy. An economy that continuously saves and invests 20% of national income will have a higher level of output than one investing 5%, but it will not have a higher steady state growth rate. Thus the broad economic message of the Solow-Swan model is that steady growth is possible in a purely competitive world, provided that there is growth in either population or technology, or both.

Contributions to growth and total factor productivity

Solow (1957) further developed this model in a way that provided the foundations for the subsequent "growth accounting industry". Starting with total differentiation of the production function (1), and substituting for the partial derivatives of Y from (1) with respect to each of its arguments, yields:

$$(5) \qquad \dot{Y}/Y = \eta \dot{A}/A + \beta \dot{K}/K + \alpha \dot{L}/L .$$

Equation (5) can then be used in two main ways in the empirical study of growth. Given that in the competitive model capital and labour are paid their marginal products and assuming constant returns to scale, β and α can be estimated from the relative shares of capital and labour. A variant of (5) with those weights can then be used to estimate the relative contribution of capital, labour, technology and other factors to growth. Solow made pioneering estimates in 1957, the results of which he later described as “startling” (Solow 1987), and these have been much refined and amplified by Denison and others (Denison 1985). Solow found that 7/8th of the growth in real output per worker in the US economy between 1909 and 1949 was due to “technical change in the broadest sense” and only 1/8th to capital formation. Denison’s 1985 estimates covered the US economy for the period 1929 to 1982. Of the growth in real business output of 3.1% per annum over that period, he found that the increase in labour input with constant educational qualifications accounted for about 25% and capital input for 12%. Most of the remainder is accounted for by technological progress and by the increased human capital of the work-force. What was “startling” about these results was the relatively minor contribution to output growth arising from the increase in the traditional factors of production, capital and labour.

The other related use of equation (5) is to estimate the “Solow residual”, or total factor productivity. This is defined as the difference between output growth and the weighted sum of the growth rates of factor inputs (K and L), using constant return to scale weights. That is, total factor productivity growth (TFP) is given by:

$$(6) \qquad TFP = \dot{Y}/Y - \beta\dot{K}/K - \alpha\dot{L}/L\ ,$$

where $\beta = 1 - \alpha$, and β and α are derived from the shares of capital and labour in total income.

Total factor productivity is thus the growth in output not accounted for, on these assumptions, by the growth in capital and labour inputs. This method is now used very widely around the world in measuring productivity. This recent use has confirmed the broad Solow-Denison findings, in that for most modern economies total factor productivity growth is significantly more important than expansion of inputs in explaining total output growth. However, it must be remembered that the method rests on the assumptions embedded in the Solow model and that, as a consequence, the finding that the larger proportion of growth is to be explained by an exogenous “technical change in the broadest sense” constitutes something of an admission of defeat for economic analysis.

Estimating the rate of return to R&D

This basic framework has been adopted in a vast international literature to estimate the rate of return to R&D, which has been remarkably consistent in finding high private and social returns to R&D in modern industrial economies. For example, the Industry Commission (1995) concluded that the economy-wide rate of return to R&D was 50-90%:

> *On the assumption that the rate of productivity growth in the non-market sector has been zero, an economy-wide rate of return to Australia's R&D effort can be calculated at between 50 and 60 per cent. On the assumption that productivity growth in the non-market sector has equalled that in the market sector, the measured economy-wide rate of return to R&D rises to about 90 per cent* (Industry Commission 1995, Appendix QB.40).

The standard approach to such estimation is to divide the technology variable A in (1) into two components, a stock of knowledge variable R and a variable Z that represents a matrix of other factors affecting productivity growth. The production function then becomes:

$$(6) \qquad Y = K^{\alpha} L^{\beta} R^{\gamma} Z^{\eta},$$

and the counterpart of equation (5) becomes:

$$(7) \qquad \dot{Y}/Y = \alpha\,\dot{K}/K + \beta\,\dot{L}/L + \gamma\,\dot{R}/R + \eta\,\dot{Z}/Z.$$

That is, the rate of growth of the knowledge stock contributes to output growth as a factor of production, with elasticity γ. The rate of return to knowledge ($\partial y/\partial R$) is that continuing average per cent increment in output resulting from a one per cent increase in the knowledge stock. This can be readily derived from the elasticity γ by

$$(8) \qquad \partial y/\partial R = \gamma.\,(Y/R).$$

The normal approach to creating a measure of the stock of knowledge, for a given industry or for the economy as a whole, is to use the perpetual inventory method to create the knowledge stock from the flows of R&D, using the relationship:

$$(9) \qquad R_t = (1 - \delta)\,R_{t-1} + R\&D_{t-1},$$

where δ is the rate of obsolescence of the knowledge stock. This method also requires some starting estimates (R_0) of the knowledge stock, and estimates can be sensitive to that assumption. Then the capital stock at time *t* is given by:

$$(10) \qquad R_t = (1 - \delta)^t R_0 + \sum_{i=0}^{t-1} (1 - \delta)^I R\&D_{t-1}$$

Given a series for R and for the variables Z, it is then possible to estimate γ by either of the two methods noted above: estimate equation (7) with the parameters α .. η unconstrained, or obtain estimates of the parameters α and β (constrained to be equal to one) from the factor shares of capital and labour, calculate TFP by a variant of (6) and regress R and Z on TFP to obtain γ.

Incorporating the efficiency of R&D and the accessibility of knowledge

This standard approach makes some key assumptions. Here we note three assumptions in particular. It is assumed that:

- All R&D generates knowledge that is useful in economic or social terms (*efficiency of R&D*);
- All knowledge is accessible to all firms or other entities that could make productive use of it (*accessibility of knowledge*); and
- All types of knowledge are equally substitutable across firms (*substitutability*).

A good deal of work has been done to address the fact that the substitutability assumption is not realistic, as particular types of knowledge are often specialised to particular industries. But much less has been done on the other two, which are our focus here.

We define the accessibility parameter ε as the proportion of the knowledge stock that is accessible to those who could use it productively, and an efficiency of R&D parameter ϕ as the proportion of R&D spending that generates useful knowledge. Then starting with a given stock of useful knowledge R^*_0 at the start of period zero, useful knowledge at the start of period 1 will be given by:

$$(10) \qquad R^*_1 = (1 - \delta)\, R^*_0 + \phi\, R\&D_0,$$

where the contribution of R&D in period zero to the knowledge stock is reduced by the parameter ϕ to allow for unproductive R&D. This means that the stock of useful knowledge at period *t* is given by:

$$(11) \qquad R^*_t = (1 - \delta)^t R^*_0 + \phi \sum_{i=0}^{t-1} (1 - \delta)^i\, R\&D_{t-1}$$

If the period over which knowledge is accumulated is long, so that $(1 - \delta)^t R^*_0$ is small relative to R^*_t, then R^*_t can be approximated by ϕR. However, only a proportion of useful knowledge may be accessible, so that accessible useful knowledge at period *t* is εR^*_t, and hence approximately $\phi\varepsilon R_t$, where R_t is the stock of knowledge as calculated under the standard methods.

Using this approximation and noting that it is accessible useful knowledge that is the correct factor in the production function, (6) becomes:

$$(11) \qquad Y = K^\alpha L^\beta (\phi\varepsilon R)^\gamma Z^\eta$$

If ϕ and ε are independent functions of time, then the results of estimating a linearised version of (11) that excludes them will be misleading. However, if we assume that these parameters reflect institutional structures for research and research commercialisation in a given country, and can hence be taken as fixed (and as less than or equal to one), then the standard results stand, but need to be reinterpreted. Again using R as the stock of knowledge calculated by the standard method (which assumes $\phi = \varepsilon = 1$) and R^* as the corresponding accessible stock of useful knowledge, then $R = R^*/\phi\varepsilon$, and the rate of return to useful and accessible knowledge becomes:

$$(12) \qquad \partial y/\partial R^* = \gamma.\,(Y/R^*) = \gamma/\phi\varepsilon.\,(Y/R) = \gamma.\,(Y/R).1/\phi\varepsilon.$$

Thus, if ϕ and/or ε are less than one, the rate of return to R^* is greater than that to R by the factor $1/\phi\varepsilon$. This does not imply that the measured rate of return to R is biased, because $R^* = \phi\varepsilon R$.

Assume now that there is a one-off increase in the value of ϕ and ε, from the constant values of ϕ_0 and ε_0 to new values of $(1 + \delta_\phi)\phi_0$ and $(1 + \delta_\varepsilon)\varepsilon_0$, respectively. Then the rate of return to R^*, that is:

$$(12) \qquad \partial y/\partial R^* = \gamma. (Y/R). (1/\phi_0\varepsilon_0)$$

is fixed, but the return to R will increase:

$$(13) \qquad \partial y/\partial R = \gamma. (Y/R) = \phi_1\varepsilon_1\, \partial y/\partial R^* = \gamma. (Y/R). (\phi_1\varepsilon_1 /\phi_0\varepsilon_0)$$

$$= \gamma. (Y/R). (1 + \delta_\phi).(1 + \delta_\varepsilon)\varepsilon_0.$$

It follows from (13) that, because the increase in efficiency and accessibility leads to a higher value of R^* for a given level of R, the rate of return to R will increase by the compound rate of increase of the percentage changes in ϕ and ε.

Estimating the benefits of a one-off increase in accessibility and efficiency

The basic result of the foregoing is that, if accessibility and efficiency are constant over the estimation period but then show a one-off increase (*e.g.* because of a move to open access) then, to a close approximation, the return to R&D will increase by the same percentage increase as that in the accessibility and efficiency parameters.

Table 4.1 shows the recurring annual gain from a given percentage change in both accessibility and efficiency across a range of rates of return to R&D. It assumes, in the interim, that the increase in both parameters is the same, that the change (*e.g.* to open access) has no *net* impact on the rates of accumulation and obsolescence of the stock of knowledge, and that the information are discoverable. Because they are based on estimates of social returns to R&D, these impacts are national. Estimates of social returns to R&D are based on aggregates and their use for specific forms of R&D, such as Australian Research Council competitive research grants, will be subject to greater uncertainty. Hence, these estimates should be treated with caution.

Table 4.1 Estimates of benefits of a one-off increase in accessibility and efficiency (AUDm)

GERD	Rate of return to R&D				
12,250	25%	40%	50%	60%	75%
Per cent change in accessibility and efficiency	Recurring annual gain from move to open access (AUD million)				
1%	62	98	123	148	185
2%	124	198	247	297	371
5%	314	502	*628*	753	942
10%	643	1,029	1,286	1,543	1,929

Cont'd

GovERD	Rate of return to R&D				
5,438	25%	40%	50%	60%	75%
Per cent change in accessibility and efficiency	Recurring annual gain from move to open access (AUD million)				
1%	27	44	55	66	82
2%	55	88	110	132	165
5%	*139*	223	279	334	418
10%	285	457	571	685	856

Public Sector	Rate of return to R&D				
5,912	25%	40%	50%	60%	75%
Per cent change in accessibility and efficiency	Recurring annual gain from move to open access (AUD million)				
1%	30	48	59	71	89
2%	60	96	119	143	179
5%	*151*	242	303	364	454
10%	310	497	621	745	931

Higher Education	Rate of return to R&D				
3,430	25%	40%	50%	60%	75%
Per cent change in accessibility and efficiency	Recurring annual gain from move to open access (AUD million)				
1%	17	28	34	41	52
2%	35	55	69	83	104
5%	*88*	141	176	211	264
10%	180	288	360	432	540

ARC	Rate of return to R&D				
481	25%	40%	50%	60%	75%
Per cent change in accessibility and efficiency	Recurring annual gain from move to open access (AUD million)				
1%	2	4	5	6	7
2%	5	8	10	12	15
5%	*12*	20	25	30	37
10%	25	40	51	61	76

NHMRC	Rate of return to R&D				
350	25%	40%	50%	60%	75%
Per cent change in accessibility and efficiency	Recurring annual gain from move to open access (AUD million)				
1%	2	3	4	4	5
2%	4	6	7	8	11
5%	*9*	14	18	22	27
10%	18	29	37	44	55

Source: CSES Project model, Authors' analysis.

Using the same R&D expenditures as above, we find that (closely approximating the impacts scenarios outlined above):

- With gross expenditure on R&D at AUD 12,250 million in 2002-03 and a 50% rate of social return to R&D, a 5% increase in accessibility and efficiency would be worth AUD 628 million;
- With government expenditure on R&D at AUD 5,438 million and a 25% rate of social return to R&D, a 5% increase in accessibility and efficiency would be worth AUD 140 million;
- With public sector R&D expenditure at AUD 5,912 million and a 25% rate of social return to R&D, a 5% increase in accessibility and efficiency would be worth AUD 150 million;
- With higher education R&D expenditure at AUD 3,430 million and a 25% rate of social return to R&D, a 5% increase in accessibility and efficiency would be worth AUD 88 million;
- With ARC administered funding (competitive grants) at AUD 480 million and a 25% rate of social return to R&D, a 5% increase in accessibility and efficiency would be worth AUD 12 million; and
- With NHMRC grant expenditure at AUD 350 million and a 25% rate of social return to R&D, a 5% increase in accessibility and efficiency would be worth AUD 9 million (Table 4.1).

Note that these are recurring annual gains from the effect on one year's R&D. Assuming that the change is permanent they can be converted to growth rate effects.

The potential cost-benefits of open access

It is possible to express these impacts as benefit/cost ratios. To do so, we focus on a limited range of costs that relate to a change from the current position to open access to higher education research via a national system of institutional repositories. Thus we are comparing the estimated additional incremental cost of open access institutional repositories in Australian higher education, with the potential additional incremental benefits from moving to open access to Australian higher education research (other things remaining the same).

For the purposes of estimation, we assume that:

- The underlying R&D expenditure, and hence underlying benefit, increases by 10% per annum;
- The underlying knowledge stock, and hence benefits, depreciates at 10% per annum from the year of R&D expenditure;
- The full benefit from open access takes five years to build up, so is immediately felt for R&D in year 5 and after;

- The costs are discounted by 5% and the benefits are discounted by 5% plus 10% (15%); and
- There is a 100% compliance with open access for each of the classes of research expenditure.

Table 4.2 Potential annual benefits of enhanced/open access, circa 2003-04

Research sector	*Expenditure AUDm*	*Social returns*	*Increase in accessibility & efficiency*	*Annual impact AUDm*	*Benefit/cost ratio*
Gross expenditure on R&D	12,250	50%	5%	628	214
Government expenditure on R&D	5,438	25%	5%	139	47
Public sector R&D	5,912	25%	5%	151	51
Higher education R&D	3,430	25%	5%	88	30
ARC funded research (NCGP)	481	25%	5%	12	4.1
NHMRC funded research	350	25%	5%	9	3.1

Note: Benefit/cost ratios are calculated over 20 years for a full system of institutional repositories in Australia costing AUD 10 million a year and achieving a 100% self-archiving compliance.
Source: CSES project model, Author's analysis.

Under these assumptions, we find that, over 20 years, a national system of institutional repositories in Australia costing AUD 10 million a year would cost around AUD 130 million (Net Present Value). Whereas, the modelled benefits of open access for each class of research expenditure would be:

- *Public sector expenditure on R&D*, with impacts at AUD 151 million a year would realise benefits of around AUD 6.7 billion – a benefit/cost ratio of 51 (*i.e.* the benefits are 51 times the costs);
- *Higher education expenditure on R&D*, with impacts at AUD 88 million a year would realise benefits of around AUD 4 billion – a benefit/cost ratio of 30; and
- *ARC administered competitive grants funding*, with impacts at AUD 12 million a year would realise benefits of around AUD 530 million – a benefit/cost ratio of 4.1.

Obviously, there is unlikely to be 100% open access to all public sector research, because of commercial limitations, confidentiality and non-compliance. Nevertheless, whether applied across the board or to sector specific research findings it appears that there may be substantial potential benefits to be gained from open access. While it is difficult to calculate the quantum of those benefits with certainty, these simple preliminary estimates of the potential impact of enhanced/open access on social returns to R&D suggest that moves towards open access may have a significant cost-benefit advantage.

5 Emerging Opportunities and Futures

This section concludes the analysis with a brief exploration of scholarly communication futures. It draws on the literature to suggest possible evolutionary pathways in order to shed light on key points of policy leverage and how change might be affected.

The main functions of scholarly communication of registration (establishing intellectual priority), certification (certifying the quality and validity of the research) and dissemination/awareness (assuring awareness of, and accessibility to, the research) have been integrated in traditional scholarly publishing. The common thread in the literature on possible futures is the expectation of a fragmentation of these functions.

5.1 Near term futures

Prosser (2005) provided one insight into a possible near term future for open access. He noted that in the new environment dominated by the internet and digital publishing technologies it is perhaps no longer the case that integrating these functions is the most efficient solution. He went on to note that if researchers place the results of their research into their local institutional repository three of the functions of a traditional journal would be immediately met (*i.e.* registration, dissemination/awareness and preservation). The one function of the traditional journal that self archiving does not fulfil is certification or peer-review. However, authors who wanted their work to be peer reviewed could, after they had deposited it in their local repository, send it to their journal of choice. At this stage the work would be evaluated as in the current system and, if considered by the editor of the journal to be acceptable, the paper would be published in the journal and so receive the journal's quality stamp. The authors could then place a peer-reviewed 'post-print' onto their local institutional repository ensuring that both versions were archived. In this scenario, all research material is made freely available in a world-wide network of fully searchable repositories. A sub-section of the material in the repositories (*i.e.* peer reviewed papers) receives a certification 'quality stamp' from journals. This process is financed by the authors' institutions and funding bodies (*i.e.* 'author-pays'), rather than through the readers' libraries (*i.e.* subscription), so allowing free access for all interested readers to all peer-reviewed papers via the internet (Prosser 2005).

Velterop (2005) makes the same basic point, suggesting that:

> *Self-archiving and publishing are both complementary and competitive… Because what we usually call 'publishing' (or 'formal publishing') combines a few functions: organising and managing peer-review; quality control of text, figures and the like; attaching the respectability 'label' (conveying, among other things, credibility, impact factor, place in the pecking order, etc.); and dissemination (the actual 'publishing' in the sense of 'making public') electronically and in print.*

> *There is complementarity because publishers, on the whole, do not do the 'making public' optimally, and self-archiving in OA repositories does not perform the other functions such as organising and managing peer-review, QC, 'labelling' and print distribution.*
>
> *The competition comes from the fact that, in order to recoup their costs, most publishers load the charges for all their services just on dissemination, via subscription/licensing fees. Historically logical, but now, in the internet world, ironic, given that it is the service they perform least optimally. Self-archiving competes, because potentially it can perform the dissemination function much better.* (Velterop 2005).

This suggests that, for the immediate future, we might see open access repositories and 'author-pays' open access journals as complementary parts of the evolving system, wherein repositories provide registration, awareness and archiving, and open access 'author-pays' journals provide the certification (primarily through peer review).[12]

5.2 Mid term futures

In the mid term future, it is likely that such a system might evolve, with more focused and specialised services providers emerging and a rationalisation of overlapping activities, which would lead to a more cost effective and efficient system. One important step would be to eliminate the duplication of activities across the system, with the physical production and distribution of journals (and, perhaps, monographs) being a starting point. In the 'born digital' environment, cost savings could be made by stopping the production of journals (and, perhaps, research monographs) in print form, and replacing them with overlay journals and services (*e.g.* peer review, branding and quality control services) which depend upon open access archives and repositories for distribution and add value to their content.[13]

Such a development has been foreshadowed by a number of authors (Smith 1999; Van de Sompel, *et al.* 2004; Smith 2005; Simboli 2005; etc.). In his outline of the future 'Deconstructed Journal', Smith (2005) presented the picture of traditional and deconstructed journal models shown in Table 5.1 (below). Smith also noted that many of the elements of the deconstructed system already exist, with publishers and learned societies among the best placed to offer the specialist peer review services. It is worth noting that a similar system could also work for scholarly monographs.

