Innovation and Information Infrastructure: Making Sound Investments for E-Research

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Overview

This ECAR research bulletin provides a framework to assist universities in making sound investments in research information infrastructure in an increasingly complex, global knowledge economy. Although this bulletin is written from an Australian perspective, it is clear that in today's globalized world, many of the drivers and challenges are common across the world's developed and developing nations—hence, the strategies adopted by nations and universities are becoming increasingly similar. To make sound investments in research information infrastructure, it is necessary to understand the vision, motivations, and strategies of key agents in the research endeavor and to realize that we must collaborate to compete and that universities must constantly balance strategic and tactical outcomes when making decisions. For purposes of this bulletin, the key focus will be on the nation, the researcher, and the university.

The term *research information infrastructure* in this bulletin is used in the broadest sense. While much has been written about *e-research* and *cyberinfrastucture*, the reality is that all research now requires the use of information and communication technologies—it is simply a matter of degree. Research information infrastructure within the bulletin refers to the information professionals, scholarly information, tools, and technologies that underpin the research endeavor. This definition most closely resembles that of Borgman: "Encompassing the nation's networks, computers, software, information resources, developers, and producers."[1]

Highlights

Research and innovation are human activitites, relying upon individual creativity and imagination, building upon existing knowledge. "Innovation is built on stocks of knowledge and capability, and the information flows of innovation capital around these."[2] If universities are the heart of the innovation system, then information infrastructure is the circulatory system. We now live in a time in which information and communication technologies have fundamentally reshaped the ways in which knowledge is created, shared, and preserved. Networks and associated technologies enable everyone to create, collaborate, access, and share knowledge. The boundaries between nations, organizations, disciplines, and people have become permeable, increasing complexity while creating new opportunities and challenges. This world has been characterized as a global knowledge economy.

The Innovation Imperative

Innovation theory, and our understanding of the role that universities play in driving regional and national innovation, has evolved over the past 20 years. National prosperity in a knowledge economy rests upon the ability of a nation to apply existing knowledge and to innovate to build economic and social prosperity. By equipping people with the skills to innovate, to embrace new and better ways of doing things, business and industry thrive, productivity increases, and the nation benefits from a more prosperous and educated workforce. Many nations are responding to the innovation imperative through significant investment in universities, research, and national information infrastructure. In Australia, the government's innovation strategy, *Powering Ideas: An*

Innovation Agenda for the 21ˢᵗ Century, seeks "to create a better Australia—a fairer, richer, healthier, and greener Australia that can meet the challenges and grasp the opportunities of the twenty-first century. … Our aim is to make innovation a way of life."[3]

The Place of Universities

"An internationally competitive economy begins with an internationally competitive innovation system—and that begins with internationally competitive universities."[4] Universities, as primary creators and disseminators of knowledge, understandably feature heavily in the national innovation strategy. Together with a nation's research agencies, libraries, and cultural institutions, universities play an important role as repositories of existing knowledge, and they are hubs for the generation and exchange of new knowledge. While networks are making more information accessible, facilitating collaboration, and enabling everyone to contribute to knowledge creation, universities remain at the heart of a nation's innovation capability. Innovation increasingly happens on distributed inter-organizational networks rather than within an organization. Universities form part of multifaceted social or information channels or mechanisms through which information, knowledge, and other resources are shared or co-produced—a much richer picture of university engagement than simply knowledge transfer.[5] It is this richness that also creates complexity, creating new opportunities and new challenges for universities.

The Place of Information Infrastructure

A nation's information infrastructure is central to its innovation system: from high-speed networks, advanced computing, and collaboration tools through to capturing research data for reuse and making government data and national collections held by libraries, museums, and other agencies more accessible. Not only do researchers and innovators require the tools to undertake their work, they require access to past knowledge upon which their creativity is founded. This highlights the need for a high level of interaction between knowledge providers and knowledge users. The role of the information professional will be critical to the broader innovation agenda.

