GROUP OF EIGHT

Go8 Backgrounder 23

Measuring the impact of research – the context for metric development

September 2011

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Executive summary

Current economic conditions and the increasing competition for government funding are leading to an increased focus on the impact of research. Other factors contributing to this interest include the development of ERA which measures the academic excellence of research and the view that impact measures would complement this assessment; a general concern to improve the operation of the national innovation system; and the need to demonstrate to the public that research funds are well-spent.

Measuring the impact of research is difficult because not all impacts are direct and some can be negative or result from the identification of problems that require a non-research response. The time between the performance of research and when its benefits become apparent can be significant, unpredictable and differ for different kinds of research.

The likelihood of research having impact depends not just upon the potential of the research but also on the willingness and ability of players in the wider innovation system to make use of the research; and any research does not exist in isolation but draws on the work of other researchers. In assessing impact it is necessary to acknowledge that research aiming to achieve impact will often have a high risk of failure and that there can be different perspectives about whether a particular impact is positive or not.

Attempts to measure impact, especially if these are ongoing, can distort behaviours such that they might diminish the probability of research reaching its maximum impact. A rigorous assessment of research impact has also to develop appropriate counterfactuals and consider opportunity costs.

Research can have impact through many routes and in different ways. These range from building national capability through advancing knowledge and supporting university teaching, to producing a direct financial return to the institution performing the research and having major economic impact through increases in productivity, employment, competitiveness and business formation. Research can also contribute to national wellbeing through its social impacts and by improving environmental management and sustainability. There are also many intangible benefits of research which are nevertheless real and of value – including on national reputation and attractiveness as a place to learn, work and invest.

There is a wide range of methods that it is possible to use to evaluate research impact. They can operate at the level of individual projects or programs, institutions and nations. Each method has its own characteristics and advantages. While different methods can appeal to different target groups, none is complete in itself and none offers unambiguous or certain results. Studies of the same project or program at different times or across different time spans can produce widely varying results, reflecting the uncertainty of research and the way in which the value of research outputs can change, depending on the context within which they exist – including subsequent advances in research.

Measuring the impact of research is necessary and can be useful but it is important to use the results of such evaluations with care, recognising their fragility. In particular, it is important to assess impact in terms of the impacts the research aimed to achieve, not across all impacts which are possible.

Introduction

The recent economic downturn has revived debate on the impact of research. A climate of increasing financial stringency makes it imperative to demonstrate that government investments in research are effective and providing value for money.

In an environment of increasing and competing demands on funding, decision makers need to know that their support of research is contributing to the wellbeing of all Australians in concrete and demonstrable ways; and that that this investment is providing benefits greater than those that might arise from spending similar amounts in other areas. This is especially so as providing additional resources for competing programs can contribute (sometimes in more obvious and direct ways) to some of the outcomes research aims to achieve. As one obvious example, additional funding for the Pharmaceutical Benefits Scheme, for medical training or for hospitals might well have a more rapid (if shorter term and in the long run less significant) impact on health outcomes than increasing research funding.

An additional reason for studying the impact of research is that this can complement the work of the ERA initiative, which measures the academic excellence of research. While there is evidence that academic excellence contributes to achieving impact (for example, as shown by the analysis of academic papers cited in patent documents), there is a view that the absence of readily available measures of impact can downplay the importance of some research that aims to achieve direct impact, especially when such research does not result in publications in high impact journals.

More generally, there is a perception that Australia is not benefiting from its research investments to the extent to which it could and should. Measurement of research impact might provide data that will facilitate improvements in the operation of the national innovation system, in part by providing an improved understanding of the means through which research has impact and of how researchers can better use the impact pathways available to them.

While the demand for increasing information on the impact of research is reasonable, supplying the necessary data is neither simple nor easy. The creation, transfer and subsequent application of knowledge and the success and effect of this are difficult to measure. This is because the relationship between research, knowledge transfer, application and the economic, social and other outcomes these can produce is complex. This backgrounder aims at exploring some of these issues and compares existing approaches in order to facilitate wider debate.

Measuring impact is difficult

Discussions about the impact of research and how to measure it are even more problematic than discussions about excellence and what we mean by it. There are many reasons for this. Research can have many different types of impact and the routes through which it achieves these impacts are diverse, often convoluted and not at all transparent. The time necessary to achieve an impact can be significant (even beyond the life span of individual researchers) and in some cases the impact may not be direct. Moreover, the apparent impact of a piece of research in the short term can be very different from its impact in the longer term – as shown by examples as diverse as Gregor Mendel in genetics or Alfred Wegner with continental drift.

Impact can be negative or indirect

While the focus of impact measurement tends to be on the beneficial effects of research, it is not unknown for research to create unintended or unwanted impacts that we need to balance against any obvious benefits. (The impact of chlorofluorocarbons on the ozone layer, of lead in petrol or the potential health and environmental impacts of some pesticides provide obvious examples.) Moreover, in many cases the benefits that flow from research can take the form of preventing harm or reducing damage, rather than of making things better. This is the case for much health research (disease prevention, more productive lives), environmental research (including research into natural hazards) and social science research (e.g. crime prevention). While it is not possible to measure directly the economic consequences of many of these impacts,

it is important to recognise and value them. Other research has impact by identifying problems about which we might not otherwise be aware and to which we need to respond – as with anthropogenic climate change or the hole in the ozone layer.

Impact depends on players outside the research system

An equally fundamental issue is that the researchers themselves might have had no idea of the potential benefits (or harm) of their research or its longer term implications. The impact that research has will often depend on the imagination, creativity and identified needs or problems of people outside the research system. This does not downgrade the importance of the research but it does raise questions about the use of potential impact as a means of selecting research proposals for funding. Consumers are often more imaginative and creative than researchers (and even better than business) in finding applications for new technologies.