A reconfiguration of activities would likely provoke adjustment of stakeholder responsibilities. Owen (2002) suggested that it might mean large commercial publishing firms shifting their emphasis from content/copyright-based to value adding activities built around open access objects (*e.g.* harvesting content from open access archives and repositories, packaging and adding value through the addition of abstracting and indexing and a range of powerful searching, linking, interrogation, access and usage reporting functions). For publishers, this may also involve the development of products and services that increase value for targeted vertical markets (Akie, *et al*. 2004). Such a system would see the deconstructed or overlay models develop, and a reduction in existing and near term duplication of activities (and costs).

Table 5.1 Traditional and deconstructed journal models

Activity	*Agency in traditional model*	*Agency in deconstructed model*
Quality control (Content)	Referees, organised by publisher	Independent Certification Agents (CAs)
Quality control (Appearance)	Sub-editors, organised by publisher	In-house, freelance sub-editors, or organised by CAs
Conferring recognition	Referees and journal editorial board	Independent CAs, or editorial boards of overlay journals
Making available	Publisher – printing and online distribution	Author or institutional self-archiving on open access archive of repository
Making aware or marketing	Publisher – marketing the journal to libraries and researchers/practitioners	Overlay journals, search engines, web directories, subject portals, weblogs, etc.

Source: Smith, J.W.T. (2005) Open Access Publishing Models: Reinventing Journal Publishing, *Research Information*, May-June 2005. Available http://www.researchinformation.info/rimayjun05djmodel.html accessed December 2005.

Indicatively, based on a survey of the literature on costs, SQW (2004) suggested that refereeing accounted for around 22% of total article costs. On this analysis, the elimination of production and distribution, subscription management, and sales and marketing activities would almost halve journal production costs. Based on the cost model for Australia, HERDC journal article publication alone would have cost AUD 60 to 115 million in 2003 – implying potential savings of AUD 30 to 57 million.

5.3 Longer term futures

In the longer term, emerging possibilities may gradually replace some of the objects and activities that have been central to scholarly publishing (Houghton 2005a). There are many developments in scholarly communication and research practice emerging from increased use of ICTs and the internet for research, research communication and publishing that may enhance and/or eventually replace current practices, current objects and activities. The following short examples demonstrate some emerging possibilities.

When looking at key objects the principal questions are: what role does the object play and are there viable alternatives? Perhaps the most central object in scholarly publishing is the *journal*. For authors the journal title is a brand, built upon quality control, prestige of editorial affiliations, citation and impact factors. For readers, however, the availability of online journal databases and the tendency to search online for authors or by keywords mean that readers are now accessing articles more independently of journal titles. Hence, the journal may become somewhat less important to readers. The journal has also played non-publishing roles in the research community. For example, journals have formed the basis for networks of scholars, for which the editor forms a focal point around which members of the editorial board, regular reviewers, contributors and readers orbit. Such networks of scholarship can be extremely important (Houghton *et al*. 2003). Journals have also provided fora for ongoing discussion of particular topics of interest to the scholarly communities they serve (SQW 2003). For all of these roles, however, there are now alternatives emerging based upon emerging ICT applications – such as discussion groups, web logs, etc. Friedlander and Bessette (2003, p9) observed that the nature and role of scholarly journals are changing, and Smith (2000) suggested that with the development of the web, journals no longer form the primary communication medium. Indeed, for most of the roles traditionally played by the journal alternatives are emerging and are being used, albeit, to date, in rather experimental ways. To date, perhaps, the major exception is the role of the journal in research evaluation, which is still heavily dependent upon journal-based rankings, citations and impact factors.

When looking at key activities in scholarly publishing few are more central than *peer review*, but here too there are changes that may reduce dependence upon it. There is some concern that peer review is not working well, especially for multi-disciplinary or trans-disciplinary research (Odlyzko 2002; Jefferson *et al.* 2003; Peek 2003; Worlock 2005). More importantly, in the increasingly multi-disciplinary, multi-site, collaborative world of research both the value of, and necessity for, peer review may decline. Whereas in the past an individual scholar might report findings, it is now increasingly the case that reports of research findings reflect the collaborative work of a number of scholars, institutional and stakeholder interests. By implication at least, they have all seen, vetted and, in some senses, peer reviewed the material. Moreover, as primary data are more widely available via open access databases and papers more commonly include direct links to accessible data elements, reported findings are more readily replicable and checkable. There are also new, technology-based alternatives to peer review emerging, such as online commentary and reader reviews, threaded discussion (Nadasdy 1997; Varian 1998; Singer 2000), and there are procedures for, and controls over posting to archives and repositories – such as institutional affiliation and status, or what Kling *et al.* (2002) referred to as Guild Publishing and the substitution of peer review by ‘career review’.

Esposito (2004) suggested that the peer review system was suitable for print publishing, where any alterations or mistakes would be expensive to fix, but it is not necessary for electronic publication. Odlyzko (1995) suggested a continuum of peer review, which would allow a pre-print to be made available online immediately. Comments and responses could be added to the paper, and then an official peer review process would begin, taking into account any comments already made. Such a system would be more suitable to electronic publishing, it is argued, as it could increase the speed of dissemination, improve the discursive elements of academia, and still retain an official, organised and trusted system of refereeing articles. The only condition required is that a reader is made aware of what stage of the continuum each article is at (Allen 2005).

This is not to suggest the immediate abandonment of particular objects or activities, but rather that their roles may be changing, and the evolution of the scholarly communication and publishing system may involve the dissolution of existing and emergence of new combinations of objects, activities and responsibilities – such as, for example, the decline of commercial publisher control over peer reviewed journal titles and the rise of open access subject archives and institutional repositories populated by free-standing digital objects of all kinds, with quality control based around career review, online user commentary and more formalised but diffuse review processes, and impacts measured as hits, downloads, citations and links, which better reflect use by both readers and other authors, and the impact of the work, than do citations alone.[14]

Whatever the future, the emerging system should take account on new and emerging research practices. As Van de Sompel, *et al.* (2004) put it:

> *…dramatic changes in the nature of scholarly research require corresponding fundamental changes in scholarly communication. Scholars deserve an innately digital scholarly communication system that is able to capture the digital scholarly record, make it accessible, and preserve it over time… the future scholarly communication system should closely resemble – and be intertwined with – the scholarly endeavor itself, rather than being its after-thought or annex…*
>
> *In the established scholarly communication system, the concept of a journal publication dominates our definition of a unit of communication. Such publications come with well-known characteristics, some of which are unattractive in light of the changing nature of research. For example, publications are unable to adequately deal with non-textual materials, which are generally regarded to be add-ons rather than essential parts of the publication, let alone be publications in their own right. Furthermore, significant communication delays are introduced as the result of the integration of peer-review in the publication process.*
>
> *These problems suggest a revised perspective on what constitutes a unit of communication in a future scholarly communication system:*
>
> - *The system should consider datasets, simulations, software, and dynamic knowledge representations as units of communication in their own right.*
> - *The system should accommodate complex documents that flexibly aggregate the products of the scholarly endeavor, regardless of their format or location. These compound objects must themselves be considered units of communication and, therefore, be recursively available for inclusion into other compound units. Such technology would provide for the reuse and derivation of existing results that is an integral part of the scholarly process.*
> - *The system must facilitate the early registration (and ultimately preservation) of all units in the system, regardless of their nature or*

> *stage of development. This would facilitate collaborative network-based endeavors and increase the speed of discovery. Preprints, raw datasets, prototype simulations, and the like should be afforded the ability to proceed through the scholarly value chain in the same manner that only journal publications are afforded in the current system.* (Van de Sompel, *et al.* 2004).

The combination of open access archives and repositories and 'virtual' or 'overlay' journals and certification services, along the lines outlined above, could provide the foundations for just such a system.

Responsive to needs of research, the exact path of development may be specific to disciplines or broader fields of research. Allen (2005, p15), for example, suggested that differences between disciplines lead to different levels of acceptance of open access models, with the humanities and social sciences perhaps the most conservative. ArXiv has proved popular amongst physicists partly because there was a strong culture of sharing preprints within the community stretching back to the 1970s, and using the internet was merely an application of new technology to an old system. In contrast, biomedical sciences have been less keen to self-archive preprints, which has been attributed to fear of the clinical or social consequences. This might explain why open access journals ('author-pays') which incorporate peer review, such as BMC and PLoS journals, have proved more popular in these fields. Hence, it is possible that there would be slightly different evolutionary paths in different fields of research. The common theme being enhanced access.

6 Summary and Conclusions

The environment in which research is being conducted and disseminated is undergoing profound change, with new technologies offering new opportunities, changing research practices demanding new capabilities, and increased focus on research performance. Nevertheless, despite billions of dollars being spent by governments on R&D each year, relatively little policy attention has yet been paid to the dissemination of the results of that research through scholarly publishing.

A key question facing us today is: are there new opportunities and new models for scholarly communication that could enhance the dissemination of research findings and, thereby, maximise the economic and social returns to public investment in R&D? By exploring the costs involved in scholarly communication activities and some of the potential benefits available through emerging, more open scholarly communication alternatives, this study contributes to helping us answer this question.

6.1 Scholarly communication costs

An extensive literature review laid the foundation for the development of a model of the costs associated with scholarly communication related activities in Australia. Those costs are significant.

Summing the estimated costs associated with core scholarly communication activities in Australian higher education (*including higher education related ARC and NHMRC research grant application and review, reading for those higher education staff producing HERDC compliant publications, writing HERDC publications, related peer review and editorial activities, and related publishing costs*) gives an approximate estimate of overall system costs of between AUD 2.6 billion and AUD 4.6 billion (mean AUD 3.6 billion) per year.

Nationally, these costs amount to around 30% of total higher education revenues and expenditures. Institutions vary, with estimated scholarly communication related costs accounting for 40% or more of total revenues and expenditures for some of the more research intensive universities (*e.g.* University of Queensland and Australian National University), and no more than 10% for others (*e.g.* Southern Cross and Charles Darwin Universities).

6.2 Scholarly communication benefits

A review of the literature discussing the potential benefits of emerging more open scholarly communication models provided the foundation for identifying and quantifying some of those benefits.

Perhaps the most important potential benefit of open access is enhanced access to, and greater use of, research findings, which would, in turn, increase the efficiency of R&D as it builds upon previous research. There is also significant potential for open access to expand the use and application of research findings to a much wider range of users, well beyond the core research institutions that have had access to the subscription-based literature.

There are many difficulties involved in attempting to quantify impacts and compare costs and benefits. Nevertheless, it is possible to gain some sense of the scale of potential impacts by developing impact scenarios focusing on the aggregate measure of social returns to investment in R&D, and modifying a standard growth model by introducing 'access' and 'efficiency' into calculating the returns to R&D.

Using a modified Solow-Swan growth model to estimate the benefits of a one-off increase in 'accessibility' and 'efficiency' we find that, if accessibility and efficiency are constant over the estimation period, but then show a one-off increase (*e.g.* because of a move to open access) then, to a close approximation, the returns to R&D will increase by the same percentage increase as that in the accessibility and efficiency parameters. Assuming that the increase in both parameters is the same, that the change to open access has no *net* impact on the rates of accumulation and obsolescence of the stock of knowledge, and that the information are discoverable, we find that:

- With *government expenditure on R&D* at AUD 5,438 million in 2002-03 and a 25% rate of social return to R&D, a 5% increase in accessibility and efficiency would be worth AUD 140 million a year;
- With *higher education R&D expenditure* at AUD 3,430 million and a 25% rate of social return to R&D, a 5% increase in accessibility and efficiency would be worth AUD 88 million a year; and
- With *ARC administered competitive grants funding* at AUD 480 million and a 25% rate of social return to R&D, a 5% increase in accessibility and efficiency would be worth AUD 12 million a year.

Note that these are recurring annual gains from the effect on one year's R&D. Assuming that the change is permanent they can be converted to growth rate effects.

6.3 Comparing costs and benefits

It is possible to express these impacts as benefit/cost ratios by focusing on a limited range of costs that relate to a change from the current position to open access to higher education research via a national system of institutional repositories. Thus we are comparing the estimated additional incremental cost of open access institutional repositories in Australian higher education with the potential additional incremental benefits from moving to open access to Australian (higher education) research. No other changes are taken into account (*e.g.* potentially reduced research library acquisition expenditures).

Expressing these impacts as a benefit/cost ratio we find that, over 20 years, a full system of institutional repositories in Australia costing AUD 10 million a year and achieving a 100% self-archiving compliance would show:

- A benefit/cost ratio of 51 for the modelled impacts of open access to public sector research (*i.e.* the benefits are 51 times greater than the costs);
- A benefit/cost ratio of 30 for the modelled impacts of open access to higher education research; and
- A benefit/cost ratio of 4.1 for the modelled impacts of open access to ARC funded research (competitive grants).

Obviously, there is unlikely to be 100% open access to all public sector research, because of commercial limitations, confidentiality and non-compliance. Nevertheless, it appears that there may be substantial benefits to be gained from increasing access to research findings through open access. While it is difficult to calculate the quantum of those benefits with certainty, these simple estimates of the potential impacts on social returns to R&D suggest that a move to more open access may well represent a substantial cost-benefit advantage.

6.4 Opportunities and futures

The main functions of scholarly communication are registration (establishing intellectual priority), certification (certifying the quality and validity of the research) and dissemination (assuring awareness of, and accessibility to, the research) have been integrated in scholarly publishing. The common thread in the literature on possible futures is the expectation of a fragmentation of these activities.

For the immediate future, we might see open access repositories and 'author-pays' open access journals as complementary parts of the evolving system, wherein repositories provide registration, awareness and archiving, and open access 'author-pays' journals provide the certification (primarily through peer review).

In the mid term future, it is likely that such a system might evolve, with more focused and specialised service providers emerging and a rationalisation of overlapping activities, leading to a more cost effective and efficient system. One important step would be to eliminate the duplication of activities across the system, with the physical production and distribution of journals (and, perhaps, monographs) being a possible starting point. In the 'born digital' environment, cost savings could be made by stopping the production of journals (and, perhaps, research monographs) in print form, and replacing them with overlay journals and services (*e.g.* peer review, branding and quality control services) and institutional e-presses, which depend upon the open access archives and repositories for distribution.

In the longer term, emerging possibilities may gradually replace some of the objects and activities that have been central to scholarly publishing (Houghton 2005a; 2005b). This is not to suggest the immediate abandonment of particular objects or activities, but rather that their roles may be changing, and the evolution of the scholarly communication and publishing system may involve the dissolution of existing and emergence of new combinations of objects, activities and responsibilities – such as, for example, the decline of commercial publisher control over peer reviewed journal titles and the rise of open access subject archives and institutional repositories populated by free-standing digital objects of all kinds, with quality control based around career review, online user commentary and more formalised but diffuse review processes, and impacts measured as hits, downloads, citations and links, which better reflect use by both researchers and other users, and the impact of the work, than do citations alone.

6.5 Evolutionary pathways

There are new opportunities and new models for scholarly communication that can enhance the communication and dissemination of research findings to all potential users and, thereby, increase the economic and social returns to public investment in R&D. Open access is, perhaps, the most important. From a policy perspective, the question is how to enable the current system to evolve towards a more open future. Setting the goals and using points of policy leverage to facilitate the transition are the keys.

Setting the goals

This report provides a basis for a re-examination of individual and institutional scholarly communication behaviours, and the ways in which both can be reorganised and streamlined. The study findings inform and support existing initiatives (*e.g.* the Research Quality Framework, National Collaborative Research Infrastructure Strategy and the Australian Research Information Infrastructure Committee), which are based upon a desire to ensure accessibility to, and dissemination of, research results. Through these initiatives an opportunity exists to increase the returns on our investment in research by enhancing access to it.

Accessibility to research information can be facilitated through the development of a national system of institutional or enterprise-based repositories to support the new modes of enquiry and research. All Australian higher education and research institutions should be encouraged to develop enterprise-wide digital repositories for the storage, preservation, curation, access, registration and management of their intellectual property. The ability to access all Australian research through institutional repositories will not only make it available, but will also facilitate its management and increase the impact of Australian research.

Realising the benefits of enhanced access depends upon appropriate infrastructure and incentives, to ensure:

- Widespread adoption of open access strategies by universities, research funding bodies and government agencies;
- ‘Hard or soft mandated’ deposit of research output at the national, funder and/or institutional levels;

- Fully integrated institutional repositories or relevant subject-based archives based upon open access standards; and
- Fully developed links between content 'publishing' and research management, reporting and evaluation.

In this context, there is a need to support further work towards understanding how best, and most cost-effectively, to support the research process and the research infrastructure to maximise Australian research dissemination and impact.

This study reveals a growing global open access publishing movement in the research sector. It is driven by two major factors. Firstly, a widespread sense that publicly funded research should be accessible to the public. Secondly, that the accessibility of such research is a major factor in the distribution and impact of that research and, thereby, in maximising the return on our investment in it. The cost-benefit analysis undertaken for this study reveals substantial potential benefits from open access.

Points of leverage

Research evaluation is the primary point of leverage, influencing strongly the scholarly communication and dissemination choices of researchers and their institutions. At the moment, there are more questions than answers. To what extent does research evaluation drive academic publication behaviour? Does the evaluation affect where authors choose to publish? Does this distort the market? How will outputs be assessed? Is place of publication given greater weight than content? Is published output an effective indicator of research excellence? Will alternative methods of scholarly communication, such as institutional repositories or subject archives, be significant in future research assessments? Will evaluation keep pace with changing research practices and assess all forms of research output (and outcomes) and all forms of research communication?

A related secondary point of leverage is funding, and the conditions funding bodies put upon it. In order to increase the return on their investment in research, funding bodies should encourage and support enhanced access alternatives. Following the lead of the US National Institutes of Health, the UK Research Councils and other institutions, they should promote and support the self-archiving of publications in open access repositories. Self-archiving could become a condition for funding (European Commission 2006).

To attain the goal of accessibility it will be essential to ensure that funding and grant assessment, research evaluation and reward take account of emerging possibilities and opportunities, and build in enhanced access / open access options. As Willinsky (2006, pxii) put it: "A commitment to the value and quality of research carries with it a responsibility to extend the circulation of such work as far as possible and ideally to all who are interested in it and all who might profit by it."