Managing in Complexity: The Multiplicity of Agents

"The networked information economy has not decreased the total capital intensity of information production, storage, processing, and communication, but it has decentralized its ownership."[6] Knowledge can now be created, disseminated, shared, and preserved (or lost) by everyone. Even if we confine ourselves to university research and its place in national innovation, we see a myriad of agents: individual researchers; research centers or groups, which may span organizational or national boundaries; the university; the region; the state; and the nation. Overlaying these are other informal or formal groups, such as discipline-based scholarly academies, which may be global in reach. Each of these agents brings its own priorities and motivations to the task of driving research and innovation. Yet to achieve success in a networked global knowledge economy, each must work in concert and avoid competitive behavior that works against achieving shared aspirations for an improved future. Achieving the national innovation agenda requires not just a strengthening of the parts but a strengthening of the links between those parts.[7]

This bulletin focuses on the researcher, the university, and the national government (referred to as "the nation"). The following section outlines the vision, motivations and strategies of each of these agents, drawing out the implications from a research information infrastructure perspective.

The Researcher

The noble vision of a researcher is to create new knowledge, but in order to keep doing so, he or she must build a research profile to ensure tenure and promotion and build a reputation to attract research funding and research partners. From a researcher's perspective, although the focus is clearly on the immediacy of the research, there is also an interest in maximizing the research impact through publication and citation. As the research environment has become more complex, as the reliance on information and communication technologies has increased across all disciplines, and as a variety of scholarly publishing options have evolved that each provide differing impact value, researchers are increasingly valuing the role that information professionals, with disciplinary knowledge, can play as part of their research team. Work undertaken by the author at the University of Melbourne confirmed this, as has a recent study—conducted by Intersect[8] across four Australian universities—that found that academics are seeking expertise in data management, data analysis, and IT support.

The reality is that researchers care little about where, or how, the scholarly information, systems, or infrastructure are delivered to support their research. Their primary motivation is that such services are responsive, easy to use, and inexpensive (preferably free), so that they might focus their resources (time and money) on actual research.

The Research University

The vision of a university is to create knowledge, influenced by national imperatives to seek solutions to the economic, social, and environmental challenges of the 21st century. To do this, universities must attract good researchers, strong research partners, and research funding. From a research university's perspective there is an incentive to maximize the value of the university's research outcomes for both the short and long term. Although a university's research strengths and priorities will determine where it invests in the immediate term, universities are long-lived institutions—they seek to protect their right to research the most theoretical and intractable uncertainties of knowledge, not simply those that have immediate practical application or that might be set as national priorities.[9] Universities constantly balance the tension between delivering immediate value to their nation—as measured through research rankings or commercialization of research—with their vision of creating new knowledge for future generations unhindered by the immediate political imperative. Many will seek to foster research and innovation across all their disciplines. As a result, university information strategies and policies must support the research base broadly, as well as provide support for areas highlighted as current strategic priorities.

The university's commitment to the long term also impacts on how it considers the management and accessibility of scholarly outputs. The university will be motivated to maximize its overall research impact through publication, but this will (or should) be tempered by a desire not only to increase citation impact and journal ranking but also to

maximize true impact of research through open dissemination, maximizing access for all, and protecting scholarly output for future generations of scholars.

From a research information infrastructure perspective, the university will seek to maximize the value of its investments, targeting investment where it will add the most value in the short and long term. Universities now realize they must collaborate to compete. There is a strong incentive to lobby for government funding of research information infrastructure collectively and to compete for government and other funding individually.

The Nation

At a national level the vision is to make the future better than the past; to make the nation more productive and more competitive; to address the economic, social, and environmental challenges of the 21st century; and to improve the nation's position on relevant international rakings such as those of the Organisation for Economic Co-operation and Development (OECD). Governments, in their desire to build national competitiveness through research and innovation, seek to implement policies and strategies that maximize the value of their investment in university research to increase the economic and social prosperity of the nation. In a globally connected world, nations must help their universities be more competitive and must be more attractive collaboration partners. At a fundamental level they must ensure that appropriate national information infrastructure is in place, through a combination of government investment and stimulation of private-sector investment.[10]

It is also in the national interest to maximize the value of government investments in publicly funded research through policy, by requiring open access to the scholarly outputs from the research: both the published outcomes of the research and the data that underpins the research.

