Productivity Questions for Public Sector Fast Fibre Network Financiers

Bronwyn HOWELL
New Zealand Institute for the Study of Competition and Regulation;
Victoria University of Wellington, New Zealand.

Arthur GRIMES
Motu Economic and Public Policy Research;
University of Waikato, New Zealand

Abstract: Fast internet access is widely considered to be a productivity-enhancing factor. However, despite promises of substantial gains from its deployment, the evidence from recent empirical studies suggests that the productivity gains may not be as large as originally hypothesised. If substantiated, these findings suggest that current government plans to apply significant sums to bring forward the deployment of fast fibre networks (e.g. in both Australia and New Zealand) may not generate returns to the extent anticipated by their sponsors. Drawing upon the original 'computer productivity paradox' literature, this paper develops a critical questioning framework to assist policy-makers in identifying the salient productivity issues to be addressed when making the decision to apply scarce public resources to faster broadband network deployment. Using multiple literatures, the framework highlights the nuanced and highly complex ways in which broadband network speed may affect productivity, both positively and negatively. Policy-makers need to be satisfied that, on balance, government-funded investments in faster networks will likely generate the anticipated net benefits, given the significant uncertainties that are identified.

Key words: Internet, broadband, productivity, public investment.

Fast internet access is widely considered to be a productivity-enhancing factor (e.g. OECD, 2003; CRANDALL, LEHR & LITAN, 2007). As faster broadband technologies become available (e.g. fibre optic cable), many governments fearing their economies will be left behind in the race towards faster networks have pledged significant sums to build fibre-based connections. In Australia and New Zealand, central government has taken the lead in commissioning nation-wide fibre-to-the-home (FTTH) networks (GRIMES, REN & STEVENS, 2009) whilst in the Netherlands, municipalities have taken the lead (SADOWSKI, NUCCIARELLI & de ROOIJ, 2009).

Advocates for increased government investment in faster broadband networks in advance of private sector willingness to invest invoke new growth (ROMER, 1986) and general purpose technology (GPT) (HELPMAN & TRAJTENBERG, 1996) theories to support claims that substantial spillover benefits will be accrued from investment in faster broadband (OECD, 2009). New growth theory suggests long-run economic growth emanates from spillovers arising from innovation and investment in new technologies. GPT theory attributes additional benefits to a class of technologies such as electricity (and potentially internet connectivity) associated with substantial economy-wide reorganisation of production processes (DAVID, 1990; LIPSEY, CARLAW & BEKAR, 2005).

Whilst promises of technology-driven economic growth are attractive to policy-makers, productivity gains from GPTs often take a very long time to accrue, and it is not always obvious at the time of their initial deployment: (a) which technologies will ultimately exhibit GPT status: (b) when the additional investment will stimulate maximum gains; or (c) at which point of the value chain the resources are best directed. A risk exists that scarce investment will be applied to the wrong technologies (e.g. infrastructure rather than applications), or too soon to gain the best benefits.

As the calls for government investment in fast broadband networks are little different from any other call for the commitment of government funds on the basis that social gains exceed private ones, such calls should be subject to scrutiny of the same nature as would be applied to other infrastructure or technology investment proposals before investment proceeds. Prudent evidence-based policy-making ideally requires all large-budget government spending be supported by studies quantifying the net benefits flowing from such spending. However, rigorous research into the productivity benefits of faster broadband as consumers shift from one type of internet access to another is sparse.

Empirical evidence offered in support of increased government funding is based largely upon extrapolations from extremely limited qualitative and case study analyses rather than quantitative research (QUIANG, ROSSOTTO & KIMURA, 2009). With few exceptions, the assertion that positive productivity gains will be widely available from the deployment of faster broadband infrastructures relative to widespread deployment and use of standard technologies (e.g. ADSL) remains largely untested.

The limited body of rigorous empirical analyses linking productivity returns to increased broadband investment suggests that the relationship is extremely complex and contingent upon the presence or absence of other factors. Whilst there is broad agreement that a positive correlation exists between broadband adoption and elements of economic growth relative to a counterfactual of either no internet access or only dial-up access (e.g. GREENSTEIN & McDEVITT, 2009; CRANDALL *et al.*, 2007), the results are not always straightforward. For example: the direction of causality is not always clear (CRANDALL, *et al.*, 2007); the benefits may be diminishing as broadband penetration rises (LEHR, OSORIO, GILLETT & SIRBU, 2006); and the benefits accrued may be limited to specific user groups (FORMAN, GOLDFARB & GREENSTEIN, 2009). Two recent empirical studies using data accrued from observed patterns of different types of broadband adoption (GRIMES, REN & STEVENS, 2009 (GRS) using New Zealand firm-based data and GREENSTEIN & McDEVITT, 2009 (GM) using economy-wide United States data) suggest that gains accrued from broadband investment may be substantially smaller than those projected from earlier qualitative and case studies. In particular, GRS finds that firms using 'fast' broadband were no more productive than firms using standard-speed broadband, even though firms using standard broadband were on average around 10% more productive than firms using dial-up internet access.