Inter alia, this means:

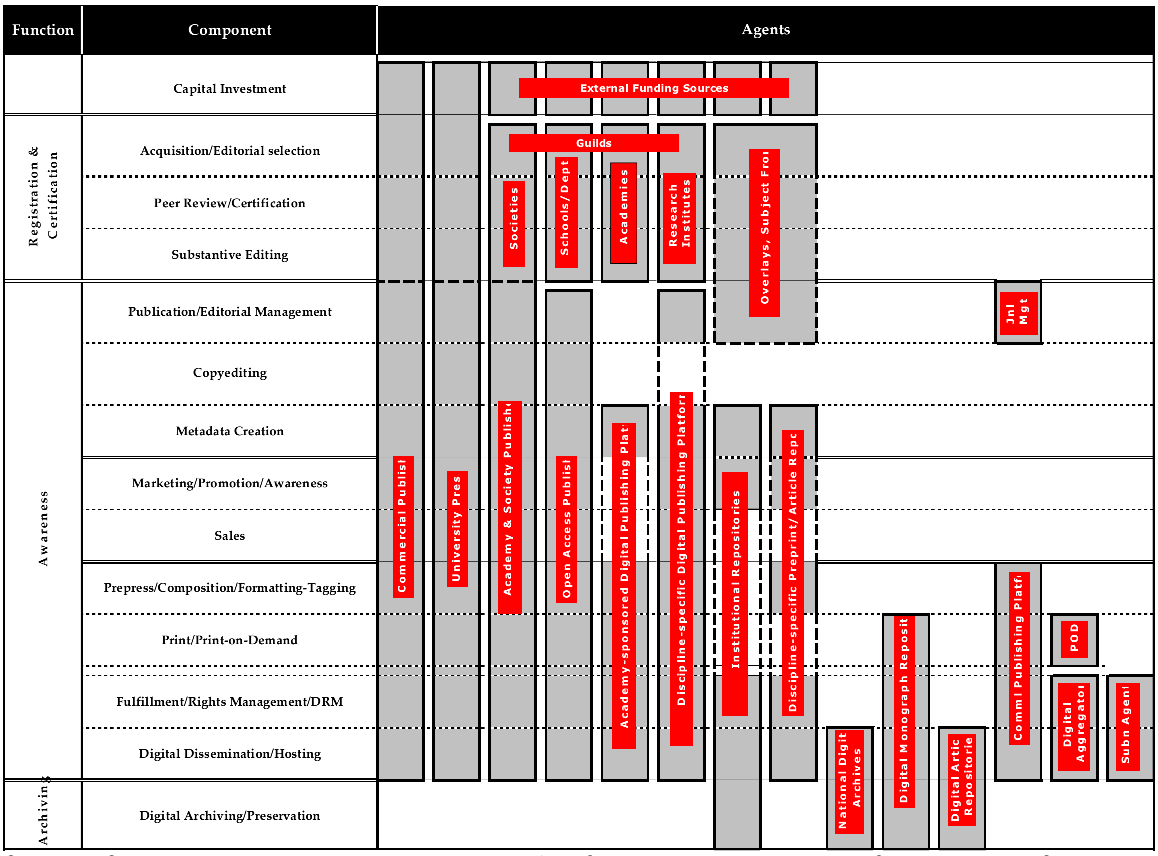
- Ensuring that the Research Quality Framework supports and encourages the development of new, more open scholarly communication mechanisms, rather than encouraging a retreat by researchers to conventional publication forms and media, and a reliance by evaluators upon traditional publication metrics (*e.g.* by ensuring dissemination and impact are an integral part of evaluation);
- Encouraging funding agencies (*e.g.* ARC, NHMRC, etc.) to mandate that the results of their supported research be made available in open access archives or repositories;
- Encouraging universities and research institutions to support the development of new, more open scholarly communication mechanisms, through, for example, the development of hard or soft open access mandates for their supported research; and
- Supporting an advocacy program to raise awareness and inform all stakeholders about the potential benefits of more open scholarly communication alternatives, and provide leadership in such areas as copyright (*e.g.* by encouraging use of creative commons licensing).

In the light of the global nature of research, Australia can also contribute through international activities. This might, for example, include working at the international level to encourage open access through international fora (*e.g.* OECD, CODATA, etc.), exploring the possibility of building upon open access to data initiatives (*e.g.* the OECD Declaration on Open Access, and The Global Information Commons for Science Initiative), and participating in international work exploring the impacts of enhanced access to research.

Appendix I Costs of scholarly communication: A literature review

This section presents a review of the literature relating to the costs of scholarly publishing and access which informs the development of the Australian cost model (See Chapter 3). It reveals two distinct approaches in the literature, with the majority of writers focusing upon the publishing process and discussing the functions and costs involved, while others explore the wider context, seeing publishing as a part of a system of knowledge creation and dissemination.

Figure A1.1 Scholarly publishing value chain: functions & agents



Source: Crow, R. (2005) ‘Business Planning for Open Access Journals,’ Open Access Scholarly Communication workshop, Kyiv, Ukraine, 17-19 February 2005.

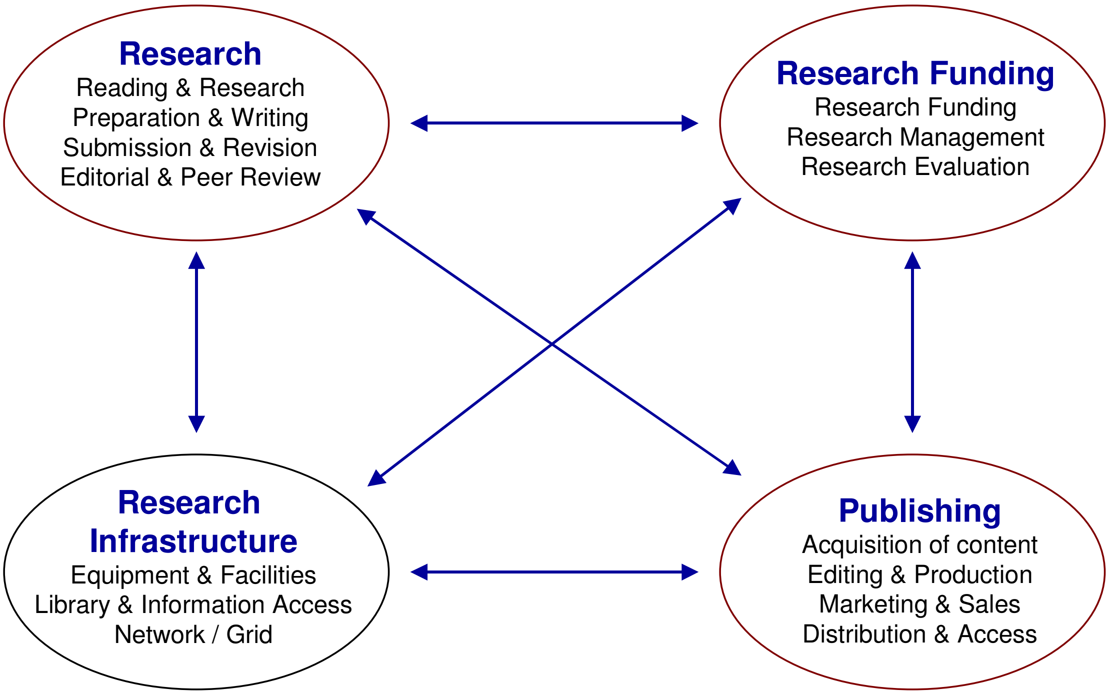
Publishing itself is a multifaceted activity, involving a wide range of activities and performing a number of key functions. Following a long tradition, Crow (2005) suggested that the main functions of scholarly communication are: registration (establishing intellectual priority); certification (certifying the quality and validity of the research); dissemination/awareness (assuring accessibility of the research to others); and preservation (preserving the research for future use). Traditionally, publishers have performed all of these functions except archiving, which has been performed by libraries and archives. Recently, however, specialist value adding services providers have emerged, and the functions are performed by a wider range of agents (Figure A1.1).

The emergence of the web and of open access archives and repositories has provided the foundations for a disaggregation of these functions and the emergence of a layered system, consisting of:

- A Content Layer – in which authors, author proxies (*e.g.* departments, user communities and scholarly societies) and institutions deposit scholarly research and other intellectual product in one or more content repositories, with the archiving function an integral part of the content layer; and
- A Service Layer – which comprises the various value-added services that provide practical mechanisms for the registration, certification, and awareness functions, supplementing or replacing those provided by the current journal publishing system.

At the same time, publishing has become more integrated into research and both it and research are becoming more integrated into other activities across innovation systems, with knowledge production becoming more diffuse, and invention, innovation and diffusion increasingly iterative and interdependent. Moreover, publishing is increasingly used for non-communicative purposes (*e.g.* research evaluation and accreditation of individuals and institutions).

Figure A1.2 Scholarly publishing activities and costs



Source: Author's Analysis.

As result, however detailed, analyses that focus on publishing activities alone are unlikely to reflect the system wide costs or benefits involved. Cost models must include the activities related to publishing, including production, distribution and consumption, *and* those related to system functions, including such things as research evaluation, the promotion and marketing of education and research institutions, and investment in, and the operation of, supporting research infrastructure (Figure A1.2). Scholarly communication costs, therefore, include:

- *Research* – the costs associated with the research that enables the production of the article, monograph or other composition, its writing and preparation, submission and revision, and editorial and peer review activities;
- *Publishing* – the costs associated with acquisition of content, editing and production, marketing and sales, and distribution and access;
- R*esearch infrastructure (distribution)* – the costs associated with access to findings, including library infrastructure and activities (*e.g.* acquisition/accession, shelving, archiving, etc.), the provision of equipment for access (*e.g.* desktop computers), and the network infrastructure for access (*e.g.* high bandwidth research networks and e-science grid computing facilities); and
- *Research infrastructure (funding and management)* – the costs associated with research funding, research management and the evaluation of research activities.

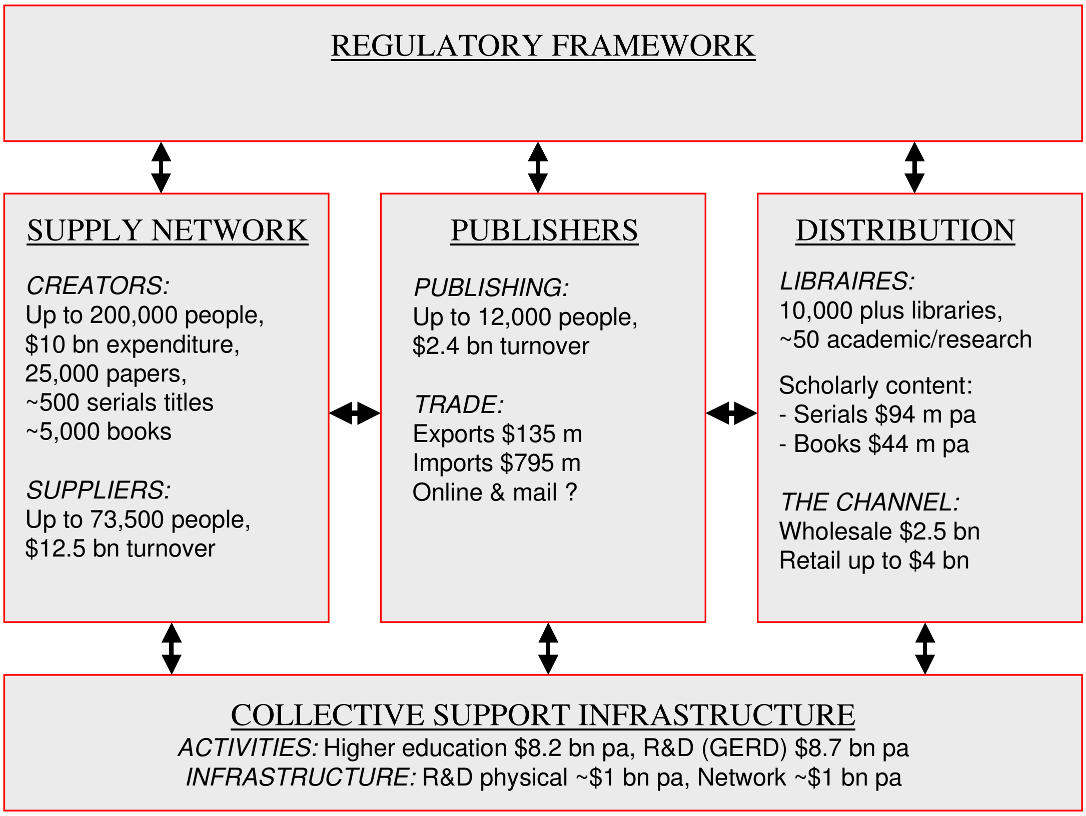
Research

Research involves both the production and consumption of scholarly publications. While publisher costs are often discussed, the wider system costs of the scholarly publishing process are less well covered. Nevertheless, it is possible to gain some sense of the activities and likely costs involved.

King and Tenopir (2004) suggested that the entire science journal system costs the United States around USD 45 billion a year in human, system, equipment, facilities and other resources (excluding transfer costs). The largest contributor is researcher time, which accounts for 88% of total costs – 10% as authors and 78% as readers. Publishers account for around 6% of total costs, libraries and other intermediaries for around 5%, and new initiatives for around 1%. Total annual R&D funding in the US was around USD 265 billion, of which around USD 40 billion is applied to research that leads to scholarly articles – USD 30 billion performed in universities, USD 5.8 billion performed by federally funded R&D centres administered by universities, and USD 10-15 billion performed elsewhere. This means that most research does not contribute to the literature, although it uses the information as an essential resource. Only around 15% to 20% of scientists in the US have authored a refereed article.

Houghton (2000) took a similar systems approach to scholarly publishing in Australia, focusing on the core value chain of content creation (authoring and editing), production (publishing) and distribution (by research libraries) (Figure A1.3). His review of higher education and research activities suggested that, at that time, scholarly content creation involved up to 200,000 Australians, whose activities were supported by annual expenditures well in excess of AUD 10 billion – the vast majority of which came from government. They produced around 25,000 journal papers and perhaps as many as 5,000 book titles a year.

Figure A1.3 Approximate scale of activities in the scholarly communication product system in Australia, circa 2000



Source: Houghton, J.W. (2000) *Economics of Scholarly Communication*, Report to The Coalition for Innovation in Scholarly Communication, ppiv-vi. Available http://www.caul.edu.au/cisc/ accessed August 2005.

The following sections present a brief review of the literature on scholarly communication system costs.

Writing

Tenopir and King (2000) found that scientists spent more than half their time in communication related activities, with reading, writing and other outputs (*e.g.* conference presentations) accounting for the lion's share. Their mid to late 1990s US surveys found that university-based scientists spent and average 85 hours writing a journal article, or 187 hours per year, while non-university scientists spent an average of 100 hours writing an article, or 10 hours per year (taking longer, but writing far fewer articles). They suggested that 75% of all journal articles were written by university-based scientists. Across a range of surveys, time spent authoring a journal article was found to range from 80 to 100 hours, and the total cost of writing, reworking and resubmission was estimated at USD 6,000 (in 1998). Citing Tenopir and King (2000), Morris (2005) suggested that the average research article takes 80-100 hours to write, costing approximately USD 6,700 in production time (in 2005 prices).

Editorial activities and peer review

Scholars make an even more substantial contribution to the scholarly publishing value chain than these figures suggest. In an international survey of more than 5,000 recent authors, Rowlands and Nicholas (2005; 2006) found that 77% had also acted as referees during the preceding year, 24% were members of editorial boards and 8% were journal editors. The same authors report that the majority of recently published authors surveyed had a positive view of their peer review experience (*i.e.* agreeing that the referees comments on their last published paper were helpful). Interestingly, those in physics and astronomy, where open access to pre-prints is common, were the least positive about their formal peer review experiences. In a more focused survey of around 1,000 researchers who had been or were being funded by DFG, Deutsche Forschungsgemeinschaft (2006, p32) found that 17.5% were the editor or co-editor of one or more journal, 23.8% served on editorial boards or scientific committees, and 11.4% reported performing other journal related functions.

Tenopir and King (2000, p139) found that the time spent (peer) reviewing article manuscripts was significant. Citing a variety of sources, they suggested that scientists were spending and average of 6 hours reviewing rejected manuscripts and 6¼ reviewing successful ones. They also noted other studies that reported ranges of 3 to 5.4 hours. Based on their costing of researcher time, they suggested that peer review was costing around USD 480 per article. Citing Tenopir and King, Morris (2005) suggested that peer review activities cost the academic community USD 480 per article in 1997 – based on an average of 3-6 hours spent reviewing per article, by 2 or 3 referees – or around USD 540 at 2004 prices.

In their analysis of content origination costs, Halliday and Oppenheim (1999, p71) modelled the external editorial and refereeing costs at 30 minutes for the editor and a total of 6 hours for refereeing (2 referees for 3 hours each) per paper. At an hourly rate of GBP 50 to cover salary and on-costs this suggests external editorial and refereeing (selection) costs of GBP 325 per paper. Rowland (2002) suggested that the average cost that journals attribute to the peer review process was USD 400 per published paper.

Reading

Tenopir and King (2000, p135) found a range of reading activity across university-based and non-university scientists, with university scientists each reading and average of 188 scholarly journal articles, 48 books and 134 other items per year. They noted that university-based scientists spent an average 58 minutes reading a journal article (182 hours per year), while non-university scientists spent 50 minutes doing so (88 hours per year). By 2003, university scientists' reading had increased to and average of 216 articles per year (Tenopir 2005). Citing Tenopir and King (2000; 2002) Morris (2005) suggested that researchers spent an average of 100 hours identifying, locating, obtaining and actually reading an average of 130 articles per year, at a cost of around USD 34 per article, and that there were approximately 900 readings per article, giving a total reading cost of USD 30,600 per article.

Table A1.1 Annual number of readings per US scientist, 1993-98

Type of document	*University*	*Non-University*
Journal articles	188	106
Trade journals	74	51
Professional books	48	53
External reports	20	12
Internal reports	26	53
Other materials	14	22
Total	370	297

Source: Tenopir, C. and King, D.W. (2000) *Towards electronic journals: realities for scientists, librarians and publishers*, SLA Publishing, Washington DC, p133.

As Tenopir and King (2002) noted, the number of articles read and time spent reading varies significantly between research fields. In 2000-01, the medical faculty surveyed read an average 322 articles per year compared to 72 for engineers (111 by 2003), and spent 118 hours per year reading compared with 72 hours (an average of 22 minutes, compared with 76 minutes). Overall, the average time spent reading articles across the research fields surveyed was approximately 52 minutes per article. Between 1984 and 2000, the average time spent browsing or searching for each article doubled. The time spent obtaining or accessing the article was about the same in the two surveys, but when the time involved in other activities, such as locating, displaying, and downloading or printing was added, the time spent totalled 17.7 minutes per electronic/digital reading in 2000, compared with 8.2 minutes for browsing print copies (including locating and photocopying the articles). This rather curious finding may reflect such factors as 'information overload' or increasing access difficulties.

Publishing

There have been many studies focusing on the costs involved in journal publishing, with far fewer exploring the costs of monograph publishing. Even in the case of journals, however, discussion rests on relatively few original sources – with authors building their analysis on a limited number of key studies. The following sections synthesise findings, focusing on costs relating to the for-profit publication of print or dual mode journals.

Journals and journal articles

Tenopir and King (2000, p237) found that US publishers produced 6,771 scholarly journals (following their definition) in 1995, with an average of 8.3 issues per title per year, and an average of 123 articles of an average 11.7 pages in length. More recently, a sampling of 4,889 journals found that the mean number of articles per journal was 121 (median 59).[15]

Waltham (2005, p12) noted that publishing costs could be divided into two component categories: *fixed* costs that are incurred regardless of the number of subscribers, and *variable* costs that are associated with each subscription. Fixed costs involve both content creation and publishing support activities. Content creation costs are all the costs associated with preparing the editorial content for publication, including the editorial office, costs of salaries and space, and reviewing, editing, SGML/HTML/XML coding and composition of both articles and non-article content, such as letters to the editor, book reviews and advertising, in preparation for print and online distribution. Publishing support activities include marketing, advertising sales, finance and administration (including management costs and the office costs of these activities). Variable costs include manufacturing and paper, printing, and binding, and distribution costs of the physical publication or online product, order fulfilment, subscriber file maintenance and customer service for all subscriber types. *Incremental costs* (or run-on costs) are those attributable to each additional subscription – such as the printing, distribution and subscriber file maintenance of one subscription.

Journal and article production costs

Estimates of *journal* production costs vary widely, with significant variation across research fields – with some requiring simple text presentation and others demanding more complex embedded formulae and images, and different fields of research characterised by very different levels of acceptance and rejection of articles submitted for publication in journals and different rates of growth in publication output (Houghton 2005b). A mix of general costings drawing on samples from various fields and specific case studies demonstrates the extent of this variation, as well as the approximate quantum of costs thought to be generally representative.[16]

Odlyzko (1997) based his cost estimates on a sample of journals in mathematics and computer science, and suggested a median USD 3,000 to USD 4,000 per article revenue for conventional publishing, and USD 250 to USD 1,000 per article for electronic only publishing with minimal processing cost. Odlyzko also noted a wide range of costs, from under USD 1,000 for some journals to more than USD 8,000 for others, which he attributed to quality differences, the lack of price competition and the differing motivations of for-profit and non-profit publishers.