Bringing It All Together

Creating a strong innovation system requires not just strong agents but strong links between the agents. The actions of the agents are interdependent and, ideally, mutually reinforcing. It is critical that we understand the motivations of the key agents.

Research information infrastructure plays a major role in both domains. Lynch[11] posed the question, "How does the campus cyberinfrastructure challenge differ from the national cyberinfrastructure challenge, recognizing that investments in these areas should be not just complementary but mutually reinforcing?" He highlights the need for local investment if a university is to be able to fully benefit from national investments. Borgman[12] noted that "the situation calls for ways to balance the local needs of individual scholars, students, and teams with the global requirements of a distributed, multidisciplinary, multilingual, multipurpose e-infrastructure." The complexity of the current environment should not be underestimated. It is clear that we must collaborate in order to compete.

Universities have the potential to play a critical role in balancing these tensions, strengthening the links between the agents of innovation for mutual gain. The visions and motivations of the key agents have much in common, and it is these shared senses

of purpose that will provide the best foundation for developing investment strategies that are acceptable—and valuable—to the multiple stakeholders. These aspirations must not be lost in the immediacy of daily demands—tactical behaviors must not come at the expense of the longer-term strategic vision.

What It Means to Higher Education

It is timely to ask if we are investing in the right ways in the right places to drive research and innovation through investment in information infrastructure. As university information professionals, we have an obligation to ensure that our universities invest wisely. We have an obligation to our researchers to ensure they are provided with the best possible research information infrastructure services. We have an obligation to contribute to, and exploit, regional, national, and international opportunities in the most effective and efficient ways. Universities occupy a privileged position, with a unique opportunity to strengthen the national innovation system, not only through their own actions but also through forging and strengthening the links between key agents within the innovation system.

A framework for investment in university research information infrastructure can be formed in three ways: by understanding the vision and motivation of three of the key agents of innovation (the researcher, the university, and the national government); by recognizing that we must collaborate to compete; and by noting the importance of balancing the strategic and tactical.

Fundamental Research Information Infrastructure

There is a level of research information infrastructure service that any researcher should expect and that every university should deliver. These services are fundamental or "pre-competitive" from a university perspective. They underpin the vision and motivations of the nation, the university, and the researcher, potentially driving competitive advantage for the nation as a whole. These are the services that are best delivered through national investment or through national or international collaboration, in the most cost-effective manner.

Influencing government policy and investment strategy, or seeking out collaborating partners, should be the preferred strategy. Examples of this would include high-capacity information networks, national identity and access systems, and data storage. National competitive advantage is derived from such networks, but from a university's perspective, unless this is an area of research for the particular university, their networks must simply keep pace. Large investments in expensive "landmark" research infrastructure, such as a synchrotron or peak computing facilities, would also meet these criteria. Even as increased performance and lower costs make it possible to derive more compute capability at a local level, whether within a university or a research group, the growth of cloud-based services and the increasing interest in driving green IT solutions make it more difficult to justify the benefit of local investment in advanced research information infrastructure.

National identity and access systems are necessary fundamental infrastructure, enabling the nation's researchers to become part of the global research community. Universities

must invest adequately to participate in such initiatives and encourage national collaboration and investment.

Assuming that appropriate security and access measures can be met, data storage infrastructure provides no competitive advantage to a university. This may be an obvious candidate for national investment, as is occurring within Australia, though it may increasingly make sense to source this internationally through the cloud.

The Complex Middle Ground

Some components of research information infrastructure services blend pre-competitive and competitive advantage in a complex fashion. This is where the tension of long-term vision competes with immediate competitive advantage for attention. Where Marginson[13] urges that we "recognize, understand, and factor into our organizational systems the post-capitalist production of knowledge goods, which is the primary zone where we make our future," a more complex investment response is required.

