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Superfast Broadband: Is It Really Worth a Subsidy?

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The views expressed are those of the authors alone.

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Introduction

Around the world, governments are investing billions to support the roll-out of fiber optic cables to communities and homes, enabling widespread access to very high speed broadband. In 2008 and 2009 alone, ten countries made commitments to spend a total of over $16 billion on 'next generation' networks.[1] Many appear persuaded that widespread access to superfast connectivity (50 Mbps and above, enabled by FTTH) is essential to ensure global competitiveness. The Australian government is investing US$28bn out of a total cost of US$41bn on "next-generation-access," on the basis that it is "central to Australia's economic future".[2] Chairman Genachowski of the US Federal Communications Commission lists first amongst the purposes of the National Broadband Plan – which promises 100 million households connected at 100 Mbps amongst other things – that it will deliver "U.S. global leadership in high-speed Internet to create jobs and spur economic growth".[3] The European Commission has relaxed its state aid rules to further its targets that 30 Mbps broadband should be available to all citizens, and 50% should be using more than 100 Mbps by 2020.[4]

Many governments see investment in fiber to the home (FTTH) as a stimulus tool to support recovery in the short run and productivity enhancements over the longer term. They hope it will provide the foundation for the improved delivery of services including energy, education and health. They suggest FTTH networks are key to attracting and expanding new Internet industries and converged communications systems including interactive TV. And they fear falling behind in terms of global competitiveness if their fiber networks don't grow faster and wider.

All else equal, faster is better – surely. But faster technologies don't always triumph; think of passenger hovercraft, maglev trains, and suspersonic airliners. These technologies didn't fail because they weren't superior, but because the demand wasn't there, or was insufficient to justify cost. Concorde (if it hadn't retired) would still be the fastest passenger aircraft today, having first flown in 1969. At the time it was being developed, supersonic passenger flight was expected to become ubiquitous. It turned out that the incremental benefits of speed to most

[1] Friedrich et al., 2009

[2] Australian PM Kevin Rudd went as far to suggest that the proposed network would be "the single largest nation-building infrastructure project in Australia's history" that would be a force for "turbo-charging Australia's economic future." (Friedrich et al., 2009).

[3] Rudd et. al., 2010, NBNCo, 2010b, Genachowski, 2010

[4] European Commission 2010

customers was not worth the extra cost. This paper suggests fiber to the home may risk being the next Concorde.

Evidence regarding previous 'ICT revolutions' suggests that we are already facing a declining economic return to ever greater bandwidth, with the impact of broadband on economic performance and educational outcomes very much up for debate. The costs of fiber rollout to the home look particularly high. Unlike previous investments to enable internet access (dial-up and DSL) it involves a major rebuild, not simply an upgrade at the edges. And the benefits in terms of new applications provided by superfast over standard broadband look limited on close examination. In particular, the argument for a market failure based around network effects or the need to provide access to vital services is weak when applied to superfast broadband. All of this suggests that governments should think very hard before spending billions of taxpayer dollars in a race to the top of the superfast broadband league table.

The focus of this paper is on the costs and benefits of using fiber to deliver home broadband speeds in excess of 50 Mbps, as an upgrade from basic broadband services such as digital subscriber lines that utilize copper wires to deliver download speeds of up to 24 Mbps. (in practice both technologies usually achieve lower bandwidth – in the US typical download rates are 16.6 Mbps and 2.9 Mbps for FTTH and ADSL respectively).[5] We do not consider: the trade-offs in business districts (a largely separate investment decision, though one often elided with investment in fiber to the home by FTTH advocates); nor the extension of the network to areas that currently have no broadband at all; nor wireless data opportunities; nor demand-side measures to encourage those currently unconnected to get online. We believe these may pay high societal returns in some cases, but they are not part of our scope. (That said, we believe that governments with money to spend on supporting broadband should seriously consider whether supporting fiber roll-out gives the best available return, given these alternatives.)