Tenopir and King (1998; 2000a) presented costs associated with the processes and functions which publishers perform as part of traditional print journal publishing. They divided activities into five functions: article processing, non-article processing, journal reproduction, distribution and publishing support. They found the first copy costs of a journal article to be between USD 2,000 and USD 4,000, and typesetting costs about USD 15 to USD 25 per page, making the production costs of a 20 page article about USD 500, and the marginal costs of printing and mailing an issue about USD 3. So a quarterly journal with about 10 articles in each issue would have fixed costs of about

USD 120,000 – with 600 subscribers the break even subscription price would be USD 212.

Table A1.2 Typical print journal production costs, circa 1998

	Cost per page *USD*	*Share* *%*
Article processing	165	45
Non-article processing costs	102	28
Reproduction costs	6	2
Distribution costs	0.07	0
Publishing support costs	95	26
Total	368	100

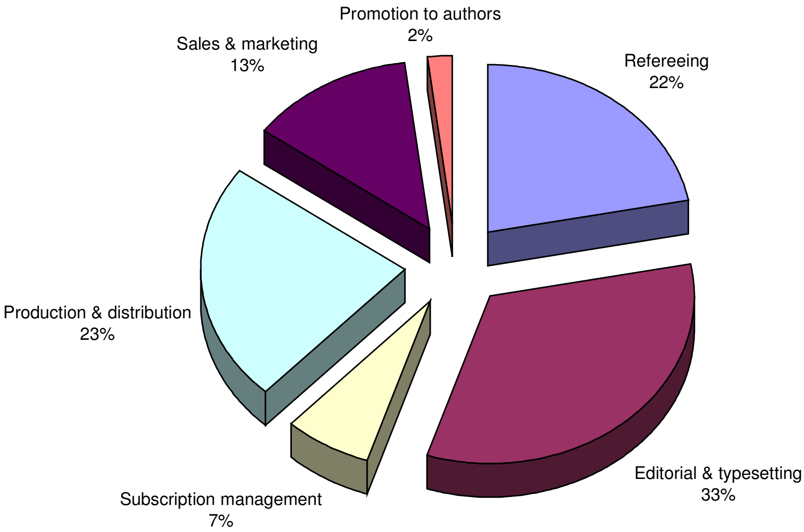
Source: King, D.W. and Tenopir, C. (1998) 'Economic Cost Models of Scientific Scholarly Journals,' *Proceedings of ICSU Workshop*, University of Oxford, 31 March to 2 April, 1998.

Tenopir and King (2000, p264) modelled journal publishing costs, circa 1995. They suggested a total average cost of USD 4,550 per article, or USD 325 per page. King (2004) suggested that traditional subscription-based print publishers indicated costs of around USD 2,000 to USD 4,000 per article if all publishers' costs were taken into account, and that he believed a typical range of costs to be USD 3,000 to USD 4,000. However, the costs of publication per article for the American Chemical Society (ACS) were reported to have been USD 1,838 in 2002 (Bovenschulte 2004).

Dryburgh (2002, p6) surveyed 10 publishers and found considerable variability in their costs, with median revenue per paper published of GBP 2,400. He suggested that median first copy costs per article were GBP 450 (ranging from GBP 200 to GBP 1,200), including GBP 75 for peer review and GBP 90 for copy editing.

Drawing on a range of sources (including Odlyzko 1997; Tenopir and King 2000; Bergstrom 2002; Dryburgh 2002; etc.), SQW (2004) suggested that editorial and typesetting activities account for the largest share of journal production costs at approximately 33%, with physical production and distribution accounting for 23%, refereeing 22%, sales and marketing 13% and subscription management 7%. They estimated that first-copy costs per article range from USD 250 to 2,000, depending upon rejection rates, with the cost of producing the first copy for a good-to-high-quality journal being approximately USD 1,500. Fixed costs, including first-copy costs, were estimated at around USD 1,650 per article and the total cost of producing an article for a good-to-high-quality journal at USD 2,750, plus a contribution to overheads and profits (SQW 2004, pp10-15).

Figure A1.4 Journal article publishing cost elements (percentage share)



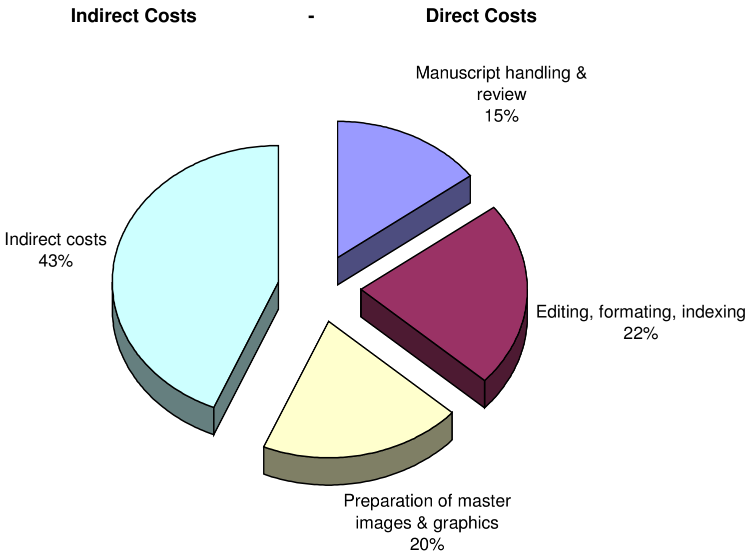
Source: SQW (2004) *Costs and business models in scientific research publishing*, A report commissioned by the Wellcome Trust, London, April 2004.

By way of triangulation, SQW (2004) noted that Blackwell Publishing, one of the world's largest journal publishers with a total of over 600 journals, generated an average revenue from libraries per paper published across all its journals of USD 1,425 in 2003. If revenue from consortia, copyright fees, advertising, reprints, supplements, sponsored subscriptions, document delivery and members' subscriptions are added to this figure the total average revenue per article for Blackwell in 2003 was just under USD 2,000 (SQW 2004, pp10-15). This would suggest that across a wide range of journals, USD 2,000 covered all costs, including overheads and an operating margin.

In its report to the UK House of Commons Inquiry, Reed Elsevier (2004) suggested that: "author fees cover only 40%-60% of the estimated costs to publish articles at the levels of quality that researchers are used to", which given typical fees of USD 1,500 implies that their costs averaged around USD 2,500 to USD 3,750 per article.

Drawing on extensive longitudinal surveys, King and Tenopir (2004) suggested that total costs per article ranged from as low as USD 500 for non-profit publishing to as high as USD 4,000 for for-profit publishing, with averages of USD 625 and USD 3,500, respectively. Their estimates suggested that indirect costs amounted to around USD 1,300 and direct costs USD 1,700 – of which manuscript handling and review costs amounted to some USD 440, editing, formatting and indexing USD 660, and preparation of master images and graphics USD 600.

Figure A1.5 Publisher cost shares (per cent)



Source: King, D.W. and Tenopir, C. (2004) 'An evidence-based assessment of the author pays model,' *Nature*, 25 June 2004. Available http://www.nature.com/nature/focus/accessdebate accessed July 2004.

Morris (2005) drew on a range of original studies, updating them to 2004 prices. Citing Rowland (2002) and SQW (2004), she suggested that the average cost to the publisher of peer reviewing was around USD 205 per article published, depending upon rejection rates. Direct costs (including the management of the peer reviewing process) were estimated to be USD 1,425 to USD 2,750 (the SQW numbers). Indirect overhead costs vary significantly, but an average of 35% of direct costs was suggested (USD 500 to USD 960). Morris also suggested an average operating margin of around 15%, leading to an estimated total for-profit publishing cost of USD 2,250 to USD 4,375 per article published in 2004.

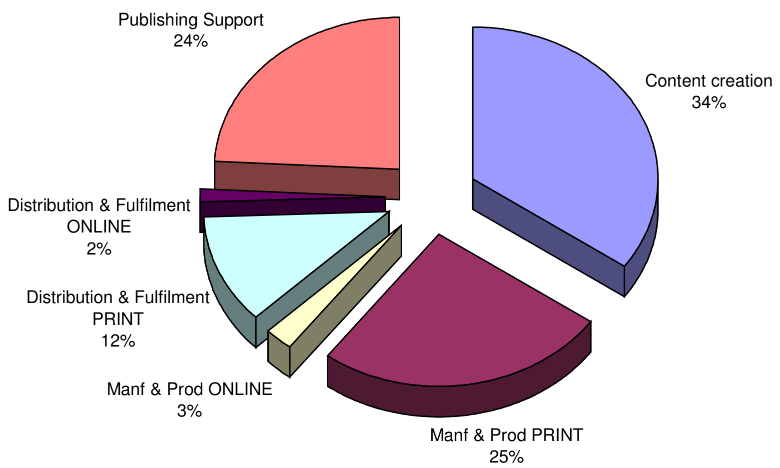
Clarke (2005) created models for various forms of journal publishing, reflecting the prior analyses of Odlyzko (1997), Bot *et al.* (1998), Rowland (2002), Willinsky (2003), Suber (2004), King (2004), Hawley (2004) and Morris (2005). The models expressly excluded the activities of the author, intermediary and consumer costs, focusing on for-profit subscription publishing of print or dual model journals. Clarke suggested that:

- Establishment costs relating to establishing the journal title amounted to around USD 100,000 or USD 667 per article published amortised over 5 years;
- Submission costs relating to submission management and peer review amounted to USD 500 per articles published;
- Article costs relating to production editing and cataloguing amounted to USD 330 per article published;

- Issue costs relating to production editing, production, protection and distribution amounted to USD 1,900 per article published;
- Generic operating costs relating to indexing, archiving, marketing and customer relationship management amounted to USD 1,000 per article published; and
- Financial costs relating to capital invested amounted to USD 600 per article published.

Hence, total for-profit publishers' costs per article published were an estimated USD 4,600 (USD 3,700 for e-only). Clarke (2005) also noted significant differences between for-profit and non-profit publishing, with total costs ranging from USD 660 per article for a non-profit association publishing an electronic only journal, to the USD 4,600 for a subscription-based multi-journal for-profit publisher.

Figure A1.6 Society publisher costs, 2004 (percentage shares)



Source: Waltham, M. (2005) *JISC: Learned Society Open Access Business Models*, JISC June 2005, p13.

Looking at society rather than commercial publishers, Waltham (2005, p13) found that the society publishers surveyed faced total costs of GBP 1,447 per article (GBP 144 per page) during 2004, with significant variation – from GBP 493 to GBP 2,232 per article. Variable costs (print manufacturing and distribution) averaged GBP 559 per article, with fixed costs accounting for an average GBP 888. Pooling the results of various studies, Waltham (2005) concluded that average scholarly journals costs included: fixed costs 67% (content creation 37% and publishing support 30%), and variable costs 33% (manufacturing 19% and distribution and fulfilment 14%). One of the most striking things is the difference between print and online costs relating to both distribution and manufacturing. Subtracting print related from total costs Waltham (2005, p47) concluded that average costs per article could fall by around one-third for e-only publication, saving an average of GBP 491 per article (GBP 47 per page).

Peer review

The costs of peer review cited by publishers also vary significantly. Rowland (2002) presented a summary of the literature on the peer review process. Citing Page *et al.* (1997) he suggested that around 3% to 5% of the subscription income of a journal was paid to editors in honoraria and support costs, which he estimated to amount to approximately GBP 75 to GBP 125 per published paper. Citing Donovan (1998), Rowland reported a range of refereeing costs from a survey of journals of GBP 50 to GBP 200, or GBP 100 to GBP 400 when adjusted for reported rejection rates. Citing Tenopir and King (2000), and assuming 10 page articles, Rowland calculated that their estimates would be equivalent to a peer review cost of USD 200 per article. Dryburgh (2002, p6) found the median cost to the publisher of refereeing per paper among the 10 publishers he surveyed to be GBP 75, with a range from around GBP 30 to GBP 145.

Citing Rowland (2002) and Tenopir and King (2000), SQW (2004) suggested that quoted peer review costs per article of the order of USD 200 appeared low, and concluded that total associated costs may be closer to USD 600. HCSTC (2004, p39) also mentioned the USD 200 number and reported a concordance with the evidence of The Public Library of Science. However, they also noted that Blackwell Publishing estimated the cost of peer review to be GBP 264 (approximately USD 525) per accepted article, rising to GBP 372 (USD 740) if editorial honoraria were taken into account.

Table A1.3 Submission and rejection rates, and peer review costs per submitted and accepted paper

	Submission Rate Papers per year	*Reject Rate Per cent*	*Submitted papers GBP per paper*	*Accepted papers GBP per paper*
A	9,000	50	200	400
B	9,000	45	33	60
C		50	60-70	120-140
D		50	100	200
E	2,100	52	150	288
F	900	65-70	83	237
G	500	50	50	100
H	650	30	146	209

Source: Donovan, B. (1998) ‘The truth about peer review,’ ISCU Press Workshop, Oxford.

Donovan (1998) reported that one major scientific society employs a staff of about 25 and spends about GBP 1.8 million to process some 9,000 papers a year, which would amount to GBP 200 per paper if all were acceptable. Since the rejection rate is 50%, the cost doubles to GBP 400 for each publishable manuscript. From the small sample examined, Donovan (1998) concluded that “peer review is expensive, with the cost for each manuscript submitted ranging between GBP 50-200, and for each paper published, between GBP 100 and GBP 400.” There is considerable evidence of the peer review load increasing (*e.g.* McCook 2006), suggesting that peer review costs may well be increasing.

Electronic publishing

Many analysts have argued that there are significant cost savings to be made from switching from print to electronic journals, and not just because of electronic distribution, as the contribution of ICTs and digital delivery to communication during the refereeing process, the use of standard templates for author formatting of manuscripts, and the production and management activities involved in journal production also lead to potentially significant savings (Houghton 2005b).[17]

Some suggest that up to 20% to 30% of the cost of a paper journal can be eliminated by switching to e-only publication (SQW 2003, p7). Bot, *et al.* (1998) reported on the costs associated with the production of the *Electronic Review of Comparative Law* (EJCL), suggesting that costs per article published ranged from USD 1,004 to USD 2,511 depending on the number of articles published per issue. PLoS (2004) provided a breakdown of electronic publishing costs, suggesting total per article costs of USD 1,070, with the largest share of costs relating to editing and layout activities. As noted above, subtracting print related from total costs, Waltham (2005, p47) concluded that average costs per article would fall by around one-third, saving an average of GBP 491 per article (GBP 47 per page).

Table A1.4 Production costs for research articles

	Per page costs USD	*Per article costs USD (11-page article)*	*Per issue costs (110-page book)*
Pre-editing macro	0.90	10.00	100.00
Copy editing	20.00	220.00	2,200.00
Figure preparation	13.65	150.00	1,500.00
Layout	16.00 (text)	176.00	1,760.00
	+12.50 (per graphics)	+138.00 (per article)	+1 380.00 (per issue)
Proofs/correction	4.75	52.25	522.50
XML Mark-Up	3.25	35.75	357.50
PDF creation	1.50	16.50	165.00
Figure conversion to JPEG	1.60	17.50	175.00
XML upload/QC	3.75	41.25	412.50
Deposit to CrossRef/PMC	1.15	12.50	125.00
TOTAL	74.05	869.75	8,697.50
TOTAL Including electronic manuscript processing		1,069.75	10,697.50

Source: PLoS (2004), *Publishing Open-Access Journals*, Public Library of Science, p12. Available http://www.plos.org/downloads/oa_whitepaper.pdf accessed July 2004.

Dual mode publication (*i.e.* parallel electronic *and* print publishing) simply increases costs. According to King and Tenopir (1998), the additional costs of operating parallel print and electronic publishing appeared to be in the range of 3% to 8%. Tenopir and King (2000, p370) suggested that dual mode costs would be around 120% of print only, and Regier (1997), reporting on Project Muse, suggested that for Johns Hopkins University Press total costs for both print and electronic editions were about 130% of print only costs. Dryburgh (2002, p23) found publishers reporting that electronic delivery added around 5% to copy editing costs, 5% to 20% to typesetting costs and 5% to 15% to subscription management costs. Similarly, running a dual mode subscription *and* open access (*i.e.* 'authors choice') journal would incur additional costs.

Production costs for 'purpose built' e-only journals should be lower, but there may be large overhead costs involved in the ICT equipment, software and skills required. Shirrell (1997) commenting on MIT Press figures comparing print and electronic journal production costs noted that: "…the total first copy costs of the electronic journals average USD 40 to USD 43 per page, and those for the print journals average USD 23 per page. …For a 200 page issue, this would amount to about USD 4,000… MIT can produce a print edition less expensively than an electronic edition when the distribution is under 500."

There are also significant infrastructure and training costs involved in the transition from print to digital delivery, and publishers have invested heavily in their digital delivery platforms in recent years (Fisher 1997; Shirrell 1997; Day 1998; Hunter 1998; etc.). Comparing print and electronic publications costs, Fisher (1997) concluded: "It seems that the direct costs of publishing an electronic journal are substantially below that of a print journal with comparable pages. The overhead costs, however, are much higher." Some of these are one-off, but many may be ongoing.

Specific areas of additional costs cited in the literature include: unexpectedly high customer support costs, with support staff requiring sophisticated and expensive technical skills; additional costs associated with licensing online content, with complex licensing agreements; additional marketing costs, with the complexity of the product increasing; and additional metadata costs, with the production of richer metadata (The National Academies 2004). As a result, many of the cost savings initially expected from e-publishing have yet to be realised.

Author fees

Notwithstanding other sources of revenue, author fees being charged in the author-pays model are indicative of per article costs. Examples include:

- BioMed, with other revenue sources and author fees ranging from USD 550 to USD 1,680 in late 2005;
- American Institute of Physics' Author Select, which charges USD 2,000;
- Blackwell Online Open, which charges author fees of USD 2,500;
- Springer Open Choice, which charges USD 3,000;

- Public Library of Science, has other revenue sources and author fees of USD 1,500;
- American Physiological Society, Company of Biologists and Hindawi examples cited by Walker (2004), which charge author fees of USD 995 to USD 2,160; and
- Oxford University Press, which charges author fees of USD 1,500 for subscribers and USD 2,800 for non-subscribers.[18]

While some of these fees may be subsidised and all are evolving and experimental, they reflect similar publisher related costs to those outlined above. In her survey of learned society publishers, Waltham (2005; 2006, p29) found that in order to cover the average online only costs and deliver the average surplus, author fees would have to be set at GBP 1,166 for a 10-page article.

Monographs

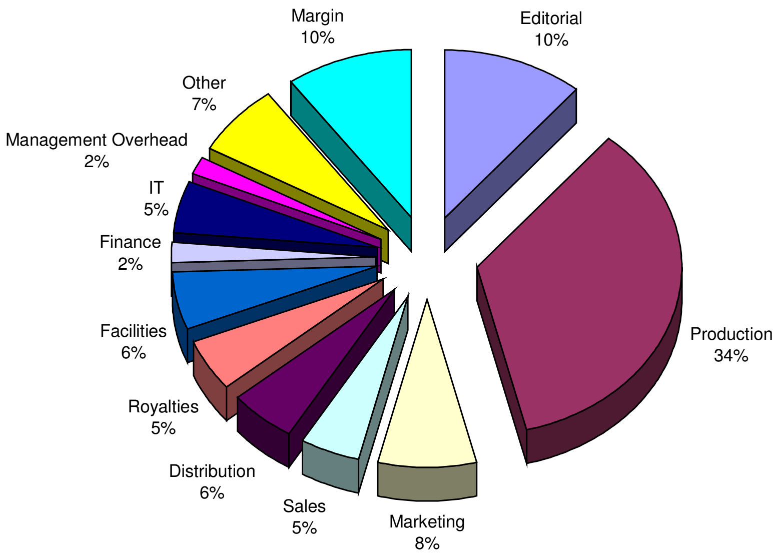
The market for research monographs is typically global, whereas that for textbooks tends to be national – with texts tailored for local use. Monographs may sell few copies in any one country, but sell globally; whereas textbooks may sell many copies, but only in one country. Either way, the critical factor for the publisher is to estimate the size of the market as accurately as possible in order to avoid unsold inventory or lost sales opportunities (Halliday and Oppenheim 1999).