The equivocal empirical findings from these studies suggest some pause for thought before governments embark upon substantial fibre investment strategies predicated upon economy-wide productivity benefits from infrastructure investment alone. As broadband is a subset of ICTs, it cannot be discounted that the empirical findings are signalling the existence of a disjunct between *ex ante* anticipated returns and *ex post* revealed productivity gains; i.e. a 'broadband productivity paradox' reminiscent of the 'computer productivity paradox' [1] in the late 1980s and 1990s (e.g. SOLOW, 1987; TRIPLETT, 1999; DAVID, 1990; HALTIWANGER & JARMIN, 1999; GORDON, 2000; JORGENSON & STIROH, 2000; OLINER & SICHEL, 2000; STIROH, 2002).

In the spirit of the exploratory literature generated from the 'computer productivity paradox', this paper sets out a critical questioning framework to explicate the issues to be considered in assessing the (apparently contradictory) claims of large productivity gains accruing from faster broadband technologies *versus* the evidence of smaller-than-anticipated economic gains in the empirical assessments to date. This critical

[1] Robert Solow's famous observation was "You can see the computer age everywhere but in the productivity statistics".

questioning framework can be used by policy-makers to examine a range of industry- and country-specific factors that may have a bearing upon the gains available from significant government investment in faster broadband networks, as well as inform future empirical research by identifying factors that will need to be taken into account in the design and testing of empirical models.

The framework will focus specifically upon the gains arising from faster broadband given that standard broadband has already been widely deployed. Two hypotheses are formed and then appraised in respect of gains at both the firm- and economy-wide level:

- that there are material productivity gains available from investment in faster broadband networks, but for a variety of reasons, these have not been able to be discerned; and
- that there are few widespread, ubiquitous productivity gains available at the present time from investment in faster broadband networks, given the range of activities for which businesses use broadband connections and the range of applications available.

It is not the authors' intention to draw an overall conclusion of which of the hypotheses is more likely to be valid, but rather to identify and explore the range of issues that should be considered in assessing the likelihood of investment in faster broadband networks delivering the required objectives.

■ Productivity gains are real but not detected

As a starting point, it is apposite to consider the possibility that there are real and material productivity gains available from deployment of faster broadband networks, but that existing studies have not detected them. In respect of the 'computer productivity paradox', Triplett articulated two scenarios that can be applied directly to faster broadband:

- "you don't see computers in the productivity statistics yet, but wait a bit and you will"; and
- "whether or not you see computers everywhere, some of what they do is not counted".

Its too early to detect productivity gains

As fast broadband is still in its early days of deployment, and broadband is a derived demand dependent upon the development and uptake of applications that make use of fast broadband's capacities (BAILEY, 1997), it is possible that to date, studies have been unable to discern productivity gains because the applications that will take advantage of the benefits of fast broadband either have not yet been developed, or have been developed, but have not yet become widely deployed. Plausible explanations include:

- information asymmetries mean potential users do not know of either their existence or potential benefits or else take time to become aware of them and incorporate them into their production processes (JOVANOVIC & ROB, 1989; GREENWOOD & JOVANOVIC, 1998);
- it takes time for potential users to learn how to use the new applications, meaning the productivity gains take time to be yielded (ATKESON & KEHOE, 1997 & 2001; GOOLSBEE & KLENOW, 1999); or
- there are other complementary investments required to enable firms to take advantage of the benefits of faster broadband, (HELPMAN & TRAJTENBERG, 1996; JOVANOVIC & STOLYAROV, 2000).

Substantial evidence exists that productivity gains from the deployment of Information and Communications Technologies (ICTs) generally require substantial complementary investments (such as in human capital and the reorganisation of production processes to take advantage of computer capabilities) (BRYNJOLFSSON, HITT & YANG, 2002). The gains became discernable only substantially after the time of investment, in respect of both the ICTs and the complements (BRYNJOLFSSON & HITT, 2003). Moreover, it has become apparent that the gains did not emerge evenly across all sectors of the economy, emerging first in the ICT manufacturing sectors, then general manufacturing, and only more recently in other computer-using sectors (OLINER & SICHEL, 2008).