In this paper we will attack the contention that fiber generates considerable externalities and therefore is deserving of government subsidy. However, we should be clear what we are *not* saying. We don't believe:

- "There is no commercial case for fiber". In a number of circumstances, such as high population density, or competitive threat from cable operators or for greenfield sites, there may well be a commercial case for fiber.

[5] RVA, 2010

- “Fiber does not bring externalities”. Clearly there are some externalities from high speed broadband, just as there are from many other products from bicycle helmets to gym memberships, which don’t get government subsidy. Our contention is that the externalities have been overstated, and that therefore the case for subsidy has not been well made.
- “We will never need fiber to the home”. We believe it is probable that in the long term the great majority of households in the developed world will want fiber, perhaps to support widespread 3D-TV. However we doubt whether the need for fiber is so urgent that governments must spend considerable sums to accelerate roll-out.
- “We don’t need fiber in the middle mile.” As basic broadband fixed and wireless use picks up, we will need more and more capacity in the middle mile. And in some cases, there might even be a role for government intervention.
- “Don’t use fibre to extend coverage to areas where copper doesn’t provide basic broadband.” In many markets universal broadband access is a reasonable policy goal, and existing copper networks are often not able to deliver it, particularly to customers far from an exchange. Subsidising fiber (at least to the node) may be an appropriate solution if it is cost- and performance-competitive with wireless solutions.

To take one concrete example of what we are not saying: much of the US federal stimulus resources used for broadband rollout involved fiber in the middle mile and to anchor institutions. We are not arguing in this paper that those resources were wasted.

The next section examines what past ‘ICT revolutions’ – and in particular past forecasts for the impact of basic broadband – might suggest for the overall economic impact of superfast broadband. The paper then turns to what we know about the costs of ubiquitous fiber access, and what we can say about the incremental benefits of such access in terms of applications. We briefly discuss the potential of alternate technologies to deliver faster broadband at considerably lower cost (if somewhat slower speeds) than FTTH before looking at the logic behind concerns with broadband rankings. The final section outlines our conclusions.

The economic impact of past ICT revolutions

Given the enthusiasm around the economic impact of superfast broadband, it may be worth remembering we've been here before, and not long ago. It is eleven years since Alan Greeenspan argued the Internet had "altered the structure of the way the American economy works." It is ten years since Thomas Friedman suggested that, thanks to the Internet, we were in a period of radical change "possibly more sweeping and complex than any period since 1776-1789", and ten years since the G8 declared that IT was "a vital engine of growth for the world economy". [6]

Fiber advocates continue to cite productivity benefits of the ICT revolution as one of the reasons to invest in next generation networks. In 2009, then Australian Prime Minister Kevin Rudd, in announcing the government's substantial fiber investment, said: "It has also been estimated that innovation from information and communications technology is the single biggest driver of business productivity. It drives 78 per cent of productivity gains in service businesses and 85 per cent in manufacturing". [7] This section reviews the evidence regarding the impact of IT investments in general and broadband rollout in particular to examine if FTTH advocates are correct in suggesting that past IT investments have had such a dramatic impact that ubiquitous fiber is a low-risk, high-return next step.

Sadly, Greenspan and Friedman's forecasts about the economic impact of the Internet appear optimistic in retrospect, and the last decade has hardly been the rosiest for US or global economic performance. Indeed, US GDP per capita growth in this decade was the lowest of any since 1960. Around the world, IT–producing industries *have* seen considerable productivity growth over the last twenty years. But the evidence of considerable spillovers from economy-wide IT investment is limited. Investments in IT in the US appear to have had an economic impact much as one would expect from investments in roads, power plants or factories. And during the course of the last decade, the impact of IT on overall productivity has been falling, not rising, according to Kevin Stiroh of the New York Federal Reserve. [8] In Europe, most studies can't find any impact of IT use on productivity. Even a recent paper that is more optimistic suggests only that "the overall slow-down in productivity growth that happened in Europe after 1995 would have been even more dramatic" had it not been for IT use. [9]