The market for research monographs has contracted in recent years as a result of research libraries cutting monograph spending to maintain journal subscription, and publishers often report a reduction of their monograph print runs from more than 1,000 to 750 and even less. University presses have also been under considerable pressure to make profits or to break even, so that there has been a trend towards publishing more general trade books and books that are more likely to sell, rather than the traditional academic monograph. University presses, therefore, find themselves "on the horns of a dilemma" (Thompson 2005, p67). On the one hand they see a responsibility to serve their scholarly communities, and on the other hand they are trying to remain financially viable. With sales of some specialist titles falling to the low hundreds it is increasingly difficult for publishers to meet monograph production and inventory costs (Watkinson 2001) and it is becoming more difficult for authors to find a publisher for research monographs. The British Academy was sufficiently concerned as to the future of the scholarly monograph that it included a section in its report *E-resources for Research in the Humanities and Social Sciences* (British Academy, 2005).

Watkinson (2001, pp24-25) examined some of the costs associated with publishing research monographs, and suggested average print runs of around 750 (range 400 to 1,500) and falling, average selling prices of around USD 40, and average sales of around 400. Using his cited pricing metric of 'six times unit cost' implies unit costs of around USD 5,600 in 2000. Dryburgh (2002, p17) surveyed 10 publishers and found median commissioning costs of GBP 1,800 and development editing of GBP 1,600.

Taking other publisher costs into account would imply total costs of at least GBP 4,000. One leading UK publisher reported unit production costs in 2000 of GBP 5,000 to GBP 6,000 for hardbacks. A local university press reported a unit cost of production of AUD 13,000.

Figure A1.7 Arts & humanities monograph publishing cost shares, circa 2000



Source: Author's analysis.

Electronic publishing of monographs and texts offers opportunities for innovation, cost savings and value adding. Cost savings may be greater than for journals due to the extent of formatting and editorial work and the high cost of physical distribution to stock and the management of inventory. Electronic publishing of research monographs also promises to enable the publication of scholarly works for which there may not be a sufficiently large commercial market for them to find a print publisher, thus alleviating one of the current crises in publishing in the arts and humanities. E-presses, particularly institutional e-presses, also offer significant opportunities for cost effective and wider distribution and access to scholarly research monographs.

Costs are relatively modest compared to the overall budgets of universities, libraries or information centres and a relatively small part of overall scholarly communication costs. For example, the Australian National University E-Press operates on around AUD 250,000 in salaries per year, with all overheads covered within the university. Other, Australian-based university e-presses report similar costs (ranging from around AUD 180,000 to AUD 250,000 for direct salary costs). Derricourt (2005, p16) believes that by using only a small percentage of the annual cost of research "could fund a different model for institutional publishers, including university presses, to disseminate research output of monograph length."

As is the case with journals, however, dual mode publishing adds costs. Watkinson (2001, p44) reported one publisher's estimate of dual mode monographs costing 125% of print only costs. Nevertheless, having the complete works, or part thereof, online can be important in the decision to buy – enabling the reader to consume enough of the text to know that he/she wishes to buy. The early experience in the United States (*e.g.* National Academies Press) was that if monographs were made available free of charge online, sales of the hard copy increased two- or three-fold (Halliday and Oppenheim 1999; EPS 2004). More recently, a South African open access publishing project made books available online free of charge and the sales turnover of the HRSC Press in question rose by 300%. (Eve Gray and Associates, 2004). If this is the case, increased revenue might compensate for the additional costs of dual mode – although other experience appears to suggest a potentially negative impact.

Research infrastructure

Research infrastructure costs include those relating to library and information access, equipment and facilities, and the network and computer systems that underpin research communication activities.

Library and information access systems

A number of analysts have pointed to the significance of research library costs in overall scholarly communication system costs. Cooper (1989) estimated the cost of storing a single issue of a journal in the average library at USD 25 to USD 40 per annum. Bowan (1996) estimated that the total handling costs of a title in UK research libraries varied from around GBP 60 to GBP 113 per annum (an average of GBP 86). Odlyzko (1998) suggested that the journals 'crisis' was really a library costs crisis, claiming that for every USD 1 spent on journals a further USD 2 was spent on library processing and storage costs. Citing a number of previous studies, Tenopir and King (2000, p216) suggested that the unit cost of processing and maintaining purchased journals had been estimated at USD 71 per title for university libraries and USD 81 for special libraries. To these fixed costs one should add usage costs (*e.g.* re-shelving), which were estimated at USD 1.05 per reading for university libraries and USD 1.48 for special libraries.

Morris (2005) reported that the average journal acquisition cost in the North American ARL libraries in 2003 was USD 283, but noted that their costs may be somewhat high – citing University of Pittsburgh costs of USD 98 per electronic journal and USD 168 per print journal in 2004. Tenopir and King (2004) reported an average 154 articles per journal title in 2002 and a median circulation per journal of 1,900. Morris (2005) suggested that these averages imply a cost per article of USD 1.88, which across 1,500 libraries amounted to a system wide USD 2,820 per article.

Box A1.1 ARL library expenditures

In 2003-04, ARL reported that expenditures for all types of electronic resources (computer files, electronic serials, bibliographic utilities and networks, computer hardware and software, and document delivery/interlibrary loans) had increased substantially, but none more than expenditures for electronic serials. In all, expenditures amounted to USD 424 million – of which expenditures for computer files (one time/monographic) were USD 32 million, expenditures for electronic serials USD 270 million, expenditures for bibliographic utilities, networks, etc. (library) USD 26 million, expenditures for bibliographic utilities, networks, etc. (external) USD 17.4 million, expenditures for hardware and software USD 66 million, and expenditures for document delivery/interlibrary loan USD 13 million. Electronic materials accounted for one-third of total materials expenditures.

Source: ARL Statistics. Available http://www.arl.org/stats/arlstat/04pub/04intro.html accessed January 2006.

Morris (2005) also reported that North American ARL libraries acquisition related costs represented around 40% of total costs in the print era, with staff costs accounting for 46% and other costs 14%. In UK academic libraries, acquisitions account for around 36% of expenditure, staff account for 45% of costs and other costs 19%. At 40%, Morris (2005) calculated total costs of USD 435 per journal title per library, equivalent to USD 2.82 per article per library and USD 4,230 per article overall.

Cost per article, per page, per read and per citation

In relation to access costs, Morris (2005) suggested that per article costs in ARL libraries was around USD 1.88. LISU (2004) reported that for UK academic libraries in 2002-03, the average cost of a book (including audiovisual items) ranged from GBP 14.67 to GBP 18.77, and the average cost of periodicals ranged from GBP 54.39 to GBP 105.76 per title. Using the same multiplier as Morris (2005), the implied cost per article in UK academic libraries would have been from 35 to 69 pence.

Using citation data, Lesk (1997) suggested that 22% of scientific papers published in 1984 were not cited during the subsequent decade. This figure rises to 48% for social science papers, and no less than 93% for humanities papers. If citation were considered use, then per use costs of journal papers would be high indeed. Costs per article read are, of course, lower – assuming that many reads do not lead to citation.

Costs per read also vary widely between disciplines. Odlyzko (1998) suggested that the cost per reader of mathematical articles was of the order of USD 200, whereas Varian (1997) quoted the director of a major United States medical library saying that his policy was to cancel anything for which the cost per read appears to be over USD 50. Work at Stanford University suggested that 'high use' material is anything less than USD 50 per use, while 'low use' material costs some USD 200 or more per use.

Bergstrom and McAfee (2005) calculated the cost per page and per citation for a sample of 4,894 journals, finding a mean price per article of USD 8.86 and per citation of USD 1.90. The range was considerable. Indeed, they found a marked difference between for-profit and non-profit publishers, with the for-profit costs at USD 12.55 per article and USD 3.20 per citation, compared with USD 3.09 per article and USD 0.53 per citation for the non-profits. Aside from issues relating to the definition of for-profit and non-profit in the context of society publishing, a weakness of this analysis was its use of listed subscription prices, which are often quite different from the prices actually paid under 'Big Deal' licensing arrangements.

In their analysis of UK academic library journal costs and usage, Woodward and Conyers (2005) reported an average (mean) of 173 downloads per title across a sample of four major publishers, at an average (mean) cost of USD 3.68. However, there was considerable variation, with downloads per title ranging from 122 to 286, and costs per article download from USD 2.39 to USD 5.51.

Tenopir and King (2000, pp216-217) suggested that the average journal article was read 900 times. With publishing costs of around USD 4,450 per article acquisition costs would be around USD 5 per reading. To this they suggested adding around USD 1.48 in non-acquisition library costs and USD 12.22 in user costs when users travel to the library to read print journals. They noted that the largest factor in per reading costs is user costs, with online delivery to the desktop making a significant contribution to cost savings in this area.

Electronic journals

Tenopir and King (2000, p379) noted that e-only journals would offer libraries the opportunity to save on the costs associated with handling print copies, which were estimated to be in the range of USD 70 per title per year. They would also be able to save the USD 1.48 spent in handling per article reading.

Montgomery (2000) explored the relative costs of print and e-journal collections at Drexel University library. She suggested that the saving of physical space alone was significant, with annual space costs around USD 240,000 for Drexel, and a facility that would cost USD 2 million to construct, compared with relatively modest additional server and technical support costs involved with e-journals. In 2001, Drexel's print journals cost some USD 120 per title, compared with e-journal costs of around USD 95 per title. Reporting the same study, Montgomery and King (2002) reported operational costs for print journals of USD 15 per use (USD 17.50 including subscription costs), and that for electronic journals of USD 0.45 per use (USD 2 including subscription costs).

Shonfeld *et al.* (2004, p27) found that US research libraries' 25 year life cycle per title costs varied from USD 13 to USD 69 for electronic journals, compared with USD 48 to USD 353 for print journals, with saving arising from reduction of libraries' shelving, handling and preservation costs. Drawing on the same study, Cox (2004, pp7-8) reported that across 11 US research libraries', 25 year life cycle per title costs for electronic journals were between 20% and 60% lower than print journal costs.

Among the few to focus on book related costs, Lewis (2004) cited library processing costs for a hypothetical library of USD 50 for print monograph processing, compared with USD 25 for e-book processing.

Archives and repositories

There are reports of the installation and operational costs of open access archives and repositories in the literature which give some guidance as to the costs involved. As elsewhere, exactly what is included and what is assumed to be covered within the overhead costs of the institutions hosting the archives and repositories varies from case to case. Importantly, the scope of the archive/repository may also vary considerably, with some catering for e-prints only and offering limited functionality, while others embrace a much wider range of digital objects and seek to integrate more fully into teaching and learning, research management and reporting functions.

Odlyzko (1997) presented one of the earliest estimates of the costs of operating the 'Ginsparg archive' (arXiv.org), in which he noted that, at that time, it was processing around 20,000 papers per year. As a minimum, Odlyzko thought the costs to include a half-time systems administrator and the costs associated with the depreciation and maintenance of server related hardware, which with overheads he estimated to be around USD 100,000 per year – or USD 5 per article. At the maximum, he suggested the inclusion of the USD 1 million development grant, full-time staff at USD 300,000 per annum, five servers costing up to USD 20,000 each, and broadband communications costs of up to USD 100,000 per annum – amounting to USD 75 per article.

More recently, Getz (2005) reported that current host Cornell University provides USD 200,000 per year as a direct subsidy for arXiv, which now receives around 50,000 postings a year – an average of USD 4 per article. Hickerson (2004), who has been intimately involved in the operation of arXiv at Cornell, reported that costs for the operation of arXiv should average USD 200,000 annually – including system maintenance and upgrades, managerial and administrative support costs. He also noted that there had been 20 million full text downloads during 2002, implying per read costs of around 1 US cent.

Swan and Brown (2005) noted that an average-sized research-based university can set up a functional archive for USD 10,000. Kemp (2005) quoted costs from ten libraries from the USA, UK, Canada and Ireland, revealing a range from around USD 7,000 to USD 1 million for repository set-up costs. Swan *et al.* (2004) and Swan and Needham (2005) reported on the establishment and operational costs of four major institutional repositories:

- MIT DSpace – which was set up with a USD 1.8 million grant, involved three FTE staff and the purchase of USD 400,000 worth of system equipment. Annual running costs include USD 225,000 staff costs, USD 35,000 equipment costs and USD 25,000 operating costs.
- Queens Qspace – cost CAN 52,065 to establish, of which CAN 50,000 was spent on technical staff. Annual operating costs include CAN 25,000 to cover library and IT staff costs.

- The National University of Ireland repository – was set up with a grant of EUR 5,000 for a server and EUR 15,000 for staff costs. Annual operating costs are limited to one FTE staff for maintenance (EUR 30,000).
- Nottingham's SHERPA – involved set up costs of GBP 3,900, of which GBP 2,400 was spent on installation and customisation staff costs and GBP 1,500 on a server. Annual operating costs are GBP 33,900, of which GBP 30,000 is allocated to the coordination and collection of material.

Swan *et al.* (2004) also noted that the SHERPA project experience suggested article input or 'self-archiving' costs of the order of GBP 4.46 per article.

Table A1.5 Institutional repository cost examples

	Currency	*Cost*	*GBP*
Installation costs:			
MIT (DSpace)	USD	2,450,000	1,300,000
Queens (DSpace)	CAN	52,065	22,750
NU Ireland (Eprints)	EUR	20,000	17,500
Nottingham (Eprints)	GBP	3,900	3,9000
Operating costs (per year):			
MIT (DSpace)	USD	285,000	160,000
Queens (DSpace)	CAN	50,000	22,250
NU Ireland (Eprints)	EUR	30,000	26,250
Nottingham (Eprints)	GBP	33,900	31,250

Sources: Swan, A. *et al.* (2004) *Delivery, Management and Access Model for E-prints and Open Access Journals within Further and Higher Education*, EPIC & Key Perspectives, p42; and Swan, A. and Needham, P. (2005) 'Developing a model for e-prints and open access journal content in UK further and higher education,' *Learned Publishing* 18(1), pp25-40.

HCSTC (2004) cited cost estimates for UK higher education institutions, which included total installation costs of GBP 3,900 per institution and annual operating costs of GBP 31,300. These costs included a supported 'self-archiving' service, but assumed that technical support costs would be absorbed by the institution's existing IT services and did not allow for the potentially considerable costs of preservation (which was treated as a separate issue).

Rankin (2005) suggested that each institution's repository project team would be likely to involve 1 to 3 people (FTE) for a year during set-up, with ongoing support thereafter requiring less that one person. Fully costed, this would imply perhaps AUD 250,000 in staff costs during the first year and perhaps AUD 80,000 to AUD 100,000 per year thereafter. Rankin also suggested that, depending upon the envisaged scale and rate of content ingestion, a dedicated server might cost NZD 5,000 to NZD 15,000. Harboe-Ree (2005) suggested that a suitable server to support an institutional repository could cost AUD 10,000 to AUD 15,000.

Estimates of the cost of deposit and self-archiving vary. As noted, on the basis of experience with the SHERPA project, Swan *et al.* (2004) suggested article input costs of the order of GBP 4.46 per article. Carr and Harnad (2005) concluded that the average time spent entering metadata would be as little as 40 minutes per year for a highly active researcher. At the time of writing this would be equivalent to perhaps AUD 50-60 per year in self-archiving time (fully costed).

Table A1.6 Institutional repository costs for UK further and higher education (GBP)

Cost element	*Per Institution*	*UK National*
Installation costs:		
Server	1,500	196,500
Software	..	..
Installation (5days)	600	78,600
Customisation (15 days)	1,800	235,800
Total Installation	3,900	510,900
Operating costs (per year):		
Technical support	..	..
Archiving service	30,000	3,930,000
Upgrades/Migrations	1,300	170,300
Digital Preservation	..	..
Awareness / Advocacy	..	..
Total operating	31,300	4,100,300
Article deposit costs (per article)	..	4

Source: HCSTC (House of Commons Science and Technology Committee) (2004), *Scientific Publications: Free for all?* Tenth Report of Session 2003-04, The Stationery Office, London. Available http://www.publications.parliament.uk/pa/cm/cmsctech.htm accessed July 2004.

Service charges for commercial and semi-commercial services are also indicative. Moranti (2005) reported that at the Inter-Academic Consortium for ICT (CILEA) in Italy, a non-profit organization providing ICT facilities to universities and research centres, they have established and are running several repositories for different institutions, primarily using EPrints and DSpace (open-source software). The cost has been EUR 7,200 for start-up and first year management, then EUR 2,400 per year for operation, including the use of hardware facilities, training and remote assistance. From the institution's side, CILEA recommend a working group with some faculty members and librarians for analysis, set up and promotion (at least initially), then a part-time librarian for maintenance, if the repository is based on self-archiving. The amount of faculty involvement is up to the institution. They have found that most do not require specialised IT people beyond basic set-up and maintenance.

Other commercial repository services (*e.g.* ProQuest) are available, which cover the 'database' services but not data entry and recruitment. Individual subscription prices in Australia appear to be between USD 25,000 and USD 35,000 (depending upon student numbers), although others have suggested significantly higher prices in larger US institutions (*e.g.* up to USD 125,000 for institutions of around 35,000 students).

Going somewhat beyond the topic of this study, but nonetheless an important consideration in overall costing, a number of analysts have pointed to the need to develop clear policies for repositories in order for them to be of sustainable value. Hunter and Day (2005, p3) noted that:

> *There is much more to the setting up of an institutional repository than choosing some repository software, implementing it, and requesting staff to contribute content… Each institution needs to have a common understanding of the purpose of the repository as well as a set of policies that define its intended scope, together with information on issues like deposit, access, and sustainability* (Hunter and Day 2005, p3).

This needs to be taken into account when looking at costs, and it is likely that the above cost estimates underestimate the importance of senior level engagement in policy and advocacy. Moreover, the role of the repository, the type and extent of content it is intended to contain and its role in longer-term preservation are all issues affecting costs (and benefits).

Looking at specific areas of cost, Hunter and Day (2005) noted that the manual creation of descriptive metadata can be a time-consuming process and tends not to be a priority for research staff, so some thought has to go into developing processes that may support the submission workflow. This may include the use of library staff to review and enhance the metadata creation process. Other issues include management of depositing and conduct of deposit activities, management of intellectual property rights relating to both the content and related metadata, management of access and control over levels of access to various digital objects, content quality control and management of standard quality kite marking, preservation in terms of file formats and related software, the range of file formats permitted, and the extent and nature of integration of the repository into research reporting and evaluation.

In a salutary warning on repository costs, Crow (2002) suggested that irrespective of scope, all the institutional repository projects so far have observed that the effort and organizational costs required to address repository policy, content management, and faculty marketing issues dwarf the technical implementation effort.

Network and computer systems

Indicative of the systems costs for large publishers, it has been reported that Elsevier invested at least GBP 45 million in its ScienceDirect service over the last five years (Worlock 2004). Hunter (2004) noted that there were over 5.6 million articles in Elsevier's ScienceDirect, at least 10 million researchers regularly use the service and full text downloads are doubling annually, with an expectation of over 275 million downloads in 2004 (and another 100 million at sites that hold the files locally). It has cost more than GBP 200 million to create and maintain the service, including GBP 24 million to digitise the backfiles of all titles back to volume 1, number 1 (which for *The Lancet* was in 1823).