Perhaps one of the most difficult problems in trying to measure the impact of research is that in most cases, even when the research aims to achieve it, impact is the result of actions by parties other than the researchers themselves. Converting research outputs to innovations requires significant investment (intellectual as well as financial) and the bringing together of many complementary skills. This means that the cost of research is often a very small proportion of the cost of the investment necessary to produce the impact. This can create problems in trying to determine what proportion of the impact is due to research and what proportion to the other parties involved – who may have been able to purchase equivalent research outputs from elsewhere. Moreover, these other parties are using their intellectual as well as financial and other resources in producing public or commercial value from the research.

A further consequence of the path to impact involving many and diverse players can be that research having the potential for considerable impact may have no effect because of inaction or a lack of complementary factors within the broader innovation system. More broadly, the willingness of consumers to take risks and use new technologies can play a major role in determining whether research produces the benefits it has the potential to produce. As a simple and very direct example, the benefits of a vaccine depend not just on whether it works but on the extent to which the target populations agree to vaccination. The same research can have quite different impacts depending on its cultural context and on the size of the local market for the benefits it might offer. Among other things this can mean that at least some of the benefits of research, especially research not protected by strong IP rights, can occur in countries other than that in which the research took place.

All research builds on earlier research

There can also be the problem that making effective use of the advances in one area of research might depend on complementary progress in other areas of research or technology. For example, the major benefits of a diagnostic test for early Alzheimer's will depend on other research having developed a useful response to such diagnosis, notwithstanding that a diagnostic might allow for studies of the early stage development of the disease that themselves help lead to a useful intervention. (In a similar vein, it is interesting to speculate what Leonardo de Vinci might have been able to achieve if he had had access to the materials and other technologies we have available today.)

Equally important is that any research project builds and is dependent on all the previous research that preceded it – even the best of researchers stand not just on the shoulders of giants but on the great mass of researchers around the world who built the understanding and techniques that make current research possible.

Recent attempts to apply real options analysis (developed in the financial services sector) to research evaluation demonstrate that research creates options that have a significant economic value even if society never takes them up; and it is important to recognise the insurance potential of the capabilities that research creates, in that they provide a capacity to respond to unexpected events, challenges and opportunities.[1]

1 See, for example www.csiro.au/files/files/pa6s.pdf

Research aiming to have impact is usually high risk

Another important consideration is that research is often a high risk activity. In the normal course of things much research will fail. In the case of research whose sole aim is to advance knowledge, the failure to achieve the expected (or hoped-for) results still advances knowledge – even if the outcome is less exciting or interesting than that for which the researchers were aiming. However, for research aiming at defined commercial outcomes, failure is significantly more likely than success.[2]

Empirical analysis of business research and the experience of venture capital companies both demonstrate that only a very small proportion of projects succeed in commercial terms. Assessments of research impact need to factor in these high failure rates if they are to provide realistic and reasonable assessments of what research investments are achieving. The high risk involved in any individual research project also raises issues about what level of analysis is appropriate – whether it should be the project, particular types of research activity, the institution, the program or even total national effort.[3]

There can be different perspectives about the worth of an impact

A further complication in this area is that discussions of research impact, like discussions of excellence, often have a strong emotional underpinning, reflecting value positions that while deeply held need not be explicit or apparent – even to those holding them. There can be a tendency to value certain kinds of impact more than others in a way that does not necessarily reflect their overall significance to national wellbeing or economic development. A direct financial return is concrete and relatively easy to measure but its overall economic impact may be less than that of an intangible research outcome such as improved national reputation or social cohesion.

One complicating factor that runs through all impact assessment work is that there can be different perspectives as to whether a particular impact is positive or negative – and this can again depend on the time scale of the analysis. The impact of climate change research that flows from research identifying a problem provides an instructive if complex example but is not unique, even in much simpler situations.

Environmental research that leads to the closure of a fishery might have an immediate negative economic impact, even though in the much longer term it will preserve a resource that might again become available for use. The fishing industry and conservationists might have very different views as to the nature of the initial impact – some of which may depend on their view about the excellence of the research and its disinterested nature. Similarly, research that suggests the need to cull kangaroos to preserve biodiversity and conservation values might receive a very different response from ecologists, conservationists and animal rights activists. Issues relating to water management can have many rival stakeholders each with their own, sometimes competing, value systems, who judge the outcomes of the same research, and its potential application, in very different ways. A program to reduce obesity in children might be expensive to implement, not have any serious economic benefits for 30 or 40 years, pose complex issues for the food industry and add to the cost of food.

Assessing impact has to acknowledge alternative strategies

A further problem in trying to assess the impact of particular research projects is to define an appropriate counterfactual. In a competitive research environment, with many teams working in the same areas of interest, the failure of a particular research project might delay a sought-for outcome but another team is likely to get there eventually (and perhaps sooner rather than later). In a complex world it is unlikely that there are single solutions to any problems and in the absence of a particular research project, another – even one adopting a completely different approach – will eventually provide a solution.

2 Failure can be technical (e.g. problems with scale up), reflect cost over runs, result from a misreading of the market or have many other causes that do not present risks for basic research.

3 Issues of risk are particularly important because the high risk of research provides one of the arguments for government support. If the risk is low, the end-users should normally fund the research themselves.