[6] Quotes from Kenny, 2006

[7] Rudd, 2009

[8] Kenny, 2006, Stiroh, 2008

[9] Dahl, Kongsted and Sorensen, 2010

Meanwhile, Prime Minister Rudd's estimates of 78% of service and 85% of manufacturing productivity gains in Australia stemming from ICT appear to have been based on two papers from that country's Department of Communications, Information Technology and the Arts. These said that 59-78% and 65-85% of service and manufacturing productivity growth respectively was due to technological factors. [10] The research was looking at *all* technological factors, however, not just ICT. Thus the figures cited include the benefits of everything from biotechnology to the rise of containerized transport. It is also worth noting that what was an upper bound in the research has become a mid-point in the Prime Minister's speech. Finally, the research covered the period 1985-2001 for manufacturing and 1984-2002 for services, when the Internet was in its infancy and broadband rollout was minimal.

With regard to widespread household access to broadband (of greater immediate relevance to the fiber to the home debate), in 2002, FCC Commissioner Michael Copps cited a report by Robert Crandall and Charles Jackson written for Verizon in 2001 which suggested universal broadband access could add half a trillion dollars to the U.S. economy every year. [11] Copps concluded that broadband "for all our citizens may well spell the difference between continued stagnation and economic revitalization". [12] Sadly, the underlying research turned out to be over-optimistic. Subsequent developments suggest that Crandall and Jackson's estimates of consumer willingness to pay for broadband appeared to be too high by a factor of three.

Researchers Greenstein and McDevitt re-examined Crandall and Jackson's forecast using data for the period up to 2006. In 2006, broadband accounted for about $28 billion in Internet service provider revenue. Between $20 and $22 billion of that was associated with household use. And about a half of *that*, between $8-$11 billion, was estimated to be 'additional' rather than 'replacement' – revenues that service providers would not have received if they had continued only providing narrowband services.[13] Added to the additional revenues, Greenstein and McDevitt estimate a consumer surplus for broadband users – the difference between what they would have paid for such services and the amount they actually had to pay. This amounts to $5-$7 billion.

At maximum, this analysis suggests that broadband to households in the US left Internet services accounting for an additional $11 billion of GDP,

[10] Revesez, Anderssen and Boldeman, 2004, Revesez, Anderssen and Boldeman, 2005

[11] Crandall and Jackson, 2001

[12] Copps, 2002

[13] Greenstein and McDevitt, 2009

and increased consumer surplus by $7 billion.[14] The sum – $18 billion – is some way short of Copps' $500bn figure, and is equivalent to a little over 0.1% of America's GDP. The actual impact of household broadband access on the *size* of total GDP would be smaller than that. This at a time when around 50 million American households – or about 44% of all households – already had broadband.[15]

To fully measure the aggregate economic impact of broadband across regions and countries requires capturing the business impact and externalities missed by micro studies like Greenstein and McDevitt's. Macroeconomic studies that attempt this complete calculation of broadband's impact confront all of the usual and considerable challenges faced by growth analyses.[16]. Studies of broadband impact face the added disadvantage of a very small time frame over which to evaluate change.

Still, Korea, as the country that led the broadband rankings for a number of years, might provide a cautionary tale. The government set targets that large office and apartment buildings would be connected to fiber by 1997, and by 2005, more than 80 percent of households would have access to fast connections of 20mbps or more.[17]. In the eleven years before 1997, the country grew at an average rate of 7.6 percent per capita per year. In the eleven years from 1997-2008, it grew at an average 3.8 percent. [18] Many factors played into the growth slowdown, but this evidence does suggest broadband may play a comparatively minor positive role in economic performance.[19]

Despite the difficulties of cross-country growth analysis and the apparently disappointing experience of South Korea, researchers have followed the pattern laid down during previous generations of ICT development, estimating dramatic economic impacts of broadband rollout across countries. And as with earlier studies, broadband analyses suffer considerably with the problem of separating out the impact of

[14] There are some very high estimates of the consumer surplus derived from basic Internet access in the United States –ranging into the thousands of dollars per household (Goolsbee and Klenow, 2006). The Greenstein and McDevitt, 2009 numbers suggest the per household consumer surplus is closer to the tens of dollars for broadband in the mid 2000s.