As broadband technologies are a subset of ICTs, and (faster) broadband is a recent phenomenon, it is plausible that similar factors hamper the accrual of returns to broadband investment. The GRS finding of firm-based productivity gains from broadband investment relative to dial-up, but not from faster broadband could be a manifestation. However, the plausibility of this argument relies upon the presumption that the gains from faster broadband are yielded by applications that would not operate at all on standard broadband or their performance would be so degraded that potential productivity gains from the new applications were severely constrained. It has been argued that standard broadband did offer substantial advantages over dial-up because in addition to the speed benefits, which enabled the use of richer graphics than previously available, other factors made the technology more desirable (e.g. 'always on', cost savings from not having to purchase a second phone line) (OECD, 2003).

If faster broadband did engender new applications taking advantage of its specific characteristics, it could be expected that they would emerge first in countries where faster networks were first deployed (e.g. Japan, Korea, the Netherlands), and that applications used would differ in these countries relative to other countries. With the exception of more extensive use of gaming and real-time streaming of entertainment content, few discernably different speed-dependent applications appear to have emerged (QIANG *et al.*, 2009). In the Netherlands, where substantial sums have been devoted to developing health and education applications specifically to take advantage of faster networks, the dominant applications driving residential purchase of fast networks remain entertainment-based and new application development has been disappointing (SADOWSKI *et al.*, 2009). Whilst it cannot be discounted that new applications will emerge, equally it cannot be discounted that this current disappointing application development may continue.

Methodological issues: are we counting the benefits correctly?

TRIPLETT (1999) observed that limited research scope and poor data measurement might be partly responsible for the ICT productivity paradox. It is plausible that such limitations may affect the findings of the GM and GRS studies. In particular, as GRS measures productivity gains at the firm level, it is possible that real productivity benefits are generated by a firm's technology adoption, but that they are accrued at some other point in the value chain which is external to the firms in the study (CHOI & WHINSTON, 2000). For example, consumers benefit from reduced search and transaction costs from most online transactions, even if the firm's costs do not alter substantially as multiple forms of interaction must now be offered. Likewise, firm-based studies do not necessarily capture benefits arising from technology-enabled structural change within an industry (BRYNJOLFSSON & HITT, 2003). However, these changes if present should be discernable in industry and economy-wide studies such as GM, which find the gains less than originally anticipated.

These observations suggest that the research design of studies intended to measure the effects of faster broadband on aggregate (as opposed to individual firm) productivity growth, must ensure that:

- all relevant gains are captured within its scope;
- application use and broadband connection type are considered at all parts of the value chain for all relevant parties; and
- distinctions are made between applications, connection speed and the presence or absence of complementary investments, in order to assess the extent to which the gains can be attributed to the capabilities of the transmission mechanism, the application capabilities or other factors (BRYNJOLFSSON & HITT, 2003) .

Only if these factors have been reasonably addressed can a reliable conclusion be drawn at the aggregate level of either the extent of the attribution or the direction of causality to investment in increased broadband speed.

■ Productivity gains from faster broadband deployment are limited

This section draws its inspiration from TRIPLETT's (1999) postulation that "you see computers everywhere but in the productivity statistics because computers are not as productive as you think" and GORDON's (2000) sceptical demand-side focused view of the productivity potential of ICTs compared to other 'great inventions' of the past'. The extended analogy is that 'some may wish to see faster broadband everywhere, and it may have been portrayed as having great productivity benefits, but will it really be as productive as its promoters have claimed it will be?' A wide-ranging demand-side view is warranted as, to date, most champions of government investment in faster broadband networks are supply-side interests (e.g. content, equipment and network providers) and small subsets of users (e.g. early adopters), whose current and aspired future network demands on the network may not be characteristic of the wider demand-side body. It is questionable whether the valuations these champions have placed on the benefits from adopting faster broadband can be reliably used in the assessment of benefits arising from ubiquitous deployment of faster networks. It is noted that studies from which this paper draws on base their findings on populations (GM) and representative samples (GRS), meaning the potential for biased valuations skewing results has been minimised. They may therefore be more legitimate indicators of user valuations of the benefits of faster broadband networks amongst the wider population than network inventors and promoters.