In Australia, the principal research network infrastructure provider is AARNet. For calendar year 2004, AARNet reported revenue from ordinary activities of AUD 49 million (AARNet 2005). Few universities have reported ICT expenditure in a systematic and comparable way, although CAUDIT is currently undertaking a benchmarking study. Preliminary findings suggest that higher education institutions typically spend between 6% and 10% of their total revenues on ICTs (including hardware, software, staff, outsourcing and maintenance). This figure is similar to the 7% reported for the University of Minnesota, and similar levels at other US universities (Odlyzko 2006, p34).

Equipment and facilities

During 2002-03, a total of AUD 12.2 billion was spent on R&D in Australia, of which non-land and building related capital expenditure accounted for AUD 684 million and non-labour related current expenditures for AUD 5.7 billion. The higher education sector account for AUD 177 million of the non-land and building capital expenditure and the government sector for AUD 100 million (ABS 2004). In 2003, it was estimated that the value of research infrastructure in Australian Universities was of the order of AUD 6 billion, and that of government institutions (CSIRO, DSTO, ANSTO, and AIMS) a combined AUD 3 billion (CoA 2003, pp174-175).

Research funding and management

Costs relating to research funding and management are substantial, but increasing automation can play a role in reducing them. Major costs relate to the review and management of competitive grants through research councils and other funding bodies, and the reporting activities required for research management and evaluation.

Review and management

There is very little published information about the costs associated with the review and management of research grants, research councils and other funding bodies. However, the expenses of the ARC and NHMRC are indicative. For the year ended June 2004, ARC expenses amounted to AUD 12.6 million, of which AUD 5.5 million related to staff costs (ARC 2005). NHMRC total operating expenses for the year to June 2004 were AUD 12.5 million, of which AUD 9.9 million related to staff costs and a further AUD 6.6 million was spent on program and committee support (NHMRC 2005). The ARC received some 26,000 assessments in 2004, and paid assessors AUD 30 per assessment. ARC College of Experts members were paid AUD 15,000 per year. The NHMRC receives around 6,000 assessments each year.

Based on a small number of interviews with university research office directors around Australia, and extrapolating their staffing and budget numbers based on research active staff numbers, it is likely that total university research office budgets would have been of the order of AUD 35 million during 2004. Based on observed ratios in just a handful of cases, perhaps AUD 7 to 8 million of this would relate directly to research reporting.

Evaluation

It is instructive to consider the costs associated with assessment and evaluation exercises similar to that proposed for Australia. The UK Research Assessment Exercise (RAE) for 2008 is expected to cost around GBP 45 million. The UK funding bodies (2004) noted that:

> *Establishing the full costs of the RAE has proved an interesting challenge since the first exercise. Calculating the direct additional costs to the higher education funding bodies is comparatively straightforward. We know that for the 2001 exercise these came to some £5.6 million. The largest element in this total was costs related to panel meetings, including members' fees. However, the figure excludes the accommodation and support services provided by HEFCE. Taking account of inflation, and of the changes to assessment criteria and processes mentioned above, the direct costs incurred by the funding bodies in running the next exercise are likely be around £10 million. The exact cost will depend upon a number of key factors, in particular how fees paid to main panel and sub-panel members are determined and what arrangements are made to secure an input from international assessors. …*
>
> *A survey of the costs to the sector of the 1996 exercise, based upon returns from colleagues in HEIs, produced an estimate of some £30 million. A later study of costs was carried out in one research-intensive HEI. This produced an estimate (including opportunity costs) of £37.5 million for all HEIs in England – or 0.8 per cent of the total funds allocated on the basis of the RAE's results. We consider that these estimates reflect the amount of work that HEIs need to undertake for the exercise, over and above what might otherwise be expected of a well-managed institution, and that the costs to HEIs of our planned approach in 2008 will not be radically different.* (Funding Bodies 2004).

The Australian Government provided AUD 2.8 million over two years to establish Quality and Accessibility Frameworks for Publicly Funded Research. Annual costs of the operation and management of the Research Quality Framework (RQF) will likely be similar to that of the research councils, scaled to the level of review panel activity and amount of peer reviewing actually undertaken. Marlin (2006, p3) suggested that "early estimates point to an Australian RQF costing somewhere in the order of $25 million for government administration alone, and more than $50 million when other contributions are taken into account."

The distribution of costs

There are many ways in which the distribution of the costs associated with scholarly communication are changing, but few have generated the level of discussion that that associated with changing from subscription-based to ‘author-pays’ journal publishing has attracted.

Shifting costs with ‘author-pays’

An ‘author-pays’ system shifts the costs of publishing, and may lead to organisations, sectors and countries that are major producers of scientific and technical knowledge paying more in author charges than they would for subscription fees in a reader pays system. This raises a number of potential questions, including: will research intensive institutions (and countries) pay more for ‘author-pays’ than subscriptions, and if so, how will the budgetary flexibility be achieved? Will public sector research activities subsides private sector users (readers) – the, so called, free rider problem? And can producers pay?

As noted above, in its submission to the UK House of Commons Science and Technology Committee Inquiry into Scientific Publications, for example, Elsevier (2004) suggested that:

> *…while Britain’s spending on journal subscriptions currently amounts to 3.3% of the world’s total, UK researchers contribute a much higher 5% of all articles published globally. As a result, we estimate that the UK Government, foundations, universities and researchers could together pay 30-50% more for STM journals in an Open Access [publishing] system than they do today* (Elsevier 2004, p2).

At the institutional level, Okerson (2004) noted that Yale authors publish as many as 4,000 articles in STM titles, while the library spent just under USD 4 million on STM journals, implying a break even ‘author-pays’ fee of USD 1,000. According to Davis *et al.* (2004, p11):

> *Our Task Force has estimated that Cornell University Library (CUL) would actually spend more as an institution if the publication of all refereed scholarly articles moved from the traditional subscription-based model to a producer-payment model. If the library used its subscription funds to pay for author fees, it could see its serial expenditures rise by at least 1.5 million dollars/year. This figure is based on the number of articles published by Cornell researchers each year (over 3,500) and an estimate of the average cost ($1,500) to publish each article – an estimate that is considered to be substantially lower than what most publishers now claim to be true costs.*
>
> *…the average per-article cost would need to be lower than $1,100 for CUL to save any money in a producer-pays model. This assumes that all publishers participate in the producer-pays model. If we removed Elsevier from this scenario, the per-article costs would need to be under $800, and under $400 per article if the largest commercial publishers decided not to participate. Considering that most optimistic estimates of the cost per article to publish is*

> *$1,500, it is unlikely that CUL will save money under any producer-payment scenario.* (Davis *et al.* 2004, p11).

Conversely, others have suggested that for leading US universities 'author-pays' would cost less. For example, Velterop (2003) suggested that, based on 2001 publications and serials budgets, and with articles charges of USD 500 per article, Cornell could save USD 3.65 million, Dartmouth USD 2.6 million, Princeton USD 3.45 million and Yale USD 4.6 million. Obviously, such calculations depend upon the level of author fees assumed necessary to support the journals concerned.

Table A1.7 Subscription versus 'author-pays' cost comparisons, 2001

	Number of Articles	*Paid at input (USD500/article)*	*Journal subscription budget*	*Difference (saving)*
Cornell	3,900	1.95 million	5.6 million	3.65 million
Dartmouth	1,200	0.60 million	3.2 million	2.60 million
Princeton	2,500	1.25 million	4.7 million	3.45 million
Yale	3,600	1.8 million	6.4 million	4.60 million

Source: Velterop, J. (2003), 'Institution pays', presentation at ALPSP forum "Who Pays for the Free Lunch?" ALPSP, April 2003. Available http://www.alpsp.org/events/previous/s040403.htm accessed June 2004.

Björk (2005) used the Cornell data to estimate the serials expenditure of the 112 US universities in 2003 at USD 308 million and the number of first author papers at 318,000. He concluded that, if the US universities switched all their subscriptions to author payments, the equivalent level of payment would be USD 1,000 per published article. Others have analysed the costs on a title-by-title basis. In 2005, Stern (2005) noted that Yale researchers authored 22 articles in *Nucleic Acids Research* during 2004. At USD 1,500 author fees that would have cost USD 33,000. With institutional membership, submission fees fall to USD 500, or a total of USD 11,000 for 2004 – saving USD 22,000 on the simple author fee charges. However, Yale's subscription payments for *Nucleic Acids Research* was USD 2,855 – leaving the 'author-pays' options costing 7 to 10 times as much.

Support for open access journals

How much does it cost to run an e-only open access journal, and who might pay? King and Tenopir (2004) suggested that the investment required to start a new journal could be as high as USD 50,000, and operational investment could reach USD 20,000 with additional capital investment of perhaps USD 30,000. Thus the total investment in establishing a science journal could be as much as USD 100,000. While these figures related to print journals, there is little differences in establishment between print and electronic – with cost differences relating almost exclusively to operational activities.

Getz (2005) suggested that the cost of launching an open journal may be minimal. A campus with a standard open archive may install software to manage the flow of materials through an editorial process. For example, The Open Journal System software is in the public domain and requires relatively straightforward local implementation, and Cornell University Library is developing DPubs as open source software to serve a similar function. The editorial software maintains a database of articles in process, keeps track of each in the editorial flow, and sends timely queries to nudge the process. The upshot is that any group of faculty members who want to edit a journal would face little expense in managing the editorial process or distributing the final product (Getz 2005, p6).

Some authors are willing (and able) to pay 'author-pays' fees, but the amounts mentioned are often less than the amounts widely cited as the 'full costs' of commercial publications. Davis, *et al.* (2004, p7) noted that:

> *Authors are generally in favor of increasing the access to their own publications, yet may be unable (or unwilling) to pay the costs of making this a reality. A survey of authors publishing in the Proceedings of the National Academy of Sciences (PNAS) reveals that about half would pay to support an Open Access option. Of those who support the idea, 80% would be willing to pay only $500. These results are similar to an author survey by Oxford University Press: 54% said that they would pay to be published, yet 84% (of these 54%) would only pay $500, 12% would be willing to pay $1000, and only 4% an amount above that.* (Davis, *et al.* (2004, p7).

In some fields of research (*e.g.* biomedical) 'author-pays' is an established model, but in some other fields (*e.g.* humanities), where research funding tends to be much more limited, the prospects of 'author-pays' open access journals may be more limited. This may leave some proportion of the costs needing support from other sources (*e.g.* learned societies, foundations, grants, research institutions, etc.).

Support for open access archives and repositories

Various parties have supported the establishment and operation of open access archives and repositories, with institutions and foundations being among the most common sources of funding and support. With potential benefits from raising the profile of the institution and increasing accessibility to research outputs, as well as efficiency gains in some research management and reporting functions, many can see the advantage of providing institutional support for an institutional repository.

As far as authors are concerned, Swan and Brown (2005, p64) have found that more than 80% would willingly comply with an institutional mandate to self-archive and a further 13% would comply reluctantly. Their survey results suggest that those less willing to comply with an institutional mandate are in fields where commercial considerations may have been a factor. Interestingly, a higher than average 86% of Australian and New Zealand respondents would willingly comply, and a further 11% would do so reluctantly.

Some perceive an irony in paying to access the findings of publicly funded research when it has already been given away by the authors. When research is funded by governments it is because the research is a public good, and the private sector would under invest. The return on government investment in R&D will be maximised if the results are as widely accessible and readily available as possible. Access barriers reduce the return on government investment in R&D. Much of the literature discusses the relative merits of reader pays and ‘author-pays’. However, the public good argument inevitably leads to ‘government pays’, and there is an argument for government support for the facilitation of open access.

Appendix II Benefits of enhanced access: A literature review

The literature on potential benefits of enhanced access (*e.g.* open access) is almost entirely qualitative, suggesting the dimensions of impact but stopping short of estimating the value of benefits. Nevertheless, a review of some of the findings is suggestive of the nature and extent of the potential benefits of enhanced/open access.

Enhanced access opportunities

Perhaps the most important of the potential benefits of open access is enhanced access to, and greater use of, research findings. Allen (2005, p9) noted how the Budapest Open Access Initiative (BOAI) spoke of the "unprecedented public good" that open access could do, stressing the importance of internet technology in making it possible for scholarly literature to be distributed on a global scale and made available free of charge. The stated advantages were to "accelerate research, enrich education, share the learning of the rich with the poor and the poor with the rich, make this literature as useful as it can be, and lay the foundation for uniting humanity in a common intellectual conversation and quest for knowledge."

There is an increasing number of studies showing that open access articles are indeed used more, both in terms of citations and downloads (*e.g.* HCSTC 2004, p76; Lawrence 2001a; Odlyzko 2002; Prosser 2003; Kurtz 2004; Walker 2004; McVeigh 2004; Brody, *et al.* 2004; Harnad *et al.* 2004; Brody *et al.* 2005; Getz 2005; Hajjem *et al.* 2005; Davis and Fromerth 2006; etc.), and there is an ever growing list of such studies reported by The Open Citation Project (See 'The effect of open access and downloads ('hits') on citation impact: a bibliography of studies' at http://opcit.eprints.org/oacitation-biblio.html).[19]

Harboe-Ree (2005) pointed to a number of specific examples:

- Stevens-Rayburn (2003) noted that *Astrophysical Journal* articles that are also on the pre-print server have a citation rate twice that of papers not on the pre-print server.
- Lawrence (2001) demonstrated that "there is a clear correlation between the number of times an article is cited and the probability that the article is [free] online, with the mean number of citations to offline articles being 2.74 and the mean number of citations to online articles 7.03, an increase of 157%."
- Antelman (2004) found "a significant difference in the mean citation rates of open-access articles and those that are not freely available online. The relative increase in citations for open-access articles ranged from a low of 45% in philosophy to 51% in electronic and electrical engineering, 86% in political science, and 91% in mathematics."

- Harnad and Brody (2004) cited a number of studies that reveal dramatic citation advantages for open access (*e.g.* a study of physics articles published each year between 1992 and 2001 revealing a variation on an annual basis of between 2.5 to 5.8 times more citations for open access articles compared to closed access articles).

Harnad (2005) noted that this 'open access advantage' arises from at least six component factors, of which three are permanent and three temporary. Expressing the open access advantage as "OA advantage = EA + AA + QB + OA + UA" Harnad explained:

> *EA: EARLY ADVANTAGE, beginning already at the pre-refereeing preprint stage. Research that is reported earlier can begin being used and built upon earlier. The result turns out to be not just that it gets its quota of citations sooner, but that quota actually goes up, permanently. This is probably because earlier uptake has a greater cumulative effect on the research cycle. (A permanent effect).*
>
> *(AA): ARXIV ADVANTAGE, the special advantage of self-archiving specifically in Arxiv for physicists, because it is a central point of call: OAI-interoperable Institutional Repositories [are] likely – for many reasons – to supersede this, so it will eventually make zero difference which OAI-compliant IR one deposits in, as access will be through OAI cross-archive harvesters, not directly through individual OAI Archives.*
>
> *(QB): QUALITY BIAS, arsing from article/author self-selection; this does not play a causal role in increasing impact: the higher-quality (hence also higher-impact) articles/authors are somewhat more likely to be self-archived/self-archivers in these early (15%) days of self-archiving: this bias will of course vanish as self-archiving approaches 100%).*
>
> *QA: QUALITY ADVANTAGE, allowing the high-quality articles to compete on a level playing field, freed of current handicaps and biases arising from access affordability differences. (A permanent effect).*
>
> *(CA): COMPETITIVE ADVANTAGE, for self-archived papers over non-self-archived ones, in early (15%) days; this too will of course disappear once self-archiving nears 100%, but at this moment it is in fact a powerful extra incentive, for the low % self-archiving fields, institutions and individuals.*
>
> *UA: USAGE ADVANTAGE: OA articles are downloaded and read three times as much. (A permanent effect). (There is also a sizeable correlation between early download counts and later citation counts.)* (Harnad 2005).

While important, it should be noted that citation reflects research use only, and does not take account of wider use of online and readily accessible research findings by practitioners (*e.g.* medical practitioners, consulting engineers, etc.). There is significant potential for open access to expand and facilitate the use and application of research findings to a much wider range of users, well beyond core research institutions and large firms that have had access to the subscription-based literature.

Box A2.1 Introduction to open access

Open Access (OA) means that electronic scholarly articles are available freely at the point of use. The subject has been discussed for over 10 years, but has reached a crescendo of discussion over the last few years with various declarations in favour of OA from groups of researchers or their representatives. The UK House of Commons Science and Technology Committee considered the issue in 2004, reporting in the summer in favour of OA. This indicates the importance of the issue, and led to statements from large research funding bodies such as the Welcome Trust and the Research Councils UK.

Motivations

Ethics: There is an ethical argument that research funded by the public should be available to the public. Since research is an international activity, this crosses national boundaries.

Research Impact: The Internet provides an opportunity. Modern harvesting techniques and search engines make it possible to discover publications of relevance if they are deposited in an OA repository with a particular metadata standard. If all authors did this then the world of research would be available 'at the fingertips'. There is evidence that articles available in an OA repository have more accesses (readers), citations and therefore impact.

Costs: There is concern over the hindrance to research caused by the cost of journal subscriptions, whether electronic or paper. These costs run well above the rate of inflation with the result that libraries with restricted budgets… are no longer providing many journals needed by researchers.

Just reward: There is also concern that in traditional scholarly publishing, most of the work (authoring, reviewing, editing) is done freely by the community and that the publishers make excessive profits from the actual publishing (making available) process. In conventional publishing, the institution subscribes to the publication channel to obtain electronic access or paper copies.

Types of Open Access

At this stage it is important to distinguish several dimensions of the issue: OA can be delivered in two ways:

'green': the author can self-archive at the time of submission of the publication (the 'green' route) whether the publication is grey literature (usually internal non-peer-reviewed), a peer-reviewed journal publication, a peer-reviewed conference proceedings paper or a monograph

'gold': the author or author institution can pay a fee to the publisher at publication time, the publisher thereafter making the material available 'free' at the point of access (the 'gold' route). The two are not, of course, incompatible and can co-exist.

The 'green' route makes publications available freely in parallel with any publication system but is not, itself, publishing. The 'gold' route is one example of electronic publishing. At present it is much more common to have non-OA electronic access to publications in a publisher's database for a subscription fee…

Barriers to Open Access

Loss of publisher income: The major objection to 'green' self-archiving comes from publishers and learned societies (many of which depend on subscriptions to their publications) who fear that 'green' OA threatens their business viability. To date there is no evidence that 'green' archiving harms the business model of publishing. There is evidence that 'green' archiving increases utilisation, citation and impact of a publication. Whilst the major commercial publishers provide additional value-added services that could offset the impact of OA on current business models, the impact on learned societies may require new business models to be developed.

Copyright: Copyright agreements between authors and publishers may inhibit the 'green' route. However, to date, between 80 and 90% of publication channels (the variability depends on exactly what is counted) allow 'green' author deposit although some insist on an embargo period before the publication is available for OA. In contrast some publishers of journals – of which 'Nature' is the most well-known – do not demand copyright from the author but merely a licence to publish, leaving copyright with the author or their institution.

Green Open Access Repositories: There are two kinds of 'green' OA repository:

Thematic: where authors deposit in a (usually) central repository used by the community and maintained by an appropriate institution and where relevant material on a subject area is collected together. The best known example is arXiv.

Institutional: where the authors deposit in a repository maintained by their institution thus collecting together in one place the research output of that institution. This has the advantage of responsibility of ownership and some possible management control/encouragement of deposit. There are available open source systems for 'green' repositories; the best known being ePrints, DSpace, Fedora and ePubs.