[15] Total households from US Census Bureau, 2006. Suggesting that the consumers who gained the biggest surplus from connecting are already connected is a Pew poll from 2009 which suggests only 17 percent of dial-up Internet subscribers and non-users suggest the reason they didn't have broadband was availability compared to the 50 percent who said it was because it wasn't relevant to their lives.

[16] Rodríguez 2006

[17] Borland and Kanellos, 2004

[18] data from World Bank, 2010

[19] Perhaps the massive increase in online gaming, facilitated by the broadband revolution, played a role in the slowdown, however – the South Korean government estimates that as many as two million of its citizens are addicted to online gaming (McCurry, 2009)

economic growth on ICT rollout from that of ICT rollout on economic growth.

For example, Booz & Co. suggest that a ten percent higher broadband penetration rate in 2002 is associated with a 1.5 percent per year faster rate of labor productivity growth over the next five years and that countries atop the OECD ranking in terms of broadband rollout grew 2.2% more rapidly per year between 2002 and 2007 than countries at the bottom of the ranking.[20]. However, the Booz report does not control for other factors that are associated with more rapid productivity growth – changes in employment, the role of convergence, overall investment and so on. Nor are their results robust to a broader sample. Across the world as a whole, there is a weak *negative* relationship between fixed broadband rollout in 2001 and GDP growth 2001-2006 –a result that holds using 2003 rollout and 2003-2008 growth.[21]

Qiang (2008) suggests that a ten percent increase in broadband rollout is associated with a 1.4 percentage point increase in developing country GDP growth rates over time. (The figure for high income economies was 1.2 percentage point increase). This is based on the average rate of economic growth between 1980-2006 and the average level of broadband penetration 1980-2006.

The analysis faces the challenge that there wasn't any broadband in 1980. Even at the end of 1999, US broadband penetration was 1%.[22] Broadband can't have had a significant growth impact between 1980 and 2000. Given that, the growth benefit (if any) of broadband networks must derive from the period between 2000-2006. However, if the benefit derives from this short timeframe, the annual growth impact of a ten percent increase in penetration for high income countries suggested by the analysis in Qiang (2008) jumps from 1.2% to 4.6%. Given that average US GDP growth was only 3.2% in this period, this seems a strong claim. An alternate explanation for Qiang's results is that the countries which got a lot richer between 1980 and the new millennium were able to roll out broadband a lot faster after 2000 – precisely because they were

[20] Friedrich et al., 2009

[21] Data from World Bank ICT database, 129 countries in 2001 sample, 134 countries in 2003 sample. 2001 average, std. dev. GDP growth 4.8%, 3.1%, average, std. dev fixed broadband 4.5%, 10.3%, equation: *GDP growth = -0.05*(fixed broadband) +5.1*. 2003 average, std. dev. GDP growth 5.2%, 2.6%, average, Std. Dev fixed broadband 15.6%, 19.4%, equation: *GDP growth = -0.03*(fixed broadband) +5.6*. McKinsey, meanwhile, simply declares a "consensus" from "numerous studies" that "a 10 percent increase in broadband's household penetration delivers a boost to a country's GDP that ranges from 0.1 percent to 1.4 percent" (Buttkereit, 2009).

[22] FCC, 2000

richer, and so could afford more of it.[23] In other words, GDP growth is a cause of higher broadband penetration, not vice-versa. (We should point out that Qiang does note data weaknesses and the preliminary nature of her results in her paper).