Gordon's and Triplett's assessments of the plausibility that ICTs were not as productive as their protagonists initially thought leads to five questions which are subsequently addressed:

- are the returns to investment in broadband speed diminishing?
- are observed gains simply one-off adjustments or evidence of the creation of sustainable growth engines?
- how important is the broadband network in the production value chain?
- do broadband networks affect productivity by altering the composition of firms within the economy – i.e. altering the balance between existing (potential) users of faster broadband (the intensive margin) and new producers who would be reliant on faster broadband entering the market (the extensive margin)?
- are externalities created that detract from the benefits accrued?

Are returns to broadband speed diminishing?

The seminal message of Gordon's analysis of the computer productivity paradox is his assessment of the effects of the declining real cost of computer power and the pervasiveness of decreasing returns. He argues that unlike other "great inventions" of the past, for ICTs, the costs of production have fallen faster than the gains in utility from the development of new computing characteristics, resulting in decreasing returns. Gordon argues that for the other 'great inventions', new applications tended to lead to higher production costs, but as the welfare gains generated were even greater than these additional costs, diffusion occurred regardless of the higher prices charged for the goods.

Gordon illustrates his argument by comparing the marginal gains in word processing utility from the first invention of the memory typewriter, via the development of successive versions of WordPerfect and Word For Windows. The marginal gain in utility from each new variant was successively smaller, even though each required significantly greater amounts of computing resource in order to generate those benefits. Only the rapidly decreasing cost of producing the additional computing resource rendered it feasible for end users to purchase the increasingly more complex new computers required to operate the new applications, given the increasingly smaller marginal utility gains from each iteration of software development. He notes that the applications used most often by firms in 2000 were in large part the same ones deployed in the earlier days of computing – word processing, spreadsheets, financial management and stock control.

In a similar vein, it might be argued that the greatest gains to users in the information transportation component of the ICT industry have already been garnered from the creation and deployment of dial-up internet access and the earlier variants of broadband, simply because they made available the benefits of applications – such as email and web browsing - that were previously infeasible and for which substitutes were extremely costly. Whilst subsequent developments have increased the richness of the graphics employed (and increased the capacity required of both the transportation infrastructure and the computing resource at each end), the basic applications remain functionally similar.

For example, Facebook and Twitter are richer extensions of email, enabling instant written communication between individuals. Using Gordon's logic, the marginal benefit to their users compared to simple email pales in comparison to the marginal gain experienced by the first email users, whose messages were transmitted in a matter of minutes rather than days for a standard post letter. And whilst there is arguably benefit to be had from the increasing richness of graphic content and menu choices offered, Triplett observes that "making choices is costly, so I do not want to be forced continually to choose from a wider menu".

Faster broadband increases the value of applications through time saved in making the actual transmission[2] of information, assessed at the user's marginal valuation of time. VARIAN (2001) finds that there are very large variations in individuals' (and by extension, firms') valuation of time, depending upon whether it is paid or leisure time, the nature of other tasks the individual is engaged in and the time criticality of the applications used. When empirically tested, individuals' marginal willingness to pay for faster internet speeds is generally very low. HORRIGAN (2008) confirms that only one third of United States broadband consumers are prepared to pay a premium for faster broadband, and that on average, the premium paid is only 20% more than for standard speed connections.

2 'Transmission' as it is used here refers to both the sending and receiving (i.e. transportation) of the information.

To assess the demand-side effect of investment in faster broadband in relation to applications, the marginal benefits to users of transmitting the same information at a faster speed (say 100Mbps) than a slower one (say, 10 Mbps) must be considered, relative to the higher cost of the faster service. If the majority of internet use is confined to existing applications, the individual time savings from the faster connections are likely extremely small. The time benefits from transferring existing applications onto faster networks will make the substitution feasible only if the user's valuation of time is sufficiently high enough to offset the additional cost. Thus, only new applications or those that are critically dependent upon the faster speeds or where timeliness is highly valued will justify the additional expense to users of substituting from existing networks. Most of these applications remain yet to be developed. The marginal benefits from the vast number of existing applications currently being used will likely be small (and decreasing) with increasing in transmission speed.

Unlike the case of computers and ICTs in general, where real costs decreased inexorably over time, the costs of increasing transmission speeds are, in the medium term at least, likely to be increasing as a function of the qualities delivered, as new networks with high fixed and sunk costs must be constructed to carry traffic at the faster speeds. This contrasts with the history of broadband network costs to date, where faster speeds have been made possible by making incremental improvements to existing networks, the costs of which had been largely sunk (the pattern that occurred with ADSL and some cable networks). Given the likely scenario of increasing real network costs, without the development of a substantial number of highly-valued, widely-used new applications that cannot be satisfactorily delivered on legacy networks (which still have remaining capacity for upgrading), there may be insufficient benefits available to offset the higher costs of faster network deployment in the foreseeable future.