Advantages of Open Access

The major advantage of OA is research impact – the available e-article is likely to have more accesses, citations and impact. However, there are additional advantages:

Links: Electronic availability of a publication (whether 'green' or 'gold') has another advantage; it is possible to crosslink the publication to any research datasets and software used in producing the paper; this improves 'the research process' by permitting other researchers to examine in depth the published work and validate, or contradict, the conclusions.

Access: In the case of non-OA electronic publishing, a researcher has to access separately (with identifier and password provided upon payment of the annual subscription) the databases of publications of each publisher to obtain information. In the case of 'gold' OA publishing a researcher has to access separately the open databases of publications of each publisher to obtain information. In both of these cases the user interface is different from publisher to publisher. In the case of 'green' open access the OAI-PMH (Open Access Initiative Protocol for Metadata Harvesting) facility links OA repositories so that all repositories obeying the protocol can be harvested and their contents are available freely…

Speculation: Future

Looking to the future speculatively, it is possible to imagine 'green' OA repositories becoming commonplace and used heavily. At that point, some argue, one could change the business model so that an author deposits in an open access 'green' repository but instead of submitting in parallel to a journal or conference peer-review process, the peer-review is done either by: a learned society managing a 'college' of experts and the reviewing process – for a fee paid by the institution of the author or the author; allowing annotation by any reader (with digital signature to ensure identification/authentication).

The former peer-review mechanism would maintain learned societies in business, would still cost the institution of the author or the author but would probably be less expensive than publisher subscriptions or 'gold' (author or author institution pays) open access. The latter is much more adventurous and in the spirit of the internet; in a charming way it somehow recaptures the scholarly process of two centuries ago (initial draft, open discussion, revision and publication) in a modern world context. It is this possible future that is feared by commercial publishers.

Source: Jeffery, K.G. (2006) 'Open Access: An Introduction,' *ERCIM News 64,* January 2006. Available http://www.ercim.org/publication/Ercim_News/enw64/jeffery.html accessed January 2006.

In this regard, the notion of the 'Long Tail' is instructive. Anderson (2004) has shown how the power of the internet is transforming content industries as online distribution reveals previously unmet demand. He noted that:

> *What's really amazing about the Long Tail is the sheer size of it. Combine enough nonhits on the Long Tail and you've got a market bigger than the hits. Take books: The average Barnes & Noble carries 130,000 titles. Yet more than half of Amazon's book sales come from* outside *its top 130,000 titles. Consider the implication: If the Amazon statistics are any guide, the market for books that are not even sold in the average bookstore is larger than the market for those that are… In other words, the potential book market may be twice as big as it appears to be, if only we can get over the economics of scarcity.* (Anderson 2004).

While there may be limits to understanding in some fields, there is little reason to suppose that a similar phenomenon might not apply to open access scholarly research content. Access statistics, to date, suggest that there may indeed be a scholarly communication 'Long Tail' (See section on 'Open access to scholarly publications' below).

Quantitative analyses of open access

There has been little *quantitative* analysis of the potential benefits of open access to publications. However, there has been considerable work done on open access to research data and to government information that is indicative of the nature and potential scale of benefits.

Open access to government information and data

Pluijmers and Weiss (2005) explored open access to public-sector information, including publicly-funded scientific data. Their analysis covered the benefits of open access, the arguments for cost-recovery and the issue of government competition with the private sector, and it included case studies from the Netherlands, UK, Germany and Finland. They concluded that:

> *Open access policies are beneficial in the short term as well as in the longer term for the general public, the private sector and also for government entities (p5).*
>
> *Government entities that have already separated their commercial activities into a private entity have realized that an open access policy is necessary in order to make privatisation of the commercial arm a success. In Europe, recognition is slowly emerging that open access to government information is critical to the information society, environmental protection, and economic growth (p73).*
>
> *We believe that open and unrestricted access to government information will lead to a net boost in jobs, and additional business formation leading to increased overall tax revenue (p74).*

> *Governments should support full, open and unrestricted international access to scientific data for public interest purposes – particularly statistical, scientific, geographical, environmental, and meteorological information of great public benefit. Such efforts to improve the exploitation of public sector information contribute significantly to maximizing its commercial, scientific, research and environmental value (p75).* (Pluijmers and Weiss 2005).

It is worth looking in detail at some of the studies referred to by Pluijmers and Weiss. The Dutch Federal Geographic Data Committee attempted to quantify the economic effects of open access policies for spatial data, in which they sought to identify the potential benefits of open access policies within the community of geographic information. According to RAVI (2000), several types of benefits would occur from open access policies:

- Efficiency, with faster policy decisions and decision making in general, more efficient logistics, and less duplication of effort by various entities independently entering similar datasets;
- Quality and effectiveness, making value added services possible, particularly those relevant to business and industry;
- Use of information and communication technologies and geographic information systems increasing, particularly among small and medium enterprises; and
- New applications, products and services for businesses as well as consumers being developed. (RAVI 2000).

One of the more interesting examples cited by Pluijmers and Weiss (2005) was that of the emergence of 'weather derivatives'. They noted that:

> *The best recent example of a business opportunity created by increased availability of weather and climate information is the weather derivatives industry, which has now mushroomed to a USD 7 billion industry. This financial sector, …uses weather data to predict risks due to the daily weather. For instance, ski-equipment manufacturers and sellers will have more than average income during a more than averagely cold or snowy winter. On the other hand, the bathing apparel industry will not do as well in an unusually cool summer. The weather derivative industry ultimately seeks to hedge the risks of both* (Pluijmers and Weiss 2005, p33).

In the most recent survey undertaken for the Weather Risk Management Association (www.wrma.org), it was reported that the total value of trades in 2004-05 reached USD 8.4 billion (Stell 2005). It is particularly notable because this is comparable to the value of the worldwide STM publishing market, which was estimated to have been worth between USD 7 and 11 billion during 2003 (EPS 2004; Simba 2004).

Open access to scholarly publications

A number of authors have pointed to the potential benefits of open access to scholarly publications for developing countries, where access to the subscription literature has been limited. Chan *et al.* (2005) noted that:

> *The science base in the developing world cannot be strengthened without access to the global library of research information. Currently, this is nearly impossible due to the high costs of journal subscriptions, with the result that even the most prestigious institutes in poorer countries cannot afford to buy the journals they need. Many initiatives have been started to resolve the access problem, but progress has been slow and, since they are generally dependent on grants or subsidies, are unlikely to be long-term solutions. With the advent of the Open Access (OA) initiative, the outlook for building science capacity in developing countries has improved significantly. In particular, the establishment of interoperable open access archives that is now underway by a rapidly growing number of institutes opens opportunities for true global knowledge exchange…* (Chan *et al.* 2005).

Moller (2006) explored the potential for South Africa. Awareness of open access is often found to be higher among researchers in developing countries than it is in Western Europe and North America (Rowlands and Nicholas, 2005). Pringle (2004) noted a high proportion of open access journals from Latin America and Asia, as well as a number form Eastern Europe.

Access statistics from open access institutional repositories would suggest that access is indeed wider. For example, during 2005 the ARROW Discovery Service (Australian Research Repositories Online to the World) received hits from 105 domains ('countries'), including 15 from the Dominican Republic, 19 from Armenia, 20 from Egypt, 27 from Zimbabwe, 43 from Belarus, 74 from Latvia, etc.[20] A similarly broad range of access is revealed by most repository statistics. What is also notable is that the '.com' domain, the global top level domain for commercial internet users, ranked 5th (even though it includes only generic top level domain commercial registrants and excludes country domain commercial registrants), suggesting that a wider dissemination is possible through open access.

Pinfield (2004) is among a number of writers to have explored the potential advantages of open access institutional repositories. He noted the potential for greater research impact and the development of innovative overlay services and new forms of analysis, saying that:

> *Whilst there are a number of issues that still need resolving in relation to institutional repositories, the benefits are clear. Institutional repositories improve dissemination of content – making it quick, easy, wide and cheap. They break down access barriers to content inherent in the subscription based publishing system. The benefits of making scholarly content openly available in a timely way to anyone with a web browser are profound. Following this, once*

> *the content is easily available, interesting things can then be done with it. Search services can be developed using OAI PMH technology – creating the potential for a global virtual research archive which can be searched from a single access point. The literature can also be analysed more easily. Text mining technologies can be implemented more effectively in an open access environment. Citation analysis at the article level can be carried out. Automated plagiarism detection can be implemented on a wide scale. All of these are very difficult to operate across different subscription-based services with access toll gates.*
>
> *Open access also creates greater impact potential for research papers. The evidence for this is in two strands. Firstly, there is direct evidence that making a paper available on open access tends to produce more citations. Work has been done on a number of different disciplines and the evidence shows consistently that open access means more citations. Secondly, there is indirect evidence in this area. Open access usually creates more downloads – more readings of the article. When this fact is added to the second finding that downloads correlate closely with subsequent citations, these two findings together create another important strand of evidence that open access papers have a greater impact. In short, open access improves communication. It improves access to papers and improves the impact of papers.*
>
> *These benefits are not just theoretical ones. They are already there to see (albeit currently in a limited way).* (Pinfield 2004; 2005).

Looking beyond citation and the research community, Getz (2005) noted three important dimensions of benefit from open access, relating to: broader industry, government and society impacts; educational impacts; and the potential for greater integration of publications and other digital objects that are increasingly the outputs of research (*e.g.* numeric data sets, software algorithms, animations, sound and video files). He suggested that:

> *Although individual scholars may sense little gain in intellectual reputation from making their works openly available to broader constituencies, their institutions may well see significant advantages in attracting political and philanthropic support as well as in attracting students. (Aligning individual behaviour with collective interests is a common problem in many arenas.) Open publication is significantly more available beyond the walls of academia than subscription materials. For this reason, academic leaders in research universities may find significant value in promoting the development of open journals on their campuses. This motive might cause open journals to appear first in disciplines with sophisticated external constituencies like law, medicine, theology, business, art, and music. After the National Library of Medicine put its MedLine index in the open, use increased sevenfold. More than 30 per cent of use is by people other than health care professionals.*

> *Articles published in the open are more readily used in instruction. Many campuses support course management software systems that allow instructors to post materials for students. Students may post items as well. A syllabus can readily provide links to open articles. Subscription-based articles require copyright permissions, a process that discourages use.*
>
> *Articles published in the open more readily link to associated digital content. Readers can reach materials cited by URL. Digital objects that are not facsimiles of printed essays can be linked to text. For example, numeric data sets, software algorithms, animations, sound and video files all may be referenced and reached in the open but require transactions and delay in a subscription environment.* (Getz 2005, pp11-12).

A sevenfold increase in use of the MedLine Index upon shifting to open access, combined with the 30% use by non-professionals clearly suggests that there can be significant impact beyond subscription users – evidence, perhaps, of a scholarly communication 'Long Tail'.

In a recent feasibility study of *Institutional Repositories for the Research Sector* in New Zealand, Rankin (2005) noted that various factors have led policy-makers and research institutions in other countries to establish repositories; for example:

- They want to increase research impact and consider that publicly funded research should be publicly accessible. Placing copies of research outputs in an open access institutional repository lowers the barriers to, and cost of, access;
- They see a way to improve efficiency by linking the acquisition of research outputs with existing research management processes, enabling them to capture research output data once and re-use these for multiple purposes; and
- They want to preserve digital research outputs and see a repository as a digital treasure chest for which they have a custodial responsibility.

Institutional research repositories can create positive outcomes for all interested groups. Authors gain visibility, information seekers find research more easily, institutions raise their research profile, and funders see wider research dissemination (Rankin 2005).

Kircz (2005) explored the relative 'dis-benefits' of the subscription publishing system, noting that the published literature was not, as often described, the record of science – at least, not the full record. Firstly, because of timing, it is "the full stop after the fact" with current discussion in many fields already based on pre-prints and other communications mechanisms (*e.g.* discussion lists, web logs, etc.). Secondly, because of selectivity in publishing, it is "only a trophy cabinet" with little reporting in the formal journal literature of failed experiments, trial and error tests, etc. These points highlight two further advantages of open access: timeliness and speed of reporting, especially through the posting of pre-prints; and the potential to create a fuller record of science through mandated deposit of findings and other not previously reported materials (*e.g.* field notes or laboratory notes, related data sets, etc.) – thus avoiding the inefficiency of duplicative research and the pursuit of blind alleys. This latter was also noted by

Gallagher (2005, p8), who suggested that it is becoming increasingly clear during the extraordinary information revolution in the life sciences that everything done in the lab needs to be captured. He too noted that repositories would be “more likely than existing journals to include accessible archives of negative data.”

Box A2.2 The open-access approach for science

The practical advantages of true open access are already very familiar to many researchers in the life sciences through two longstanding successful open-access experiments: GenBank and the Protein Data Bank. The success of the genome project, which is generally considered to be one of the great scientific achievements of recent times, is due in no small part to the fact that the world’s entire library of published DNA sequences has been an open-access public resource for the past 20 years. If the sequences could be obtained only in the way that traditionally published work can be obtained, that is, one article at a time under conditions set by the publisher, there would be no genome project. The great value of genome sequences would be enormously diminished.

More significant is the fact that open access is available for every new sequence, which can then be compared to every other sequence that has ever been published. The fact that the entire body of sequences can be downloaded, manipulated by anyone, and used as a raw material for a creative work has led thousands of individual investigators to take up the challenge of developing new data-mining tools. It is such tools and the new databases that incorporate sequences, enriched by linking them to other information, that have made the genome project the success that it is today. By adapting the genome model of open access to the publication of scientific literature, we could see a similar flowering of new, investigator-initiated research and creative, value-adding work.

Source: Brown, P., in Committee on Electronic Scientific, Technical, and Medical Journal Publishing (CESTMJP) (2004), *Electronic Scientific, Technical, and Medical Journal Publishing and Its Implications: Proceedings of a Symposium*, National Research Council, National Academies Press, Washington DC, p30.

Van Westrienen and Lynch (2005) provided an insight into the drivers of adoption of institutional repositories. Exploring preliminary survey data from 13 countries, they noted that: “with the possible exceptions of Australia and the United States, currently the institutional repositories mostly house traditional (print-oriented) scholarly publications and grey literature: journal articles, books, theses and dissertations, and research reports. From this we can at least speculate that, again outside Australia and the United States, open access issues in scholarly publishing may well be the key drivers of institutional repository deployment, at least in the very short term, rather than the new demands of scholarly communications related to e-science and e-research.”

Open access initiatives

The issues of open access to all forms of research outputs has been taken up within a range of international government and semi-government organisations in the form of The Global Information Commons for Science Initiative (GICSI), a multi-stakeholder initiative arising from the second phase of the World Summit on the Information Society held in Tunis in November 2005. Its goals are:

- Improved understanding and increased awareness of the societal benefits of easy access to and use of scientific data and information, particularly those resulting from publicly funded research activities;
- Wide adoption of successful methods and models for providing open availability on a sustainable basis and facilitating reuse of publicly-funded scientific data and information, as well as cooperative sharing of research materials and tools among researchers; and
- Encouragement and coordination of the efforts of the many stakeholders in the world's diverse scientific community who are engaged in efforts to devise and implement effective means to achieve these objectives, with particular attention to developing countries. (David and Uhlir 2005).

The summary document to the GICSI initiative outlines the rationale and provides such a thoughtful summary of the current position and the potential benefits of open access that it is worth quoting at length. It states that:

> *From the perspective of the research community, access to data and information has never before been as important as it is now. The rapid advances in digital technologies and networks over the past two decades have significantly altered and improved the ways that data and information can be produced, disseminated, managed, and used, both in science and in many other spheres of human endeavor. This progress in the emerging cyber-infrastructure has enabled scientists to perform quantitatively and qualitatively new functions to: collect and create unprecedented and ever-increasing amounts and types of raw data about all natural objects and phenomena; collapse the space and time in which data and information can be made available; facilitate entirely new forms of distributed research collaboration and information production; and integrate and transform the data resources into unlimited configurations of information, knowledge, and discovery. Perhaps the most significant and obvious manifestation of these developments has been the Internet's effects in reducing the time and costs of producing and transmitting additional copies of data and information on a global basis to negligible levels.*
>
> *Researchers in public science and engineering historically have been at the forefront of many of the basic technological advances underlying new paradigms of digitally networked information creation and dissemination activities. From their pressing needs to fashion more powerful information processing communications tools have sprung a wide array of the key elements of the "Information Society". Such advances have included mainframe computers and packet-switched data networks, the TPC/IP protocols of the Internet and the World Wide Web, and still more recent innovations supporting Grid-computing and Web-based "middleware platforms" that facilitate the spatially distributed conduct of collaborative work. For essentially the same reasons, scientific research communities throughout the world also have led in efforts to develop many kinds of openly available digital resources, including*

open-source software, public-domain digital data archives and federated data networks, open institutional repositories for scientific pre-prints, journal publications and educational materials. Their members have been taking similarly active roles in organizing and maintaining a variety of open access electronic journals, some of them developing new editorial practices such as community-based open peer review.

New potentialities have thereby been opened for the improvement of human welfare through more efficient utilization of data and information, especially those arising from public investments in the conduct of scientific research. The digital network infrastructure, networked applications, and a myriad of organizations and activities that both exploit and promote their continuing elaboration can create unprecedented opportunities for accelerating the progress of science and innovation…

The benefits derived from the availability of publicly funded scientific data and information, and hence society's returns on the investments made in order to create those knowledge-assets, depends upon their being used. The open availability of digital resources from publicly-funded research at minimal transaction costs offers many advantages not only over secrecy, but in comparison with a closed, proprietary system that places high barriers to both access and subsequent re-use. Broad access to these publicly-funded information resources has many benefits: it reinforces open scientific inquiry, encourages diversity of analysis and opinion, promotes new research and new types of research, allows the verification of previous results, makes possible the testing of new or alternative hypotheses and methods of analysis, supports studies on data collection methods and measurement, facilitates the education of new researchers, enables the exploration of topics not envisioned by the initial investigators, permits the creation of new data sets when data from multiple sources are combined, helps transfer factual information to and promote capacity building in developing countries, promotes interdisciplinary, inter-sectoral, inter-institutional, and international research; and generally helps to maximize the research potential of new digital technologies and networks, thereby providing greater returns from the public investment in research…

In view of the "public goods" properties of data and information resources – which permit their concurrent use and reuse at negligible incremental costs by a multitude of parties who are able to benefit from the content without depleting it – it would be unreasonable to ignore the losses in the efficiency and effectiveness of the research system that are imposed by unnecessarily balkanized and closed access regimes. The negative impacts of the barriers to information sharing and collaborations are not confined to losses that come in the form of exploratory research opportunities that remain unexploited due to the time and costs of securing rights to use essential research tools and data that are owned by private parties; they ramify through the system, adversely affecting both private and public rates of returns from investments in

> *applications-oriented R&D, in limitations upon the extent of the benefits from wider diffusion of innovations, and contributing to widening the gap between the level of scientific capabilities and innovation capacities in member nations of the OECD and those in the developing countries…* (David and Uhlir 2005).

In this, David and Uhlir (2005) make clear the rationale for the GICSI initiative, the potential benefits of open access and the emerging possibilities for policy initiatives to greatly enhance the potential returns to government investment in R&D.