More difficult is the question of opportunity cost. Even when a particular project has produced an outcome that provided identifiable benefits, it is important to ask whether the same resources invested in a different project – even one directed at a different problem – would have provided even greater benefits. When government has provided the funding for research it becomes necessary to consider whether not collecting the money in the first place (by lowering tax rates) or spending the money on some other area of government might have produced a higher economic return.[4]

Measuring impact can distort behaviour

It is also important to appreciate that identifying and using particular metrics can itself distort behaviour and lead to unintended outcomes, especially if such metrics feed into funding allocation systems. A focus on patenting, for example, can encourage institutions to develop extensive patent portfolios that cost more to maintain than the licensing revenue they produce. Moreover, patenting, which requires the public disclosure of an invention, can inhibit small businesses taking up an invention if their business IP strategy depends on trade secrecy – and this is often appropriate for SMEs given the cost of monitoring to identify infringement and the often prohibitive costs of trying to enforce IP rights.

Just as insidious is that the areas of impact not subject to measurement will inevitably be seen as less important and not receive the attention they should. Given that some of the more pervasive and potentially far reaching impacts of research are often among the more difficult to measure, at least in the short term, this can in itself have negative consequences for the whole innovation system.

What this means

The main conclusions from these considerations are that identifying and quantifying the impact of research is difficult, that any estimate is at best a very rough guide and that the results of any assessment can vary widely, depending on the time frame used to allow for impact. An evaluation of Faraday's work on electromagnetism at the time he conducted his research, for example, would lead to very different conclusions from those that we might reach today in a world that could not operate or support its present population without electricity, electronics and photonics. While it is clearly necessary for accountability and other reasons to measure and evaluate the impact that research is having, the interpretation of such measurements has to recognise the ambiguities and uncertainties involved.

Types of impact

In order to assess research impact, it is necessary to agree on what form this impact can take. Understanding the areas in which research can have impact can help in developing a framework for identifying possible ways to provide measures (even if only partial measures) of research impact.

In focussing on the impact that the outputs of the research can have, it is important to recognise the benefits that arise from the process of research – in particular, the role that research plays in developing the skills, knowledge, values and culture of the people – including postgraduate students – performing the research. A further impact of research is that it can improve or create the infrastructure (both tangible and intangible) on which further research can depend. Neither should it be forgotten that an important impact of research is that it creates an awareness of research performed overseas and a capability to make use of it, as well as the capacity to provide non-research scientific, technical and other consultancy services. Research also creates networks of personal contacts and of groups having similar or related interests. Together, all these impacts work to create a national capability that governments and others can draw upon as they need – they provide a kind of national insurance by providing a broad set of capabilities that is available as necessary to respond to unexpected events.

4 An assessment of the cost-benefit of government research funding needs to take into account not just the funds the government provided but also the cost of raising these funds through the tax system and of delivering them to the recipients.

One factor that can influence impact measurement is that some paths to impact are more visible and provide easier measures than others. Counting the number of patents granted, licence agreements, or the income received from licensing agreements or other contracts is relatively easy. It is much more difficult to demonstrate that a book presenting the results of research directly to the public has had an impact, for example by improving health and lifestyle, developing a greater degree of social tolerance or reducing energy consumption or waste. There are so many other factors influencing personal behaviour that it is difficult to isolate the role played by any single one – even though the potential benefits from explaining how and why to adopt a healthier and more sustainable lifestyle, or the benefits that arise from a more open, tolerant and multicultural society, may be just as great as those that arise from the commercialisation of a widget. This is one reason that impact studies tend to focus more on technology and less on conceptual developments and theoretical insights.

The following discussion categorises the various forms of impact that research can produce. Different measurement techniques and indicators are necessary to deal with the different categories of impact. However, it is also necessary to acknowledge that any particular research project (or even program or funding program) may be aiming at particular kinds of impact. Moreover, research in different disciplines provides the potential for creating quite different kinds of impact, so that any framework for measuring impact has to take into account the differences between disciplines.

It is necessary to assess a project (or program or institution) in terms of the kind or kinds of impact it was aiming to produce (and capable of producing), not to assess it across the possible range of impacts that research in general can produce. To do otherwise would ignore the division of labour that exists and is necessary, within the national research system and promote homogenisation rather than differentiation and specialisation that can improve the operations of the system. This is not to say that serendipitous outcomes do not occur and it does become important to capture them when they do; but, for example, to assess an optical astronomy program in terms of its contribution to the competitiveness of Australia's manufacturing industry would not make sense.

More effective teaching

Within a university research has close links with teaching and the two influence each other in many ways. Two are of particular importance. First and most obvious is that learning within a research environment exposes students to the most current and up to date knowledge, concepts and developments before they move into the wider workforce. Exposure to researchers brings students into contact with leading edge thinking, to understanding that has not yet reached the text books and to ideas which have yet to find application.

Perhaps even more important is that learning within a research environment generates a culture which challenges existing ideas, accepts that knowledge is provisional and which respects alternative points of view until the available evidence permits discrimination. This kind of culture, which students then take with them as they move into business, government or other working environments, is one that facilitates innovation and creates a preparedness to challenge existing practices and to search systematically for ways of doing things better.

Research produces other benefits for teaching, as well. For example, teaching in a research environment can provide students with access to new and advanced equipment, some of which business might not yet use, or to innovative techniques that have application outside research. The personal contacts and networks that result can also be important in helping to develop an innovative culture outside of universities and can potentially have far reaching effects – including in the application of research.

Advances in knowledge

For research to have impact it has to have effects that go beyond the immediate outputs of the research and which extend beyond those who performed the research. At the most basic level, all research advances knowledge. Some research has this as its primary, if not only, purpose. The improvements in understanding

and the increased sophistication in our ability to modify the world that result from improvements in our understanding, together form the most common and pervasive impacts of research. This provides a number of possibilities for assessing impact. One is to assess the advance in knowledge or understanding compared to what was known before the research; another is to examine how widely the researchers disseminated the improved knowledge to those having an interest in it, or who were capable of using it or of building on it to produce further advances; and a third is to assess the extent to which researchers or others made use of the advance in knowledge that the research produced.