One-off returns or sustainable growth?

LEHR *et al.,* (2006) report decreasing productivity returns as broadband penetration increases. This result typifies the diffusion of a technology where the early adopters are the highest-valuing, and the later adopters ('laggards') are the lower-valuing ones. If new applications and increasing use of existing applications were generating increasingly higher returns for existing users, and the same applications were drawing new users to the technology in order to accrue the benefits available, then productivity returns would be closer to constant, or even increasing (BAILEY, 1997). As standard broadband exhibits decreasing returns, and fast broadband users are most likely to be existing broadband users upgrading to faster broadband, then as faster broadband becomes more widely deployed, it would also be likely that similar decreasing returns would be observed on the faster networks.

That decreasing returns is the norm for standard broadband suggests that for many firms and individuals, broadband-based applications represent opportunities to make one-off investments in a small number of applications, rather than offering a means of generating increasing firm-based returns on an ongoing basis. Many non-economic commentaries appear to assume that, as the goods that characterise the information age themselves individually exhibit increasing returns (QUAH, 2003; ARROW, 1999, 1962), the technologies that aid their production might behave similarly. However, most of the technologies and applications supporting the creation of information goods are essentially rival, excludable goods, albeit exhibiting some network effects and economies of scale (SHAPIRO & VARIAN, 1999). [3] This distinction is material for assessing the productivity potential of networks and applications.

Productivity growth models (e.g. ROMER, 1986; DAVID, 1990) require that gains as a consequence of an investment in one time period lead to even higher gains occurring in subsequent periods. If adoption of an application (e.g. MSWord) generates a gain of $10 over the expected $100 without it, the gain is 10%. But in the next period, to maintain 10% growth, total income must be $121, not $110. Unless the application enables a final good to be made that itself exhibits increasing returns (e.g. a novel, which may sell multiple copies at very low reproduction cost) (SHAPIRO & VARIAN, 1999), the second period of growth reverts to 0%. Even if the final good is one with potential increasing returns, the gains will be recorded in productivity statistics only insofar as individuals are prepared to pay a positive price for it. If technology enables its creation, but the market does not value it, then the end result is a reduction in aggregate measured productivity as the (usually sunk – e.g. time) inputs used to create it have been lost to other more productive uses in the economy.

Whilst faster broadband networks may enable movement of the inputs and outputs of the production processes used for information goods, the vast majority of goods produced and traded in the economy remain tangible,

---

3 To paraphrase Triplett, 'Word has not made me any smarter'.

standard goods exhibiting constant or decreasing returns rather than information goods with increasing returns capabilities. If new applications are adopted only to support the ongoing creation of standard goods, then the productivity gains from adoption will be one-off rather than sustainable (i.e. increasing returns). Unless faster networks can, of themselves, engender a change in the mix of products made in an economy or accelerate the diffusion of knowledge embedded in the goods already produced (as per new growth theory), then the decreasing returns observed by LEHR, *et al.* (2006) in respect of standard broadband networks are not only likely, but will possibly set in earlier on faster broadband than was observed on standard broadband.

Broadband in the production chain

Triplett contended that "you don't see computers everywhere in a meaningful economic sense (because) computers and information processing equipment are a relatively small share of the capital stock". Whilst the ICT share of capital stock has increased markedly since Triplett's observation, it is nonetheless true that the 'communication' portion of both the ICT stock and ICT's share of the total capital stock still remains small. Furthermore, broadband is essentially a transportation mechanism, albeit one that transports information. For most production processes, the transportation of input materials and carriage of finished goods of all kinds – both physical and informational – comprises only a small proportion of production costs.

Where the vast majority of inputs and finished products are physical, then the proportion of those costs that can be attributed to broadband-based transportation may be small. Thus, a small change in the costs (or a small increase in the benefits arising from) of a factor that is only a small proportion of the production process may render a very small effect on productivity– and arguably one too small to be discerned in the productivity statistics. By analogy, a faster vehicle may save time on journeys, but if very few journeys are made or the average journey is very short, the savings may be too small to be significant – and too small to justify the additional cost of the vehicle. However, the savings may be very much more material for a long-haul delivery firm.

Furthermore, drawing on production control literature, faster information transmission may not make much difference to overall productivity if the resources that process the transported information prior to its dispatch or subsequent to its arrival are scarce. Both Triplett and Gordon identify that for ICTs in general, it is more often than not the human component of the production process that is the bottleneck. Moreover, human-mediated processes are the ones that have, to date, proved most resistant to computerisation (and hence digital transmission). In the absence of applications addressing the human bottlenecks, it is not clear that the gains from faster broadband deployment will necessarily be as large as has been anticipated. Prudent policy-making should therefore take into account the rate of application development in key areas when considering network investment.