Open access benefits

In one of the few attempts to quantify the benefits of open access, Harnad (2005) sought to calculate the cost of lost citations implied by limited self-archiving of post-prints, and relate it to the case of the UK Research Councils (RCUK). He suggested that:

> *The marginal dollar value of one citation was estimated by Diamond in 1986 to range from USD 50-1,300 depending on field and number of citations. (An increase from 0 to 1 citation is worth more than an increase from 30 to 31; most articles are in the citation range 0-5.) If we convert from dollars to UK pounds sterling (27-710) and update by 170% for inflation from 1986-2005, this yields the range GBP 46-1,207 as the marginal value of a UK citation today. Self-archiving, as noted, increases citations by 50-250%, but, as also noted, only 15% of the articles being published are being self-archived today.*
>
> *We will now apply only the most conservative ends of these estimates (50% citation increase from self-archiving at GBP 46 per citation) to the UK's current annual journal article output (and only for the approximately 130,000 UK articles a year indexed by the Institute for Scientific Information, which covers only the top 8000 of the world's 24,000 journals). If we multiply by the 85% of the UK's annual journal article output that is not yet self-archived (110,500 articles), this translates into an annual loss of GBP 2,541,500 in revenue to UK researchers for not having done (or delegated) the few extra keystrokes per article it would have taken to self-archive their final drafts.*
>
> *But this impact loss translates into a far bigger one for the British public, if we reckon it as the loss of potential returns on its research investment. As a proportion of the RCUK's yearly GBP 3.5 billion research expenditure, our conservative estimate would be a 50% x 85% x GBP 3.5 billion = GBP 1.5 billion worth of loss in potential research impact. And that is without even considering the wider loss in revenue from potential usage and applications of UK research findings in the UK and worldwide, nor the still more general loss to the progress of human inquiry.* (Harnad 2005).

A similar calculation was produced for Australia (O'Keefe 2005).

However, Diamond (1986, p354) conducted a decomposition of US faculty salaries and found a positive correlation between salaries and citations. In the introduction to the Diamond article it says: "Readers should be cautious in drawing certain conclusions from Diamond's article. Diamond is not saying that every additional citation is worth 'X' amount of dollars. Economists are interested in the structure of wages and in its components, and they present their data to show that structure. Diamond does not claim that there is any simple, automatic connection between citations and salaries. There is no real evidence of such a causal connection...". Indeed, salaries are not set on the basis of citations. Nor is there a necessary or direct relationship between the research funds input and the impacts (outputs/outcomes), so there is unlikely to be such a direct relationship between RCUK expenditure and the loss from potential citations – although, at the aggregate level, the direction of that relationship is clear, and this first approximation is indicative of the possibility of substantial benefits.

Summarising the potential benefits of open access

These potential benefits of open access can be summarised in terms of a range of stakeholders. For the sake of consistency, they are presented here according to the activity systems framework outlined above – equating, approximately, to the following stakeholders: research authors; research users; industry, government and community users; research institutions, funders, managers and infrastructure providers; scholarly publishers; and governments (Figure A2.1).

Research (production and use)

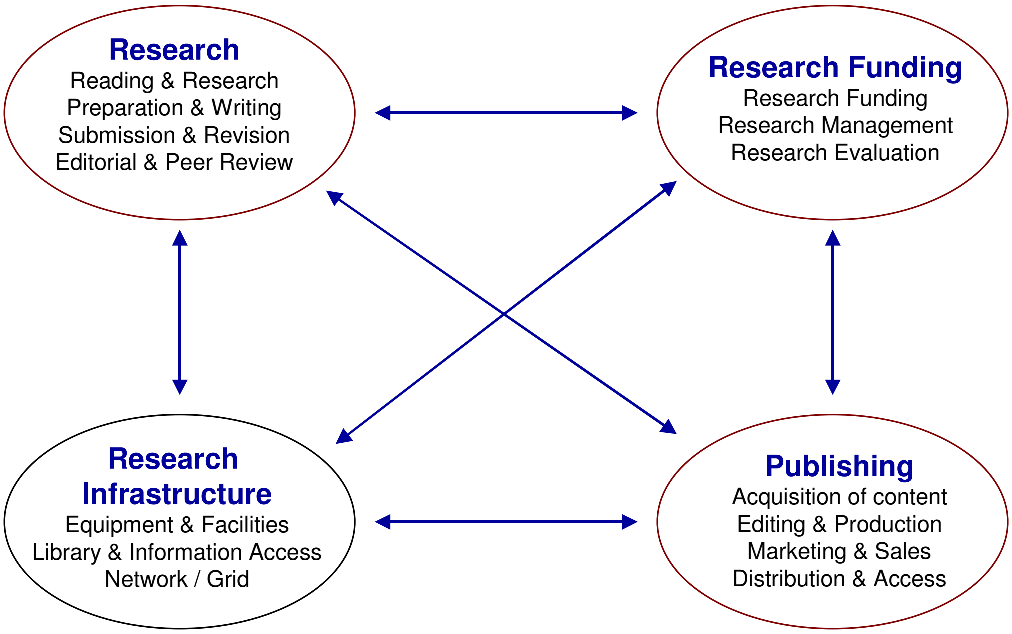
As authors researchers stand to gain visibility through open access and to see wider user made of their work. As users of the research of others, researchers stand to gain wider, faster and more complete access.

For research authors the potential benefits of open access over subscription-based toll restricted access include**:**

- Higher visibility within the research community through citation, which is likely to flow through into greater research funding and rewards.
- Wider visibility and communication beyond the research community to industry, government and community users, with open access providing access to industry, government and society that have been poorly served by subscription publishing (*e.g.* few small engineering, consulting, electronics or biotechnology firms have extensive access to the subscription literature).
- Greater support for wider range of research practices as open access supports traditional outputs (*e.g.* journal papers) and new forms of output (*e.g.* data sets, audio and video, field and laboratory notes, etc.) and integrates them into a single system, thereby providing support for emerging modes as well as traditional modes of research.
- Greater support for collaboration, with everyone having access to the whole range of literature and to a wider range of content (*e.g.* including the, so called, grey literature).

- Reduced cost and trouble for peer review, with links and references being much easier to follow and check in an open access environment than one in which the authors and reviewers may have different levels and ranges of access.

Figure A2.1 Scholarly communication system activities and stakeholders



Source: Author's Analysis.

- Time savings on management of websites for individuals, centres and institutions, with institutional repositories offering the potential to centralise the holding and management of information, thereby making it easier for researchers to maintain a Curriculum Vitae and prepare funding applications from a common set of building blocks and existing data (*i.e.* ePortfolio, web resume, etc.).
- Time savings in research management and reporting by collecting and linking publications and other outputs automatically into individual and institutional research reporting and evaluation processes.

For research users the potential benefits of open access over subscription-based toll restricted access include**:**

- Easier access and reduced search and discovery time and cost – Tenopir and King (2002) suggested that the time spent reading articles has changed little, but the time spent finding them has increased.
- No disincentive or compromise when access is open (*i.e.* using second best because its available).

- Less complication and uncertainty about permissions, with less time spent and fewer requests to use and/or reproduce open access material.
- Increased speed, the open access providing the latest results and findings without delay – especially where pre-prints are posted, but also because articles can be posted immediately upon final acceptance without waiting for the next issue of the journal to be released.
- Both increased access and increased speed will reduce the chances of duplicative research being undertaken because others do not know of results of work that has been undertaken but not yet, or simply not, published.
- Support for the emergence of new research by making available the data behind research so that it can be re-used and findings more easily checked.
- Making the supporting data available also avoids duplication of data collection and the costs involved in that (*e.g.* unnecessarily repeating questionnaire surveys, clinical trials, etc.).

Research funding and management

Research institutions, funders and managers also stand to gain visibility through open access, with wider appreciation and use of research findings, and more efficient research reporting, evaluation and management.

For research institutions, funders and managers the potential benefits of open access over subscription-based toll restricted access include**:**

- Mechanism to showcase the output of institutions and bring it to the attention of a wider audience than is the case with traditional scholarly publishing (*e.g.* contributing to 'third path' goals of the institution).
- Increased visibility and citation for the research outputs of institutions, which is likely to lead to more collaboration, industry and community linkage and more funding opportunities.
- Increased visibility for funders of the research and greater impacts from their funding dollar (*e.g.* increased awareness of the contribution of funders, etc.).
- Increased visibility of national research, which will affect the global ranking of domestic universities and may, thereby, attract increased education services demand from both domestic and international students (*e.g.* increased education services exports).
- Increased communication of research findings and issues beyond the research community, with greater access for industry, government and community to those findings contributing to the technology and knowledge diffusion goals of institutions and funders.

- Support for the management of reporting and evaluation, by providing the foundation for a single source for reporting information, thereby reducing the cost of grant applications and research evaluation reviews.
- Support for automated analysis of research impacts, citations, etc., with use statistics being broader than academic citations and so more useful for, and attuned to, the realities of emerging modes of research (*e.g.* Mode 2 research and the 'third path' goals of institutions).
- Through making research more transparent open access may help to prevent misconduct (*e.g.* making data and laboratory notes accessible as well as the text of the final paper makes the stated findings more easily verifiable).
- Open access may also help in the detection of plagiarism with texts and other digital objects more accessible and easily compared.

Research infrastructure

Research infrastructure providers and managers also stand to gain through open access, with the opportunity to develop integrated systems that accommodate all forms of research output and provide the foundation for e-science.

For research infrastructure providers and managers the potential benefits of open access over subscription-based toll restricted access include:

- Providing the foundation for the integration of all the elements of the outputs of e-research (*i.e.* catering for all sorts of digital objects).
- Providing the foundation for long-term preservation of objects.
- Supporting e-learning, with much greater opportunity to provide ready and remote access to content, and to provide that content in innovative ways.
- Supporting education through reducing the cost/time involved in creating course content, and providing course related packages.
- Enabling the development of new mechanisms for collaborative research and underpinning new forms of research.
- Raising the profile of libraries and information services, and giving them a new, enhanced role in the scholarly communication process.
- Reducing the operational costs of libraries through the switch to 'e-only' content (*e.g.* less space, shelving, handling, etc.), reducing use of access control and authentication systems, complex licensing negotiations and agreements, and simplicity of preservation (without use and copy restrictions, etc.).
- Possibly, over time, putting downward pressure on the costs of access to the subscription-based scientific literature.

Publishing

Scientific and scholarly publishers also stand to gain through open access, with the opportunity to develop more sustainable business models and to develop new innovative services business through the provision of 'overlay services'.

For publishers the potential benefits of open access over subscription-based toll restricted access include**:**

- The development of more sustainable business models, as subscription revenue is becoming difficult to sustain in the face of declining subscriptions (*e.g.* moving to 'author-pays' open access journal publishing should make revenue more predictable and stable, as it scales more easily to research output than have library budgets).
- The potential for open access repositories and archives, and their supporting standards-based access systems, to reduce the need for each publisher to continue to develop expensive proprietary access systems – and for researchers to have to learn and use multiple systems interfaces.
- Providing new opportunities for services provision overlaying the open content (*e.g.* peer review, abstracting, indexing, searching, interrogating, etc.) as has happened in the cases of the weather derivatives industry based on open access to meteorological data and open source software.
- The opportunity for open access repositories to provide the foundation for institutional e-presses, enabling them to fulfil the mission of publishing scholarly monograph materials to small specialist audiences, and enabling arts and humanities scholars to overcome what is an increasingly significant barrier to publication.
- The opportunity for learned societies and associations to raise their profile, and that of their discipline, by hosting open access content and/or mandating deposit, because of the enhanced access and use afforded through open access.
- The opportunity for learned societies and associations to develop new revenue streams through the provision of overlay services to the open access content (*e.g.* peer review, abstracting, indexing, specialist portals, etc.).

Government and the people

The greatest opportunity is for governments and taxpayers. Through enhancing free and open access for all, open access will contribute to maximising the potential returns on the very considerable public investment in research – simply by making the findings of that research freely accessible to all, rather than allowing it to be locked behind toll gates.

Glossary of Terms

AIMS	Australian Institute of Marine Science
ALPSP	Association of Learned and Professional Society Publishers
ANSTO	Australian Nuclear Science and Technology Organisation
APSR	Australian Partnership for Sustainable Repositories
ARC	Australian Research Council
Archive (subject)	Subject or discipline based archive, offering open and free access to pre-print and/or post-print papers in a particular discipline or subject area
ARIIC	Australian Research Information Infrastructure Committee
ARL	Association of Research Libraries
ARROW	Australian Research Repositories Online to the World
Article	A short work reporting research findings published in a journal
AUD	Australian Dollars
Author-Pays	Where authors, their employing or funding organizations contribute to the costs of publication in a journal which is then freely available for anyone to download, copy, reproduce and distribute according to usual Open Access rules
AVCC	Australian Vice-Chancellors' Committee
Benefit/Cost ratio	The multiple of benefits over costs
Big Deal	Where institutional subscribers pay for access to online aggregations of titles through consortial or site licensing arrangements
BMC	BioMed Central
BOAI	Budapest Open Access Initiative
BOFTSI	Building our Future Through Science and Innovation
CAN	Canadian Dollar
CAUDIT	Council of Australian University Directors of Information Technology
CAUL	Council of Australian University Librarians
CERN	European Organisation for Nuclear Research
CoA	Commonwealth of Australia
CODATA	Committee on Data for Science and Technology of the International Council for Science
CSES	Centre for Strategic Economic Studies (Victoria University)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEST	Department of Education, Science and Training
DFG	Deutsche Forschungsgemeinschaft (German Research Foundation)
DOI	Digital Object Identifier
DSTO	Defence Science and Technology Organisation
e-book	Electronic only book
e-journal	Electronic only journal
e-press	Electronic only publisher (*e.g.* University Press)
e-print	An electronically published research paper (or other literary item)

EU	European Union
EUR	Euro
FTE	Full time equivalent (staff)
GBP	UK Pound
GERD	Gross Expenditure on R&D
GICSI	Global Information Commons for Science Initiative
GovERD	Government Expenditure on R&D
HERDC	Higher Education Research Data Collection
HINARI	Health InterNetwork Access to Research Initiative
ICOLC	International Coalition of Library Consortia
ICT	Information and Communication Technology
INASP	International Network for the Availability of Scientific Publications
IPR	Intellectual Property Rights
JISC	Joint Information Systems Committee (UK)
Journal	A serial publication under a specific title that publishes collections of articles and other scholarly content
Monograph	Research publication in the form of a book
NCGP	National Competitive Grants Program
NCRIS	National Collaborative Research Infrastructure Strategy
NHMRC	National Health and Medical Research Council
NIH	US National Institutes of Health
NZ	New Zealand
NZD	New Zealand Dollar
OA	Open Access
OAI	Open Access Initiative
OAI-PMH	Open Archives Initiative Protocol for Metadata Harvesting
OECD	Organisation for Economic Cooperation and Development
Open Access	Material is made available freely and openly, without charge or usage restrictions, to anyone with internet access
OSI	Open Society Institute
PLoS	Public Library of Science
PoD	Print on Demand
Post-print	The digital text of an article that has been peer-reviewed and accepted for publication by a journal.
Pre-print	The digital text of a paper that has not yet been peer-reviewed and accepted for publication by a journal.
R&D	Research and Development
RAE	Research Assessment Exercise (UK)
RCUK	Research Councils United Kingdom
Repository (institution)	Institution based archive offering open and free access to the research works and outputs of a particular institution
RQF	Research Quality Framework (Australia)
RRTMR	Research & Research Training Management Report

Scholarly communication	System(s) for the communication of research findings
Scholarly publishing	System(s) for publishing research reports
Self-archiving	Authors (or their employing institutions) depositing material onto an open access archive or repository
SHERPA	Securing a Hybrid Environment for Research Preservation and Access
SME	Small to Medium Enterprises
SPARC	Scholarly Publishing and Academic Resources Coalition
STM	Science, Technology and Medical (publishing)
UK	United Kingdom
UN	United Nations
URL	Universal Resource Locator
US	United States
USD	US Dollar

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Endnotes

[1] There is an important distinction between open access publishing (*i.e.* open access to formally published work) and open access archives and repositories, which may contain both formally published work (*e.g.* e-prints) and works that may not previously have been formally published. Furthermore, open access is not synonymous with 'author-pays', and various kinds of cost-recovery apart from the 'author-pays' model are being experimented with by open access publishers.

[2] An overview of the development of open access (both author-pays and self-archiving) can be found at http://www.earlham.edu/~peters/fos/timeline.htm with related explanation of open access at http://www.earlham.edu/~peters/fos/overview.htm (Suber 2004a; 2004b).

[3] A parallel, complementary development is that of institutional e-presses, which replicate the activity of institutional presses (*e.g.* University Presses) in online only form.

[4] For an overview of OAI see the Open Archives Initiative (www.openarchives.org) and the introductory tutorial at the Open Access Forum (http://www.oaforum.org/tutorial/english/intro.htm).

[5] There is an implict 'trade' between scholarly content production and acquisition. These estimates suggest that publishing costs for Australian higher education HERDC outputs amounted to around AUD 150 million, while content acquisition by CAUL libraries amounted to AUD 182 million.

[6] Weighted refers to the ratio of total downloads to total subscription costs across the packages, while mean is the mean of packages.

[7] It is important to bear in mind that some of the package content may be open access. Hence, these prices do not reflect the full cost of production, some small proportion of which has already been met through 'author' charges levied by some of the titles within the packages (*e.g.* Springer Open Choice).

[8] However, apportioned on an FTE staff basis it would imply expenditures of AUD 180 million in relation to research, AUD 300 million for teaching and AUD 590 million for administration.

[9] It is notable that NHMRC is moving away from external peer reviewing and towards review panels, in part because of concern about the review burden. This may reduce external peer review costs associated with NHMRC grants in the future. Conversely, there has been a marked up turn in the number of applications to ARC this year, which may be a response to the forthcoming RQF.

[10] Assuming that all infrastructure and overhead costs are covered in the activity costings and focusing on active authors only.

[11] Acs, Audretsch and Feldman (1994), following Jaffe (1989), have shown that in-house R&D activity is important for large firms, which have sufficient scale to run their own research facilities, while small firms tend to benefit more from knowledge created in publicly funded research. See Acs, Z.J., Audretsch, D.B. and Feldman, M.P. (1994) 'R&D Spillovers and Innovative Activity', *Managerial and Decision Economics* 15, pp131-138; and Jaffe, A.B. (1989) 'Real Effects of Academic Research', *American Economic Review* 79, pp957-970; cited by Dowrick, S. (2003), *A review of the evidence on science, R&D and productivity*, Paper prepared for the Department of Education, Science and Training, Canberra, p8.

[12] This vision of the future follows that outlined by The Budapest Open Access Initiative (See http://www.earlham.edu/~peters/fos/timeline.htm).

[13] Users could still obtain print copies of journals, articles or monographs through print-on-demand facilities, but the entire production chain would be digital.

[14] It is worth noting that in an international survey of more than 5,500 senior researchers Rowlands and Nicholas found that senior authors and researchers believed that downloads are a more credible measure of the usefulness of research than are traditional citations. See Rowlands, I. and Nicholas, D. (2006) 'The changing scholarly communication landscape: an international survey of senior researchers,' *Learned Publishing* 19(1), pp31-55.

[15] See http://www.hss.caltech.edu/~mcafee/Journal/Summary.pdf

[16] It also demonstrates the key features of journal costs – high first copy costs, low marginal costs; that article processing costs are a significant proportion of total production costs; that non-article processing costs (marketing, administration, etc.) are also significant; and that physical distribution costs are a small share of total production costs.

[17] There are, for example, a number of systems for journal management now available (*e.g.* ESPERE, myICAAP, etc.).

[18] Derived from publisher websites; Walker, T.J. (2004) 'Open Access by the Article: An idea whose time has come?,' *Nature* Web Focus: Access to the Literature. Available www.nature.com/nature/focus/accessdebate accessed June 2004; and Worlock, K. (2004) 'Open Access and Learned Societies: Will open access prove blessing or a curse to learned societies?,' *Nature* Web Focus: Access to the Literature. Available www.nature.com/nature/focus/accessdebate accessed July 2004.

[19] BioMed Central report that during the first half of 2004, open access articles in Nucleic Acids Research were downloaded 52% more frequently, on average, than were subscription articles in the same journal. Similarly, PNAS found that open access articles receive 50% more full text accesses and downloads than subscription access articles in the first month after publication, and maintain higher usage in subsequent months.

[20] See http://stats.nla.gov.au/_reports//arrow/yearly/2005/awstats.arrow.html