Looking at state-level US experience, Robert Crandall, William Lehr and Robert Litan of the Brookings Institution used data on broadband subscriptions per capita, employment and output between 2003-5 to explore a relationship. They found a correlation between subscriptions and employment that was not robust and no statistically significant relationship at all with output.[24] Jed Kolko of the Public Policy Institute of California finds that an increase in the number of broadband providers in the area covered by a zip code between 1999 and 2006 is associated with more rapid employment growth in that zip code, but a negative relationship with employed residents as a percentage of the working age population and median household income. He could also find no relationship between broadband competition and telecommuting or operating a business from home.[25]

George Ford and Thomas Koutsky look at the performance of Lake County, Florida, which rolled out a municipal fiber broadband network to businesses and government buildings in 2001. They examine the relative monthly gross sales growth performance of the county between 2002 and 2004 against a set of comparator counties in Florida selected on the grounds that they had seen similar seasonal and average growth patterns to Lake County between 1998 and 2000. They argue that Lake County experienced "approximately 100% greater growth in economic activity relative to comparable Florida counties" in the two and a half years after rolling out fiber.

There are some issues with this approach. It is not completely clear why the authors look at gross sales rather than a more traditional measure of economic performance such as median household income or income per capita, or why they use the monthly growth rather than progress over the

[23] Qiang et al., 2009. See also Czernich, Falck, Kretschmer and Woessmann (2009), who attempt an interesting approach to explain growth in OECD countries 1996-2007 using as an instrument the output from a model which predicts broadband diffusion using fixed and cable subscriptions at period start. Fixed and cable subscriptions themselves would be poor instruments because they are (both) plausibly direct growth determinants (and) or correlated with an omitted growth determinant in the study. In fact, however, the results appear to be driven by the diffusion model itself that is identical across countries --in that it predicts a growth rate of broadband that is slow in the early and late 2000s. This does, of course, track the actual pattern of growth across OECD countries, but is better accounted for by the global slowdown in 2000-2002 and the financial crisis in 2008.

[24] Crandall, Lehr and Litan, 2007. It is worth noting in addition that this study looks at changes in total employment and output, not output per capita and employment rates, which are of greater interest if we are looking for an impact of broadband on incomes and quality of life.

[25] Kolko, 2010

entire period under review, or why they settle on this particular period to examine, or why they use this particular method to select comparators, or why they don't factor in anything else that might have impacted growth rates. Changing just a few of the parameters or using a more standard approach can significantly alter results. For example, if you use data from the US Census Bureau and look at median household income across Lake County and the same comparator counties used by Ford and Koutsky for the period 1999-2007, the Lake Country economic miracle pretty much disappears. Out of the eleven counties that Ford and Koutsky examine, Lake County comes in at number four. Compared to a total average growth of median household income in comparator counties over those eight years of 24 percent, Lake County manages 26 percent.[26]

Gimes, Ren and Stevens (2009) study the impact of slow and faster broadband access of firm productivity in New Zealand. The good news for broadband proponents is that the study suggests that firms with broadband connectivity do see ten percent higher labor productivity than similar firms without broadband connectivity. The bad news for fiber proponents is that the study finds no difference in the productivity differential between firms connected with ADSL and (usually faster) cable connections. At the same time, it is worth noting that the evidence presented suffers as a compelling as a case for believing in a significant economic benefit even to basic broadband access. As the study did not control for overall firm investment or worker quality, the increased labor productivity associated with broadband use may suggest nothing more than that companies which invest more in any productive capital –trucks, machines, ICT—should expect to see higher labor productivity (and a more educated, expensive labor force) as a result.