Fast broadband offers functionality in respect of both the volume of data that can be transmitted and the time taken to transmit it. Whilst large-capacity networks can enable real-time transmission of data, this requires building networks capable of meeting maximum simultaneous demand expectations at peak times. However, it does not necessarily follow that all data transmissions are time-critical.

With normal transportation infrastructures, choices can be made to transport non-time-critical cargoes at low-demand times, in order to relieve congestion and make better utilisation of existing assets (for example, air and sea freight). Such reasoning applies also to broadband-based information transportation. The question turns to identifying the truly scarce (or costly) resource. Just-In-Time inventory management became commonplace because for inventory storage, space (amongst other costs) was more expensive than physical transportation, making the time of delivery (and hence real-time delivery) a critical factor in the total cost function. By contrast, computer costs have made digital storage extremely cheap. Whilst both transmission and storage costs have decreased over time, transmission is still (relatively) dearer than storage [4]. It therefore raises the question of when and where it is optimal to store data, trading off both storage and transmission costs, and how this affects the optimal time to invest in new, costly transmission networks.

Peak and off-peak charging is common in most network industries, enabling users to make efficiency-enhancing choices about the value to them of the timeliness of network use compared to the cost of caching (i.e.

[4] Indeed, if they were not, then there is no economic justification for the currently-observed extensive use of web proxy servers.

on a computer hard drive or firm server rather than at a distant host). The benefit for network operators is that with time-sensitive pricing and low-cost local storage, existing infrastructure can be more efficiently utilised, pushing back the time at which more capacious networks must be built relative to the 'simultaneous demand' model. Policy-makers must therefore consider whether calls for investment in faster networks at the present time are predicated upon particular 'world-views' of idealised future network use that differ substantially from current usage patterns rather than economic considerations at both the network operator and user levels.

Intensive *vs* extensive margins

Analysis of the effects of new technologies, such as faster broadband, on firm performance must take account both of the impacts on existing firms (the intensive margin) and on the potential for changing the economy's firm structure structure by facilitating the entrance of new firms reliant on the new technology (the extensive margin). For instance, consider a set of "digitally-intensive" firms that: (a) make a global (or regional) location decision that embodies sunk costs, and (b) are current or potential users of substantial digital traffic; thus faster and more reliable broadband facilities reduce their overall cost structures. If a foreign country invests in a comprehensive fibre network, some digitally-intensive firms that may otherwise have located in the domestic country will instead locate in the competing country. High-skilled employees who would otherwise have been employed in these firms may migrate to the competing country to obtain employment.

Even the location decisions of firms that are currently not digitally-intensive may be affected by a fibre investment. In the presence of high sunk costs, a firm makes its location decision with respect to a long time horizon. Over this horizon its own need for fast broadband services may change in unknown ways as other technologies and demand patterns change. In the presence of this uncertainty, the firm may take out an option over future technologies by choosing to locate in a country that has a proven record of investing in fast broadband technologies. Thus even though its current productivity may not be altered by the presence or absence of a fibre network, it may still choose to locate in an economy with a proven fibre network. The extensive margin may therefore play an influential role in the location decisions of firms with current or even uncertain prospective demand for fast broadband services. This factor may be particularly germane for firms that must choose between two neighbouring countries servicing a broader regional economy (e.g. between Australia and New Zealand, or within Europe).

Given these considerations, there is the prospect of a fibre-war (analogous to a trade-war) in which fibre investments are used as a type of firm location subsidy. Modern trade theory shows that in the presence of imperfect competition and fixed costs, a subsidy may in some circumstances be an optimal response to other countries' policy choices. Applying this insight to fibre investments, if a competing country decides to invest heavily in fibre the optimal response may be for the domestic country also to invest so as to maintain level pegging; and if the competing country chooses not to invest, the optimal response may still be to invest in order to 'steal a march' on the competing country. Thus investment in fibre may be the Nash equilibrium outcome. However, in assessing whether this is the case, a clear understanding of the benefits is required and the assessed benefits must be weighed against the (potentially very large) costs.

Externalities: negative? (un)expected?

