

The Role of Digital Networks in Promoting Collaboration and Innovation

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Abstract

The huge investment worldwide in telecommunications infrastructure and Grid technology is being partly justified by the potential for digital networks to promote collaboration and innovation.

Australia's Department of Education, Science and Training (DEST) states on its recently-established e-Research Consultation website (DEST, 2005) that "e-Research has the potential to usher in a new era of innovation and help overcome the tyranny of distance by allowing our researchers to collaborate at the national and international level." The theoretical and empirical bases for this claim are not clear. In particular, while it seems reasonable to assume that the existence of digital networks are a *necessary* condition for innovation into today's research environment, are digital networks *sufficient* for innovation? The answer, of course, is no. Careful attention needs to be paid to network structure (not just the physical structure, but the *social* structure) and governance if Australia's investment in telecommunications infrastructure to support e-research is to lead to a "new era of innovation". In this paper, a review of research into social capital, economic models of innovation and the structure of the World Wide Web (WWW) is presented. It is argued that these research strands are relevant for assessing the role of digital networks in promoting collaboration and innovation. They may also be important for the design of appropriate governance structures for digital networks.

1 Introduction

The Department of Employment, Science and Training (DEST) identifies six elements of Australia' s current e-research infrastructure: high bandwidth network, distributed high performance computing, accessible data and information repositories, accessible research facilities and instruments, accessible sensor networks, agreed ICT standards and coordinated development of middleware. The Australian Government has invested heavily in e-research infrastructure: \$140m has been invested in the first element above (network infrastructure) alone - \$80m on Australia' s Research and Education Network (AREN) and \$60m on the Advanced Networks Program (DEST, 2005b).

One of the core premises underlying the investment in digital networks is that this infrastructure will lead to collaboration and innovation. DEST argues that these networks “enable researchers to access remote instruments and data repositories and provide opportunities for collaborative research” (DEST, 2005b). The key phrase in this sentence is “provide opportunities”; while one can argue that digital networks are necessary for collaboration and innovation in today' s research environment, they are by no means sufficient. Research collaboration is a social process and to assess the role of digital networks in fostering collaboration and innovation it is important to not only consider the design of the physical network (e.g. the cabling and associated infrastructure) but also the *social* networks that will be supported and facilitated by the physical infrastructure.

This paper presents a brief and preliminary review of research that could be helpful for understanding the role of digital networks in promoting collaboration and innovation. An understanding of the factors underlying the process of innovation is essential for Australia' s investment in telecommunications infrastructure and e-research to result in a “new era of innovation”.

2 Research on networks and innovation

2.1 *Social capital and innovation*

Social capital has been defined by Putnam (2000, p. 19) as "connections among individuals - social networks and the norms of reciprocity and trustworthiness that arise from them". The concept of social capital has been highly influential in the area of community development and poverty research. It has been argued that physical, human and natural capital only partially explain economic growth and that social capital is the “missing link” in understanding the process of economic development (Grootaert, 1998). The concept of social capital has been adopted by the World Bank as a possible means of improving the poverty alleviation impact of development programs.

Social capital is also gaining prominence as a framework for justifying the positive social impact of investment in information and communication technologies (ICTs). For example, the Department of Communications, Information Technology and the Arts (DCITA, 2005, p.4) argue that “There is vast potential to use ICT to build social capital and contribute to community development and formation.” The role of social capital is also cited in connection to digital networking and innovation. Fountain (1997) argues that social capital “increases the ability to build and use informational capital because trustful relationships increase information flows and bring richer meaning to information.” Mitchell (2003) points out that the mere existence of digital networks will not create social capital: “...[digital networking] does little about the problems of creating trust and confidence, and of building intellectual and social capital for the long term” and Fountain (1997) recommends that more research is needed on how social capital is built over digital

networks.

However, serious questions have been raised about the usefulness of the concept of social capital, both in the theory and practice of community development.¹ DeFilippis (2001) has questioned Putnam' s assumption that actors are exclusively driven by charitable or mutual interests and also his failure to explicitly connect social and economic capital. A major problem is that social capital does not take into account the social processes of differentiation and hierarchisation (O' Neil, 2005). The position of members or actors within a network will directly influence the social and economic benefits that they can expect to obtain from participating in the network, and thus the overall societal benefits from the creation of the network. To the extent that social capital ignores the role of role of power relations and conflicting interests that are inherent in communities and affect the ability of social networks to provide social and economic benefits to members, one needs to be circumspect about using the social capital model to understand the role of digital networks in promoting innovation.

2.2 Economic models of networks and innovation

Economic research on network formation may provide useful insights for understanding the role of digital networks in promoting collaboration and innovation. A promising aspect of economic models of networks is that, unlike the social capital framework, they explicitly acknowledge that the network benefits flowing to an agent are directly related to that agent' s position within the network. Agents will form and delete ties with other members of the network so as to maximise the flow of benefits that they experience and this activity leads to different network structures. Some network structures are going to be better than others in terms of the benefits accruing to network members (and the society as a whole).