Mechanisms such as peer review and the numbers of publications, along with citation and other bibliometric measures, can provide partial indicators of impact in this area. The citations of research papers in patent documents can provide an indication of the extent to which research is extending its influence beyond academia and the broader research community. Certainly in the short and medium term, there need be no direct relationship between the extent to which the research advances knowledge and its impact in other areas. The most exciting and step change improvements in knowledge may at first have no direct or immediate practical significance. Research of a standard to win the Nobel Prize or Fields Medal does not always produce a direct, tangible improvement in national or global wellbeing.

One direct impact of advancing knowledge can be to enhance the reputation of the responsible researchers. It is possible to assess this using proxy measures such as academic awards, election to learned academies, invitations to prestigious meetings, and so on. The high international reputation of individual researchers and institutions has an impact of national standing and on the attractiveness of a country as a place to learn, work and invest.

Additional investment

One measure of the potential impact of research is the willingness of other parties to invest further in the research and its further development. This is especially the case when those other investors come from the business sector. The preparedness of a business to invest in the development of a pilot plant or to otherwise investigate scale up, or of a drug company to pay for early stage clinical trials, provides a clear demonstration that the research had relevance to those new investors and that they recognise that it has potential for impact.

Financial return

One of the most sought-after impacts at an institutional level is often financial return. If the organisation performing the research is able to sell or licence the research outputs and receives more than the full cost of the research, it is likely to conclude that the research has had a positive impact. The proximate users of the research outputs might use a similar measure. However, a financial return does not capture the benefits flowing to the ultimate consumers, including any consumer surplus and broader spinoffs. While financial return is sometimes easy to measure, it has many limitations. Many areas of publicly supported research will not produce outputs that can lead to direct financial returns and in any case the financial return will normally be a gross underestimate of the true value and impact of research.

Economic impact

From a national perspective the economic impact of research is much more important than measures of direct financial return. Not least this is because in the case of government funded research any financial return to the government is indirect, acquired through the tax system (flowing from increased employment, competitiveness, domestic sales and exports) or from the reduced expenditure that results from increases in the efficiency and effectiveness of government service delivery. In most cases these are not easily attributable to any particular project.

Measuring economic impact is a much more difficult job than measuring a direct financial return and is much more uncertain, given the various assumptions that may be necessary and the need to take into account multiplier effects. Nevertheless, it is possible to make estimates at an aggregate level of economic impact and

examine the contribution of research to economic growth and productivity, as well as to examine the impact of research on such measures as business start-ups, exports or measures of national wellbeing.

Estimates of economic impact can be useful for some purposes and in theory can provide a more realistic estimate of the overall impact of research than more limited analysis. However, it is worth noting that a comprehensive study by the Productivity Commission, using the best available data to conduct a detailed econometric analysis of the impact of Australia's research and development on productivity concluded that:

> *A major message from all the analysis is that, at least for the time being, empirical estimates of the effects of R&D on Australian productivity are unreliable. Any assessment therefore requires a high degree of judgment.*[5]

Social impact

Many areas of research have an impact on society as a whole, for example by providing better health outcomes or increased safety and security. Research can provide knowledge and understanding that can help inform policy development or which can lead to the improved efficiency and effectiveness of public service program delivery and development. For example, research can support the development of regulatory systems which can affect everything from road rules to the availability of alternative medicines and even new voting systems.

A major problem with measuring social impact is that the routes through which research can influence individual behaviour or inform social policy are often very diffuse. Change often requires action on multiple fronts and, as in the case of commercialising 'hard' technology, requires the participation of actors beyond the researchers. The role played by research can be one of creating a climate facilitating change, as well as providing particular avenues and directions for change.

In a country such as Australia, governments look for or need a democratic mandate to take action. This requires that an issue be on the public agenda and that the public understand and preferably support the actions the government intends to take with respect to the issue. Research can play an important role in both these areas, as well as by providing rigorous analysis of the implications and broader effects of the options available to a government for dealing with an issue. Scholarly books and reviews can help create the intellectual climate within which decision makers and policy advisors operate.

Equally important is creating public interest and awareness by adopting the role of a public intellectual, communicating through the media and using other non-scholarly forms of publication. However, such activities are difficult to measure and it may be impossible to demonstrate a direct link with the policy decisions made and the outcomes of these decisions. Nevertheless, they are all important paths to the use of the research, along with other activities such as consultancy work for government departments, preparing submissions for different government inquiry processes or sitting on advisory and other committees and even social interaction with politicians and bureaucrats.

Environmental impact

There is often a more direct link between environmental research and improved environmental outcomes than is the case for many social impacts of research. Nevertheless, some kinds of environmental research face the same difficulty in demonstrating direct links between research and impact as can be found in assessing social impacts. Climate change provides an obvious example and raises the additional point that research can be important, add value and have impact by identifying problems of which we might otherwise not be aware. This is quite apart from the role research can play in generating possible solutions to the problems which it has identified. As another example, the concept of environmental services and the understanding that natural ecosystems provide services such as water purification, nutrient and mineral recycling, or pollination that are of immense economic value has improved decision making with respect to the management of land, atmospheric, freshwater and marine resources, although in many cases it would be very difficult to demonstrate a direct impact and measure its economic return.