Most government spending proposals are prepared by stakeholders with strong motivations for a project to proceed, and may therefore overstate the benefits and understate the costs. Even without this systemic benefit-cost inflation, as a consequence of bounded rationality it is unlikely that all of the possible consequences (both positive and negative) associated with a project will be foreseen. The unforeseen consequences may be either positive or negative. Whilst the negative consequences are costly, and the unforeseen ones unavoidable, prudent decision-makers should make a critical assessment of the proposal and try to anticipate which largely foreseeable costs and externalities have been omitted.

In respect of ICT, Gordon asserts that four possibly unanticipated effects have resulted in less-than-impressive productivity returns on ICT investment. These apply equally to broadband networks and warrant policy consideration when assessing the validity of calls for government investment. It is imperative that the assessment is made at an economy-wide and not just at sectoral or firm levels. First, investments made to protect market share or taking customers, profits and capital gains away from other companies is a zero-sum game. Redistributions of this nature are not wealth-creating. Second, much internet content is not reflecting new economic activity, but simply translates existing activity into an electronic medium. Whilst one-off gains are created, these are marginal gains on old activities, not the creation of new sources of wealth. Third, new technologies may lead to productivity-reducing duplication of existing processes rather than substitution. Whilst convenience may have value for some, it may lead to higher costs for those who know what they want, and have to pass through additional menus to access what was previously directly acquired. Fourth, productivity on the job may be impaired by the growing use of business computers with continuous web access for personal consumption purposes.

■ Conclusion

This paper lays out a critical framework for systematically evaluating whether (government-funded) deployment of faster broadband networks will lead to large and sustainable productivity gains. Whilst many arguments have been posited, it is not the purpose of this paper to suggest what weight should be placed on all or any of the contentions. Rather, the purpose of the framework is to highlight the complexity of the problem facing government policy-makers and decision-makers when assessing the costs and benefits of applying government funding to such projects. The ways in which ICTs in general, and broadband networks in particular, contribute to economic performance, are many, varied, highly nuanced and many of the factors interact with each other in ways that make it extremely difficult to predict the likely outcome. Ultimately, it is the role of policy- and decision-makers to place their own weights on each of these issues in the context of their own projects.

There will always be risks associated with investing in a project where there are so many unknown factors. Modern risk management theory suggests that when more or better information will materially reduce the risks, the optimal strategy is often to invest in more information acquisition or wait for more information to be revealed before committing. One exception, that may be germane to investments in faster broadband, is where opportunities would be lost (e.g. in a competitive international investment situation) by delaying investment. These factors are no less relevant for public sector investors than private sector ones. The questioning framework of this paper can assist in the design of further information gathering, as it highlights some of the questions that existing research – both empirical and qualitative - has itself raised.

References

ARROW, K. (1999): "Information and the organisation of industry", Chapter 1 in Chichilnisky, Graciela (Ed.), *Markets, information and uncertainty: essays in economic theory in honour of Kenneth J. Arrow*, Cambridge, UK: Cambridge University Press.

ARROW, Kenneth J. (1962): "The economic implications of learning by doing", *Review of Economic Studies,* 29(3):155-73.

ATKESON, A. & KEHOE, P. (2001): "The transition to a New Economy after the Second Industrial Revolutio", National Bureau of Economic Research Working Paper 8676. http://www.nber.org/papers/w8676.

ATKESON, A. & KEHOE, P. (1997): "Industry evolution and transition: a neoclassical benchmark", National Bureau of Economic Research Working Paper 6005. http://www.nber.org/papers/w6005.

BRYNJOLFSSON, E. & HITT, L. (2003): "Computing productivity: firm-level evidence", *Review of Economics and Statistics* 85(4): 793-808.

BRYNJOLFSSON, E., HITT, L. & YANG, S. (2002): "Intangible assets: computers and organizational capital", *Brookings Papers on Economic Activity,* no. 1: 137-81.

CHOI, S-Y. & WHINSTON, A. (2000): *The internet economy: technology and practice*, Austin, Texas: SmartEcon Publishing.

CRANDALL, R., LEHR, W. & LITAN, R. (2007): "The effects of broadband deployment on output and employment: a cross-sectional analysis of U. S. data", Issues in *Economic Policy* no. 6, The Brookings Institute, July.

David, P. (1990): "The dynamo and the computer: an historical perspective on the modern productivity paradox", *American Economic Review*, 80(2): 355-61.

FORMAN, C., GOLDFARB, A. & GREENSTEIN, S. (2009): "The internet and local wages: convergence or divergence?", NBER Working Paper Series w14750. http://www.nber.org/papers/w14750.

GOOLSBEE, A., & KLENOW, P. (1999): "Evidence on learning and network externalities in the diffusion of home computers", National Bureau of Economic Research Working Paper 7329. http://www.nber.org/papers/w7329.