With regard to the impact of government subsidy programs in particular, Ivan Kandilov and Mitch Renkow of North Carolina State University evaluate the impact of the US Department of Agriculture's Broadband Loan Program, which provided subsidized loans to small telecoms companies to rollout broadband access in rural areas. Over 1,000 zip codes were beneficiaries of broadband loans over the 2000-2007 period, worth a total of around $1.8 billion. While a pilot exercise did appear to be associated with some positive outcomes, the authors conclude that there is no evidence that the full program (and resulting rollout) had any impact on employment, payroll or business establishment in the beneficiary communities.[27] Finally, as a stimulus tool, based on input-

[26] And this slightly better result is not at all robust, with two percent equal to one fifth of a standard deviation in household income growth across the comparator countries. Data from US Census Bureau 2010

[27] Kandilov and Renkow, 2010

output analysis, broadband rollout is a relatively inefficient job-creation investment compared to road construction.[28]

The lack of strong evidence in favor of a considerable impact of broadband is repeated when it comes to particular applications, the best studied of which is education. Once again, the broadband to schools movement builds on a history of decidedly mixed evidence regarding the impact of computers and the Internet on classroom performance. Across countries, a number of studies conclude that there is no evidence that the availability of computers at school or home has any positive impact on student scores in internationally comparable tests. And intensive computer use is actually negatively related to outcomes.[29]

Looking at basic Internet connectivity, an examination of the e-rate subsidy program in California which provided subsidies to wire up schools concluded that there were 66 percent more Internet-connected classrooms than there would have been absent the program in 2000. But it also concluded that "the increase in Internet connections has had no measurable impact on any measure of student achievement".[30] (This study holds particular relevance to the debate over broadband support in the US at the moment, given it was co-authored by the current Chair of the Council of Economic Advisors to the President).

Rodrigo Belo and colleagues from Carnegie Mellon University looked at the impact of broadband on education in particular, finding that more intensive use of broadband in schools in Portugal is associated with lower test scores – although the effect does wear off after time.[31] The drop in achievement is particularly noticeable amongst boys, and this might not be surprising given that the five most popular activities for boys on the Internet in Portugal are email, chat, MySpace and YouTube, music and games (girls do slightly better – searching for scientific and general information reaches their top five). Similarly, a recent study of the impact of broadband rollout to households across North Carolina between 2000 and 2005 found that student test scores dropped significantly as service providers appeared in their neighborhood.[32]

Not only school kids spend most of their time online using broadband connectivity to engage in activities unlikely to increase test scores or economic performance. According to 2002 data on Internet usage in the US, moving from narrowband to broadband increases overall subscriber

[28] Katz and Suter, 2009

[29] Hanushek and Woessmann, 2010

[30] Goolsbee and Guryan, 2006

[31] Belo, Ferreira and Telang, 2010

[32] Vigdor and Ladd, 2010

Internet consumption by an average of about three quarters of an hour per day. It added a little less than nine minutes a month to the amount spent on education, health and government sites combined – or a little under one percent of the additional surfing time.[33] Again, those who adopted broadband between 2004 and 2006 were significantly more likely to say they were downloading music, purchasing goods online and visiting adult entertainment sites after adoption than before. These same upgraders were also somewhat more likely to say they were using social networking and researching medical conditions. But they were no more likely to say they were visiting government websites. For all the benefits of online music, shopping and social networking, most of them don't easily translate into capital accumulation or total factor productivity that lies behind economic growth. Given that, perhaps it should come as less of a surprise that there is limited evidence of a 'broadband bonus' in the macroeconomic statistics.

Whatever the doubts about the scale of the macroeconomic impact of previous Internet 'revolutions,' and in particular the impact of widespread household access to broadband, it is worth noting both that broadband to business may well have had an impact on economic efficiency and also that at least a behavioral impact of broadband to the home is clearly present as well. Equipment vendors such as Cisco, Juniper, Huawei and Alcatel and internet backbone providers such as Level 3 are big firms. YouTube was purchased for $1.6 billion in 2006. People are spending a huge amount of time at home online, and they are doing a lot of things that are hard or impossible to do with a dial-up connection – let alone with no connection at all. There is a widespread sense, reflected in the rapid takeup by consumers wherever it is available, that basic broadband is no longer a luxury.