Carayol and Roux (2003) introduce a model of network formation where agents form direct or indirect connections with other agents, and benefit from information flows within their network. The authors use the network utility framework initiated by Jackson and Wolinsky (1996), who introduced the concept of pairwise stable networks and use comparative static analysis of effects of adding/deleting link at or near equilibrium to derive results about economic efficiency and stability of networks. While Carayol and Roux (2003) use comparative statics to examine the stability and efficiency of different types of networks, other authors such as Hummon (2000) use agent-based modeling to study dynamic implications of Jackson-Wolinsky utility function. Agent-based modeling is a technique for studying the behaviour in complex systems: a set of agents are posited to act according to a set of simple pre-defined decision rules, with the interactions of the agents leading to system-wide *emergent behaviour*.

2.3 What can the WWW tell us about networks and innovation?

The WWW can be viewed as a huge distributed innovation network. While the Grid will provide technical infrastructure for collaboration that far exceed the capabilities of the WWW, web analysis may be useful for understanding the process of formation of innovation networks.

Most quantitative analysis of the structure of the WWW has come from the field of applied physics. Applied physics has provided the influential characterisation of the WWW as being scale-free (or following a power law), with a small number of sites receiving the lion' s share of links (Barabasi and Albert, 1999) and visitors (Adamic and Huberman, 2001). This has been explained by Barabasi and Albert (1999) using the influential concept of "preferential attachment" whereby new sites

¹ This paragraph draws from Ackland and O' Neil (2005) where these issues are discussed more fully in the context of the social impact of the Internet.

joining a continuously growing network prefer to link to sites that already have high indegree (the number of links pointing to the site), thus leading to a "rich get richer" phenomenon.

New Economic Geography (see, for e.g., Fujita et al., 1999) aims to explain why economic activity occurs where it does. At its heart is the concept of increasing returns, which broadly refers to the presence of positive feedback loops that reinforce economic success or aggravate economic loss. While the concept of preferential attachment can be seen as a form of increasing returns, the preferential attachment argument lacks a strong behavioural foundation and ignores the influence of human agency, for example business practice or politics, on the distribution of links. Barabasi and Albert (1999) do not explain why it should be that new websites prefer to connect to sites that are already well connected in the network. Another problem is that preferential attachment predicts a positive correlation between age and the indegree of sites (older sites have more opportunity to collect links). Adamic and Huberman (2000) found that this was not the case for the WWW and suggest that the indegree of a site is also dependent on its intrinsic worth to people (or "fitness") and Bianconi and Barabasi (2001a,b) proposed an extension of the Barabasi-Albert model that implements this process.

Web data can be used to identify and study innovation networks - most research organisations have a web presence, and hyperlinks are a way of identifying research connections between different groups. Web data can be used to study the factors that stimulates innovation networks to form. What forms of network structure are likely to emerge from the actions of decentralised and interacting agents and what is the value of these networks? If a power law can exist on a network such as the WWW, then it can also exist in a government-funded digital innovation network, and the consequences for innovation need to be assessed.

However, the process of collecting and analysing data pertaining to distributed innovation networks on the WWW is not straight forward. Social scientists working in this area require access to new methods of data collection and analysis that draw from the information sciences, as well as the empirical social sciences. In particular, there is a need for research software that incorporates web mining, data visualisation, as well as more traditional social science research methods such as statistics and social network analysis. The Virtual Observatory for the Study of Online Networks (VOSON) - a Grid-enabled research environment facilitating innovative and collaborative research into networks on the Internet - will be able to provide data and analytical methods to enable research into innovation networks on the WWW (Ackland, 2005; Ackland et al. 2005).

3 Conclusions

In this paper a preliminary review of research relating to the role of digital networks in promoting collaboration and innovation has been presented. The concept of social capital has been promoted by other authors as a framework for understanding networks and innovation (or providing policy prescriptions for maximising the innovation that is facilitated by digital networks). However, the social capital model has its limitations, in particular it does not adequately account for the social processes of discrimination and hierarchisation that occur within networks. Economic models of network formation may provide an analytical basis for studying innovation on digital networks as they explicitly acknowledge that not all positions in a network are equal in terms of the benefits gained from network participation. The paper also highlighted the insights into networks and innovation that can be gained from studying the structure of the WWW - the largest distributed innovation network ever built.

What is certain is that for Australia' s considerable investment in digital networking infrastructure to lead to a new era of collaboration and innovation, careful attention needs to be paid to network

governance and management issues. What forms of digital network governance are more likely to promote innovation in the distributed innovation networks that are being built? It is clear that the approach to governance will be influenced by the conceptual framework used to understand innovation networks, and more theoretical and empirical research is required to assess the validity of the social capital and the network utility frameworks.

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