GORDON, R. (2000): "Does the 'New Economy' measure up to the 'Great Inventions of the Past'?", *Journal of Economic Perspectives* 14(4): 49-74.

GREENSTEIN, S., & MCDEVITT, R. (2009): "The broadband bonus: accounting for broadband internet's impact on U.S. GDP", NBER Working Paper Series w14758. http://www.nber.org/papers/w14758.

GREENWOOD, Jeremy & Boyan JOVANOVIC (1998): "Accounting for growth", National Bureau of Economic Research Working Paper 6647. http://www.nber.org/papers/w6647.

GRIMES, A., REN, C. & STEVENS, P. (2009): "The need for speed: impacts of internet connectivity on firm productivity", Motu Economic and Public Policy Research Working Paper 09-15. http://motu-www.motu.org.nz/wpapers/09_15.pdf.

HALTIWANGER, J. & JARMIN, R. (1999): *Measuring the Digital Economy*, Center for Economic Studies U.S. Bureau of the Census and University of Maryland.

HELPMAN, E., & TRAJTENBERG, M. (1996): "Diffusion of General Purpose Technologies", National Bureau of Economic Research Working Paper 5773. http://www.nber.org/papers/w5773.

HORRIGAN, J. (2008): *Home broadband adoption 2008,* Pew Internet and American Life Project.

JORGENSON, D., & STIROH, K. (2000): "Raising the speed limit: U.S. economic growth in the Information Age", Harvard University Working Paper.

JOVANOVIC, B. & ROB, R. (1989): "The growth and diffusion of knowledge", *Review of Economic Studies,* 56:569-582.

JOVANOVIC, B., & STOLYAROV, D. (2000): "Optimal adoption of complementary technologies", *The American Economic Review* 90(1): 15-29.

LEHR, W., OSORIO, C., GILLETT, S. & SIRBU, M. (2006): "Measuring broadband's economic impact", Presented at the 33rd Research Conference on Communication, Information, and Internet Policy (TPRC), Arlington, Virginia, September 23-25, 2005. Revised January 17, 2006.

LIPSEY, R., CARLAW, K. & BEKAR, C. (2005): *Economic transformations: General Purpose Technologies and long-term economic growth*, Oxford: Oxford University Press.

OECD:

- (2009): Working Party on Communication Infrastructures and Services Policy. *Network developments in support of innovation and user needs.* Paris: OECD.
- (2003): Information and Communications Technologies, *ICT and economic growth: evidence from the OECD countries*. Paris: OECD.

OLINER, S. & SICHEL, D. (2008): "Explaining a productive decade", *Journal of Policy Modelling* 30(4): 633-73.

OLINER, S. & SICHEL, D. (2000): *The Resurgence of Growth in the late 1990s: Is Information Technology the Story?* Mimeo, Federal Reserve Board.

QIANG, C., ROSSOTTO, C. & KIMURA, K. (2009): "Economic impacts of broadband", Chapter 3 in World Bank, 35-50, *Information and Communications for Development 2009: Extending reach and Increasing Impact*, Washington, DC: World Bank. http://allafrica.com/sustainable/resources/view/00011823.pdf.

QUAH, D. (2002): *Technology dissemination and economic growth: some lessons for the New Economy*. Centre for Economic Policy Research. http://www.cepr.org.

ROMER, P. (1986): "Increasing returns and long-run growth", *Journal of Political Economy* 94(5).

SADOWSKI, B., NUCCIARELLI, A. & de ROOIJ, M. (2009): Providing incentives for private investment in municipal broadband networks: evidence from the Netherlands, *Telecommunications Policy* 33: 582-95.

SHAPIRO, C., & VARIAN, H. (1999): *Information rules: a strategic guide to the network economy*, Boston, Massachusetts: Harvard Business School Press.

STIROH, Kevin (2002): "Are ICT spillovers driving the New Economy?", *Review of Income and Wealth*, 48(1):33-57.

SOLOW, R. (1987): "We'd better watch out", *New York Times Book Review* (July 12): 36.

TRIPLETT, J. (1999): "The Solow productivity paradox: what do computers do to productivity?", *Canadian Journal of Economics* 32(2): 309-34.

VARIAN, H. (2002): "The demand for bandwidth: evidence from the INDEX project", Chapter 3 in CRANDALL, R. & ALLEMAN, J. (Eds), *Broadband: should we regulate high-speed internet access?*, Washington, DC: AEI-Brookings Joint Center for Regulatory Studies pp. 39-56.