Included within this domain are the scholarly publications, research data, and associated tools created by our researchers. Access to the world's scholarly information, which provides the foundation for the development of new knowledge, is arguably fundamental. Everyone benefits. Collaboration and investment at a national (or even international level, such as the Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP3)) ensures the best outcome for a university and the nation. Houghton and Sheehan[14] analyzed the literature and quantified the potentially measurable impacts of enhanced access to research findings for researchers, government, and the wider community. These benefits included more timely access to accelerate collaborative research, adoption, and commercialization; a greater opportunity to inform professional practice; the potential to create more informed citizens and consumers with implications for better use of health care, social benefits, and education; and potentially improved productivity. Their modeling showed significant economic benefit from open access to publicly funded research, with, for example, an estimated 5% increase in access and efficiency in Germany worth $3 billion USD. Yet peer-reviewed prestige publication is still the route to academic success and improved university and national research rankings. Publishing in the "right way," which may exclude opportunities for open access publishing, can significantly increase research impact as measured through citation and journal ranking, increasing a university's competitive advantage.

Scholarly output now includes not only the published works but the research data, tools, and techniques associated with the research. An unknown amount of this research data will have value for the future as an important part of scholarly output. While researchers are motivated to have ready access to the data, tools, and techniques they have previously used for their own benefit, there are strong disincentives for researchers to engage with long-term data management, including concerns of loss of competitive advantage. Universities serve to benefit in a range of ways (see the following section). Again there will be an inevitable tension between maximizing institutional value while contributing to the global store of knowledge. This is an area where the researcher, the university, and the nation all have the potential to gain competitive advantage if a more coordinated approach is taken but where the ideal investment model is still unclear.

Government policy and investment in services that encourage open access to the outcomes of publicly funded research make good sense, but they must be viewed in terms of balancing tactical short-term advantage for the university with longer term strategic advantage for both the university and the nation. This is an area of evolving policy, an area that will provide great opportunities and many challenges, requiring all the agents to work in concert to achieve the best shared outcomes.

Ensuring senior university executive awareness of, and engagement in, national (and international) research information infrastructure opportunities will be critical if the most effective investment decisions are to be taken in the complex middle ground.

Driving a University's Competitive Advantage

As the services move closer to the actual researcher, more competitive advantage can be derived from targeted investment. Where the bulk of research income comes through competitive grant funding for specific projects, and where government funding of the indirect costs of research is allocated to researchers and research groups on an "as earned" basis (as in many Australian universities), there is limited incentive for researchers to minimize duplication of services and infrastructure, particularly if they believe they would need to relinquish control if they did coordinate such efforts. The researchers putting forward a research proposal may not know what infrastructure service options exist or how best to maximize the impact of their research (see, for example, the earlier studies mentioned). It is unlikely that they will understand how best to manage their research data if it is to provide long-term value to the scholars of the future. It is pointless to assume that this will be resolved through researcher training. Researchers are motivated neither to understand the evolving national research information infrastructure framework nor to become experts in information/IT, and these issues do not constitute a good use of researcher time and expertise. They may, across some disciplines, have an understanding of the landmark facilities available to them, though this should not be assumed.

A university has the potential to derive competitive advantage by including information professionals both at the inception stage of the research proposal and as required throughout the research itself (though this latter work may be best covered by the research grant funding). This will ensure that the research maximizes use of existing university, state, or national services and infrastructure (a university motivator), while minimizing the resources the researcher must put into providing research infrastructure (a researcher motivator) and driving more effective use of public funds (a national motivator). For the university, it provides a distinct competitive advantage in many ways: producing more effective research, making the outputs of its research available for current and future scholars, attracting research partners and scholars, and ultimately enhancing the university's research profile.

While research data management forms part of the complex middle ground, there is real competitive advantage for a university through investment in this area. Existing research data can be re-mined and reused; research algorithms, tools, and techniques can be easily shared; and large data sets can be visualized to render complex findings in useable ways. With appropriate stewardship, research data has the potential to significantly increase research impact, provide competitive advantage to the university

and the researcher by increasing their profiles, and attract research partners and new researchers. Universities are one of the enduring features of the research landscape and they are arguably a logical home for long-term commitment to data stewardship. One of the policy problems with data curation and preservation is that the costs persist long after the project ends. Yet universities have invested significant sums of money (through government funding) in building and sustaining library collections for future generations of scholars. They have done so based on a belief that the library plays a key role in supporting their research and learning through preserving and making accessible scholarly output. Borgman[15] suggests that research data may become the new "special collections" for libraries.