5 www.pc.gov.au/__data/assets/pdf_file/0004/37183/economicmodelling.pdf

Intangible impacts

While economic, social and environmental benefits clearly add to national wellbeing, there are other less tangible benefits of research that may be difficult to measure but just as important. Research in areas such as history, archaeology and the biology of indigenous plants and animals can add to a sense of national and cultural identify. Internationally recognised research across any field adds to national reputation, can be an important factor in gaining Australia a seat at the international table and demonstrates that Australia is a nation contributing to the study of global problems and playing its part in seeking problems to them. Australia's reputation as a leading nation in radioastronomy has the potential to make Australia the location for the SKA, a $2 billion international research facility with the prospect of considerable spin-off benefits for Australia.

In a very real sense, international research is a 'trading network' in which nations are able to access the knowledge and technology produced by others according to the level at which they are contributing. Research of a quality to bring Australia into this network has a considerable value above and beyond the benefits of any other impacts it might have. Moreover, having a reputation that flows from internationally recognised research strengths is important in attracting to Australia the very best researchers from overseas, helps facilitate international collaborations and is a factor that multinational corporations take into account when considering where to invest. In a more practical sense, having a strong domestic research base is also necessary to keep abreast of international research and preserves the capability to understand the significance of such research and make use of it.

Methods of measuring impact

As already mentioned, there are many possible ways to measure the impact of research, although none can provide unambiguous or unarguable results. Moreover, evaluation of the same project, program or institution at different times or over different time spans can lead to widely divergent conclusions as radical innovations are rare, uncertain and unpredictable. The various assessment methods operate at different levels of aggregation, from that of individual projects to the overall impact of total national investment in research. Some are retrospective, some are prospective and some can be either.

These different methods serve different purposes and it is necessary to choose a method or methods that best relate to the purpose the assessment exercise is to serve. In practice it is usually necessary to use a variety of methods operating at different levels to provide useful and reliable information on the impact that the research has had. No single method is able to provide a complete picture. Nevertheless, each of these methods can contribute to our understanding of the relationship between research and its economic, social and environmental outcomes, as long as we recognise its limitations.

While different methods produce data having different degrees of robustness, this does not alter the fact that different approaches can appeal to different audiences. An econometric analysis that excites Treasury is not necessarily the best way to convince the general public that governments should fund research. Exciting and unusual anecdotes that attract media interest can help demonstrate the importance of research to the broader community but lack the rigour that many decision makers require. Sectoral case studies and cost-benefit analyses might interest bureaucrats in line departments but officials from the Department of Finance might give them less credence on the grounds that they are selective and tendentious. Any strategy to communicate the importance of research to economic development and broader national wellbeing has to use a diversity of approaches selected to meet the particular needs of individual target groups.

Input measures

While by definition input measures do not identify impact, they can be useful in benchmarking exercises and in setting the boundaries for the kinds of impact one might expect at a national level. Important indicators can include the proportion of national effort going into basic, applied and experimental development research; the proportion of research performed in different research fields or directed towards different socio-economic

objectives; and the proportion of research effort directed towards agreed national priority areas. In all cases the trend data can add valuable information. Another important input measure can be the source of funding – for example, business funding or grants requiring end-user participation may (or should) be more likely to lead to immediate impacts than funding from government programs aimed at supporting universities.

Input measures can demonstrate the way in which research institutions and program delivery agencies are responding to the government's national priorities, and are aiming to achieve impact in areas the government has deemed as important. Similarly, figures showing trends in the value of commercial contracts received by a university can indicate the extent to which it has developed capabilities that the private sector has identified as being important enough to invest in. Other measures of cross sectoral collaboration and interaction, including partnerships, might also provide proxy input indicators of (at least potential) impact.

A more intangible input measure, but one which can significantly affect the likelihood of research having a positive impact, is the nature of the research management process. Sophisticated research management involving fast failure approaches and the continual evaluation of research according to criteria that relate to the excellence of the science, its continuing relevance to the intended objective and changes in the path to impact environment will have a greater propensity to achieve impact than research managed in a different way or left to the intellectual curiosity of an individual researcher. However, the purpose of research has to determine the appropriate research management style and what makes best practice for experimental development is by no means best practice for basic research.

Output measures and benchmarking

Output measures can help in assessments of research productivity, but only if placed in the context of the intent of the research and the objectives of its funding body. The immediate outputs of research are clearly one of the stages on the path to impact. Publications and then citations can demonstrate the extent to which the research is having or has had influence. However, while assessments of academic research excellence might focus on the most academically prestigious journals, measures of research impact might need to consider other publications – including client reports, technical manuals, patents, text books, the media, newsletters, submissions to government inquiries and communications directed towards the general community or to particular industry sectors, and so on.

Other output measures can include the use of processes that have the potential to lead to impact. These can encompass the use of technology transfer mechanisms such as industry seminars, industry secondments (in either direction), field days which demonstrate new techniques and approaches, participation in government committees and policy development processes, participation in industry and academic meetings and seminars, preparing popular publications, research consultancy work and the provision of other advisory or technical services. While none of these is an impact in the narrow sense, they all indicate an intent to have the research used and a preparedness to take action that will bring the research to the attention of those with an ability to use it. In many cases these kind of mechanism operate at a level above that of individual projects and provide access to the knowledge, experience and capabilities that have accumulated from research over many years.

Expert review

Just as peer review can be useful in assessing the quality of academic work in an academic context, expert panels with relevant experience in different areas of potential impact can be useful in assessing the difference that research has made. Such panels can also provide useful comment on the extent to which researchers are making effective use of the mechanisms that have the potential to lead to impact.

As with peer review there can be issues related to the subjectivity of the judgements made and it is important to ensure that the experts have the experience necessary to assess the particular impacts the research claims. Despite these limitations, the use of expert panels can provide informative evaluations, especially when comparing claims from different institutions or groups. Expert panels are often useful in conjunction with some of the other methods that are available and can sometimes help temper their shortcomings.