Lynch[16] sees the biggest challenge for universities as the design and staffing of organizations that will work with academics to access local, national, and global cyberinfrastructure services; assist faculty to manage their data; prepare for handoff for curation; and aid researchers in data reuse, mining, and computation. By providing such services, the university has the opportunity to gain real competitive advantage in both the short and long terms.

While open-access publishing forms part of the complex middle ground, universities can gain real competitive advantage by making targeted investment in this area. In a complex, evolving scholarly information environment, it is neither reasonable, nor sensible, to expect researchers to know how best to maximize their research impact through publishing, nor to understand how best to balance the benefits of open access publishing with decisions about increasing impact though publishing in highly ranked journals. Real competitive advantage can be gained by a university's establishing a publishing advisory service to assist researchers in maximizing their research impact.[17]

The new environment rewards researchers who profile themselves and their work most effectively. Researchers seek to build their research impact and profile, universities seek to build their research impact and ranking, and nations seek to maximize their research investment and build national competitiveness. They all stand to benefit from sophisticated systems that link information about university research strengths, researchers, grants, and publications. There is merit in national policy and investment in this area, but universities and individual researchers, who hold most of the data, will be motivated to promote themselves and their work. While this might be a candidate for the middle ground, in the short term it is likely that the greatest competitive advantage will flow to those universities that promote their research and researchers. Ideally this should occur within a framework that works for the nation and also for the individual researcher.

Conclusion

Innovation, by definition, means change is constant. Universities have a privileged position within a nation's innovation system, with a unique opportunity to strengthen the nation, not only through their own actions but through forging and strengthening the links between key agents within the innovation system—building the bridge between researchers and university and national priorities. To achieve success in a networked global knowledge economy, each of these agents must work in concert, ideally avoiding competitive behavior that works against achieving shared aspirations for an improved future. These issues are self-evident when we consider the research information

infrastructure required to drive competitive advantage. By better understanding the vision and motivation of three key agents of innovation, by recognizing that we must collaborate to compete, and by balancing the strategic and tactical, it is possible to work toward an appropriate university investment strategy. There is a level of research information infrastructure service that any researcher should expect and that every university should deliver. These services are fundamental from a university perspective. They underpin the vision and motivations of the nation, the university, and the researcher, driving competitive advantage for the nation as a whole, not privileging any university specifically. These are best delivered through national investment and national or international collaboration, in the most cost-effective manner. There is a complex middle ground, where collaboration and negotiation, coupled with investment at all levels, will provide the ultimate solution. Yet there are some services that provide distinct competitive advantage to a university. It is these that will yield the greatest investment benefit in the medium term.

This bulletin reflects the context from a time-bounded Australian perspective, a time when policy and technology are rapidly evolving. It is clear that many nations are following broadly similar strategies as we each grapple with increasingly shared challenges and opportunities. As university information professionals, it will be our role to assist our universities, and our nations, in making informed investment decisions. This bulletin has sought to provide some insight into the complexities, challenges, and opportunities of the global knowledge economy in which we all play a part.

Key Questions to Ask

- How does our institution understand the current and future research information infrastructure needs of our research community?

- How does our institution determine what needs are best delivered through collaboration and what should be an institutional investment?

- How do we ensure that our researchers are aware of the information infrastructure services available to them to support their research?

- Do our organizational structures make clear who works with the researchers to:

  a. access local, national, and global cyberinfrastructure services,

  b. help faculty manage their data,

  c. prepare for research data handoff for curation, and

  d. aid them in data reuse, mining, and computation?

- How would we best measure the degree to which our current investment in research information infrastructure provides competitive advantage?

Where to Learn More

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