Anecdotes

Many researchers can provide narrative accounts of the economic or other benefits that their research projects have produced. Such anecdotes do not rely on detailed analysis but simply describe how a particular research project contributed to the development of an identifiable outcome that extended beyond the research community. Anecdotal evidence is often personal and subjective but does demonstrate an awareness among the researchers of the ways in which their research can have impact – which is important in itself. While a long list of outcomes based on anecdotal accounts can appear impressive, it does not provide any quantitative indication of the level of economic benefits or of what level of additional investment was necessary to achieve them. However, it does identify some of the economic benefits that research is producing and can help illustrate their variety.

Case studies

Case studies use the detailed analysis (to varying degrees of rigour) of individual projects to explore the ways in which research produced an economic or other outcome that contributed to national wellbeing. The preparation of case studies is often a research project in its own right and involves people other than those working on the research under study. While case studies provide data at the micro-level and the impacts they identify relate only to the particular project or program they examine, case studies do have many advantages. In particular, they can help identify the players involved beyond the research performers and can help in estimating the total costs of converting an invention into an innovation. Case studies are necessarily retrospective and will usually draw on anecdote as well as data, not least because of the complexity of the innovation process and the diverse array of players usually involved. However, they can play an important role in developing a better understanding of innovation processes.

Cost-benefit analysis

Cost-benefit analyses, like case studies, normally start with particular research projects or programs. They are often less rich in detail, although richer in quantitative data, than case studies. The objective of a cost-benefit analysis is to identify the full costs of the research and to assess in detail the economic value of the benefits that have flowed from the research or to estimate the likely benefits that will flow from current investments. A single study can be expensive and this limits the extent to which it is possible to use them.

The quality of cost-benefit analysis can vary enormously. For example, some analyses take into account only the cost of the research and ignore the often greater financial investments that come from those using or commercialising the research. There can also be significant differences in the extent to which the analysis takes into account the full range of benefits that flow from the research or concentrate on the direct commercial outcomes. The assumptions made in conducting the analysis (including the details of the counterfactual) can make a big difference to the conclusions, especially when looking at projected rather than retrospective benefits. There may also be problems in attributing costs or benefits to individual projects, given the many interdependencies that inevitably exist, as hindsight studies make clear.

Most cost-benefit analysis examines carefully defined projects or small programs but some studies take a broader approach, as when they examine the return on the research investments made by whole funding programs or by institutions. However, the broader the study, the more courageous the assumptions the analysts have to make. Collating the data necessary for even a single project can be difficult and time consuming. For this reason a broad survey tends to combine an unsophisticated (even simplistic) cost-benefit analysis with an anecdotal approach. This kind of analysis can often fall into the category of 'advocacy research', in that it collects data and conducts analysis to support an already agreed position.

As an example of what cost-benefit analysis can achieve, a major study of the return on investment in ARC funded research examined the benefits it could trace from ARC research funding. The study used the following categories of benefit:

- building the basic knowledge stock;
- the generation of commercialisable intellectual property;
- improving the skills base;
- improving access to international research and international networks;
- better informed policy making; and
- health, environmental, social and cultural benefits.

The study examined links between ARC funding and each category of benefits, past and current and estimated the total social rate of return (the permanent increase in GDP as a percentage of the dollar cost of the investment that lead to this increase) on ARC investment in Australia at 39 per cent. This is high, considering that the average social rate of return on publicly funded R&D appears to be around 25 per cent. The authors noted in addition that this estimate of returns from ARC funded R&D is only a partial measure of overall benefits, as it was not possible to quantify some benefits (such as health, environmental, social and cultural benefits). Overall, the study (commissioned by the ARC) concluded that it is highly plausible that ARC funding generates higher returns than is the average for all publicly funded R&D.[6]

Hindsight studies

Whereas case studies start with research projects and work forwards to map their impact, hindsight surveys start with an impact and work backwards to identify what contributions research made to the impact. A case study may show that a single area of research contributed to many different impacts, a hindsight survey might identify that many different areas of research were necessary to achieve particular impacts. As with all such studies there can be a high degree of subjectivity and the findings can depend on the interest, knowledge and perspectives of those conducting the study. Moreover, a rigorous hindsight survey can be very expensive and time consuming.

The first hindsight study was probably that performed by the US Office of the Director of Defense Research and Engineering in 1969.[7] This analysed twenty weapon-systems and major military equipment to identify applications of science and technology not used in predecessor military systems designed to meet roughly the same requirements. The study traced back the evolution of the new technology represented in each system to critical points called "research or exploratory development (RXD) events." Specialist teams identified 710 such events. The analysis separated the basic research performed to solve a specific assigned problem (directed basic research) from the basic research performed to expand the frontiers of scientific knowledge (undirected basic research). The analysis found that RXD Events from directed research emerged in systems development approximately nine years following their conception, while it took 20 or more years for some events from the undirected category to have an impact. More importantly, the study noted that 95 percent of the knowledge used in these events was an outcome of activities supported either directly or indirectly by the Department of Defense; and that 61 percent of the RXD Events identified had a specific systems' requirement as a research objective and that over 85 percent of the technological events occurred after a problem applications group had defined the problem they needed solved.

Even before Project Hindsight had produced its final report, university researchers responded to these conclusions by noting that because Project Hindsight looked back only 20 years, it had missed the basic research that provided the underlying foundation for the technological developments it had studied. To redress this, the National Science Foundation commissioned a study (*Technology in Retrospect and Critical Events in Science*) which performed a hindsight analysis on five major technological developments (ranging from the contraceptive pill to the electron microscope) and looked back 50 years.[8] This concluded that 70 per cent of the 340 events the study identified were the result of non-mission (basic undirected) research, with 20 per cent

6 www.arc.gov.au/pdf/ARC_wealth_of_knowledge.pdf

7 www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=AD0642400

8 Illinois Institute of Technology, Research Institute. 1968. Technology in Retrospect and Critical Events in Science. Chicago: Illinois Institute of Technology.

originating from mission research. Furthermore, universities had performed around 75 per cent of the non-mission research and a third of the mission research.

In considering the difficulties posed by hindsight studies, it is worth reflecting that foresight studies aiming to predict future technological developments or even advances in science are even more problematic. Even the best informed experts are likely to miss some of the most momentous impacts of research that may occur over the coming years because research – and the impacts it will have – are by their very nature unpredictable and depend in part on chance and the concatenation of circumstance. Many of the most significant and pervasive outcomes of research were not the result of deliberate planning but an outcome of the accidental interplay of curiosity, imagination and opportunity.

Surveys

Case studies and cost-benefit analyses are necessarily selective and local, in that it is necessary to choose particular examples for study. It can be difficult to extrapolate any conclusions beyond the particular project or organisation under study. In contrast, surveys can provide a more comprehensive and more balanced set of data. They can provide a means of gathering comparative data, especially but not exclusively data that is useful in comparing different institutions or sometimes programs. However, by themselves surveys usually address only part of the impact equation and while they can collect data that it is possible to use for quantitative comparisons, in some cases this may be subjective (as with stakeholder surveys).

Stakeholder surveys

Some forms of survey may gather a type of anecdotal information, but from a user rather than researcher perspective. For example, it is possible to survey the customers and other stakeholders of research-performing departments or of technology transfer offices to assess stakeholder views of the importance of the research and the ease of working with the researchers or research office to create impact. The responses will usually be qualitative, anecdotal and unsophisticated. Nevertheless, stakeholder perceptions of impact and the willingness of a university to work with outside agencies to achieve impact can be valuable in a political context. Such surveys can also help identify ways of increasing impact by improving linkages, changing perceptions and removing impediments to the flow, exchange and use of knowledge. Trends identified in stakeholder surveys can also help indicate changes in the willingness of an organisation to respond to the possibilities for achieving impact.

It is necessary to take care in interpreting stakeholder surveys because of the conflicting views that can exist about the proper role and responsibilities of the organisations involved. For example, business expectations of universities can be unrealistic and ignore the broader roles of universities in serving the whole community and in doing research that complements business research, rather than substitutes for it. A survey seeking general comments from business on university research might have a very different response from a survey seeking comment on the contract research a university performed for business.

Commercialisation surveys

While stakeholder surveys collect subjective and anecdotal data, commercialisation surveys normally collect quantitative data relating to matters such as the number of staff devoted to technology transfer, spin-off companies, patents and other IP rights applied for or granted, and licensing income. They may include customer data, showing the number of customers and the size of contracts. These surveys can provide a comparable set of data from different organisations.[9]

While commercialisation surveys provide quantitative data that can be useful for comparisons, benchmarking and monitoring trends, it is still necessary to exercise care in the interpretation of such data. The potential

9 The most recent Australian National survey of Research commercialisation is at: www.innovation.gov.au/Innovation/ReportsandStudies/Pages/NationalSurveyofResearchCommercialisation.aspx

for narrowly defined commercialisation activity will vary depending on the discipline mix of an institution, its balance between different types of research activity and its particular roles, responsibilities and strategies. Moreover, commercialisation as measured by surveys provides a very narrow perspective on research impact, even in the confined context of achieving impact through business.

Commercialisation surveys generally do not examine the cost side of the equation and either ignore (or do not assess) the actual economic impact of each organisation's activities. (In most cases the economic impact of a technology would far exceed the licensing fees going to the inventor, or even the improved financial performance of the firm using a technology.) Maintaining IP rights, for example, can impose a significant cost if there is no customer interested in using those rights. These surveys also miss the economic impacts that can be more difficult to measure, such as those relating to the impact of the research on skills, policy advice or the very many uses of research that occur without the need for explicit commercialisation vehicles.

An important issue in mandating such surveys as measures of institutional performance is that they can influence the behaviour of organisations covered by the survey such that they favour strategies that increase the financial return to the organisation as distinct from those which increase the economic return to the nation. For example, using commercialisation surveys to measure performance can encourage patenting and the granting of exclusive licences in situations when the best return for the nation might come from the rapid and free diffusion of the technology to those able to use it. Patenting a research method, while producing a revenue stream for the patent owner, might decrease impact by restricting the use of the technique.

Commercialisation surveys can also encourage the formation of spin-off companies that face all the attendant risks of a new business when the most certain path to market might be through an existing business. This can be of particular significance for organisations performing research in sectors such as agriculture or in public good areas such as environmental management. This raises interesting policy issues relating to the responsibilities that go with the use of public research funds, quite apart from the implications of promoting strategies that have the potential to reduce impact. A further problem is that using performance indicators such as patent applications (or even grants) can encourage patenting even when the technology patented may be of little if any commercial value. Institutions can end up spending more on patent fees than they receive in licensing or other revenue flowing from their patents.

Economic models

The development of conceptual and theoretical models can help explain why research is important and provide an understanding of the means through which research can lead to improved productivity or economic growth. They provide intellectual support for a relationship that many supporters of research take for granted. These models have value in themselves in providing potentially testable explanations and provide a means of examining the impact of research in quantitative terms. This is because econometric analysis can use empirical data to assess the impact of research expenditure on the economy using these models.

Science and technology policy analysts have argued that research is important to economic growth for many years but it was not until the appearance of the 'new growth theories' heralded by Paul Romer's 1986 paper *Increasing returns and long-run growth* that these arguments achieved a level of respectability with the economic decision makers in government. This new theoretical framework stimulated a great deal of empirical work that has led to a much better understanding in economic terms of the impact that research investments can have.

The most important characteristic of the new growth theories was that they recognised increasing returns to scale in production. In particular, the most important drivers for these increasing returns are the stock of knowledge generated by research and development; returns to investment in education and skills; and returns from learning by doing. These economic models tend to emphasise the non-rival nature of knowledge – that it is possible for one person to use knowledge without in any way detracting from the ability of someone else to use the same knowledge. This combines with the non-excludability of knowledge, the ability of anyone to take existing knowledge and build on it to create more knowledge which itself is non-rivalrous and non-excludable.

While such models do not in themselves provide a measure of the impact of research, they do provide part of the context within which governments make decisions about the funding of research and why government investment in research is worthwhile and responsible. They enable potentially testable explanations to replace assertion and provide a framework for econometric analysis.

Econometric analysis

Case studies, cost benefit analysis and surveys all provide data that can relate to individual organisations. Econometric analysis uses a range of numerical analysis techniques to explore the macro impacts of research. The coordinating departments (such as Treasury, Finance and Prime Minister and Cabinet) often favour econometric analysis because it operates at a national level and is not possible to manipulate its outcomes through the careful selection of examples, as with other some other methods. Even so, there are important consequences flowing from the assumptions made in developing the models and the robustness of the available data.

Econometric analysis uses empirical data to explore the economy-wide consequences of changing investment in research and the economic impacts of research performed in different sectors (government, higher education, and private) rather than individual agencies. Such analysis can demonstrate a relationship between productivity growth and research, so helping to justify government funding of research. However, because it is operates at a macro level, econometric analysis does not help make decisions about where the research funding should go or about the performance of individual research agencies. On the other hand, because it does not need to identify the individual benefits but considers only the overall economic impact, econometric analysis might help capture those economic returns which can be very difficult to measure at lower scales of analysis. However, by its very nature, such analysis cannot capture some of the more intangible impacts of research or those that arise from reducing or preventing negative effects rather than facilitating positive outcomes.

As an example of the use of econometric analysis, an influential OECD study investigated the long-term relationship between productivity growth and technical change.[10] Multifactor productivity (the residual after removing the contributions of labour and capital from GDP growth) provided the measure of productivity. Sources of technical change used in the analysis were business R&D, foreign R&D (business R&D performed in other OECD countries) and public R&D (including the government and higher education sectors). The study used data from 16 OECD countries from the period 1980-98. Among the conclusions of the study was that:

- The effect of government and university performed research on productivity is positive and significant, outweighing the cost of public research.
- The effect of public research is larger in countries where universities (as opposed to government laboratories) have a higher share in public research. This may reflect government laboratory research addressing public missions that do not impact directly on productivity (defence, health, and environment) whereas universities provide industry with basic knowledge that provides the basis for technological innovation. (The paper also suggests that one reason for this is that universities receive a greater proportion of their funding through competitive processes.)

More recently, the Productivity Commission in its detailed and useful study of public support for science and innovation in Australia, conducted a detailed and technical review of similar work from around the world. Their report provides a useful summary of Australian and international work. The Commission's summary of its analysis of econometric and other work aimed at assessing the impact of research was that:

> *Taking account of multiple sources of evidence, there are likely to be significant aggregate economic, social and environmental benefits from publicly supported science and innovation, but quantitative estimates are unreliable.*

10 Dominique Guellec and Brunovan Pottelsberghe de la Potterie: (June 2001): *R&D and productivity growth: panel data analysis of 16 OECD countries*. STI Working papers 2001/3 OECD DSTI/DOC (2001)3

Conclusions

There is no doubt that research has a major impact on our quality of life and on our general wellbeing; or that it achieves these impacts through a diversity of pathways and through indirect as well as direct routes. We can see this simply by looking around at the materials we use, the technologies available to us and the speed at which things change.

The outcomes of research affect every aspect of our existence – whether work, social life or leisure. Everything from our health care and entertainment experiences to the structure of our economy, new businesses and communication opportunities are completely different now from what they were even 20 years ago. Research, the improved understanding it provides and the technologies it produces, impact on every aspect of our life and social relationships.

While it is obvious that investment in research has impact and that many of these impacts make life better, it is much more difficult to demonstrate the contribution made by individual research projects or to quantify the contribution that research has made, especially given all the other inputs necessary to achieve successful innovation. This should not be surprising, recognising that many of the most important contributions of all research are systemic rather than linear. They do not exist in isolation. Their creation built on much that had gone before and their impact was the result of significant and complex contributions from outside the research system, as well as on a large element of chance.

Even though it is difficult, it is still necessary to try to measure the impact that research has, partly to meet the general accountability that applies to all investments and especially to government funding, but also as an aid to making investment decisions in the first place and to improving the effectiveness of the national innovation system. At the same time, it is necessary to consider that by its very nature research is dealing with what we do not know, so that the significance of its outputs are to a greater or lesser degree unpredictable – which is why serendipity is always important.

In attempting to evaluate the impact of research it is important to recognise the limitations that flow from the complex innovation system within which research operates, the varying pathways through which impact can arise and the different timelines within which different kinds of research might develop their value. It is necessary to recognise that different kinds of research aim to produce different kinds of impact and to assess research projects within their own boundaries of intent and the purpose for which they received funding. This requires a careful choice of the available methods and even more care in interpreting their results. Most importantly, it is necessary to recognise that an evaluation is at best tentative as subsequent research can have a major effect on the potential impact of previous research.

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