At the same time, however popular they are, it is hard to get from You Tube, Flikr and Skype to sustained increases in GDP growth. You Tube may be worth more than $1.6 billion, for example, but that amounts to 0.01 percent of US GDP. And, looking at consumer surplus, it appears that there is a declining return to additional bandwidth in terms of new or better applications that excite consumers. In particular, there appears to be a declining return to additional bandwidth in terms of applications of the type that might usually attract government support.

It is worth noting that, where fiber rollout has occurred to date, the evidence is of more intensive Internet use for gaming and entertainment content but few new discernibly different speed-dependent applications.[34] Fiber advocates make the opposite case about future

[33] Hitt and Tambe, 2007

[34] Howell and Grimes, 2010

investments –that FTTH in particular will allow the rollout of high-value applications which cannot be delivered in any other way, suggesting additional bandwidth carries considerable returns. We will examine the strength of that case in later sections.

The costs of fiber

Whether the returns to additional bandwidth decline or grow, it is unarguable that the marginal cost of additional bandwidth delivered by fiber is considerable.

Fiber is the third upgrade of the telecoms network to support the Internet[35]. The first was dial-up. This was comparatively inexpensive – a 56Kbps modem cost $100 in 1997, in dial-up's heyday.[36] The per-line share of the ISP's modem bank was a further $90.[37] For this sub-$200 upgrade, society got email (still the most frequently used application), functional e-commerce (Amazon's IPO was that year, when it already had $150m of revenue), User-Generated Content (Geocities was the top site in 1997), online news (bbc.co.uk launched that year, and many other media sites had been operating for some time) and social networking (SixDegrees, the first such site launched in 1997).[38] The benefit of this 'network upgrade' surely massively outweighed the cost.

The next upgrade was a Digital Subscriber Line, requiring a DSL modem in the home and a Digital Subscriber Line Access Multiplexer in the telephone exchange. In 2005 (the year broadband overtook dial-up in the US) the cost of a DSL modem was $100, and the-per port cost of the exchange equipment was $50,[39] for a total upgrade cost of $150. This enabled always-on, reliable internet and brought us YouTube, Flickr, Skype, Hulu and iPlayer, cloud computing and much more. Again the benefit of the upgrade almost certainly outweighed the cost anywhere that already had copper wires rolled out. (The Data Over Cable Service Interface Specification, or DOCSIS, upgrade to cable networks provided even greater benefits at similar cost).

However, the third upgrade --to fiber-- is different. Rather than swapping out equipment at either end of an existing access network, fiber requires building an entirely new network. This will make the upgrade substantially more expensive. Verizon's costs for rolling out a fiber-to-the-home network in the US are in the region of $2,750 per home connected – in other words, roughly eighteen times more expensive the DSL upgrade.[40]

[35] In addition to the DOCSIS upgrade to cable networks to support broadband.

[36] Moskowitz, 1997

[37] Lieda, 1998, with an estimate based on ten subscribers per port on the modem bank

[38] This and subsequent estimates exclude backbone costs.

[39] Keith, 2006

[40] Fiber costs based on Verizon's projected 2010 costs per home passed and per home connected, and assuming 33% penetration. See Thonis 2008. Note that fiber costs per connected household vary substantially based on geography, architecture (for instance fiber-to-the-home vs fiber-to-the-curb), penetration rates and so on.

Furthermore, while the focus of the debate over the costs (and benefits) of fiber is frequently on the edge network (from the home to the exchange), this may not be the only cost involved in ensuring the delivery of superfast connectivity. Frequently congestion in the 'middle mile' (inward from the exchange) can degrade performance. As noted above, the average US FTTH customer achieves download rates of 16.6 Mbps, even though their access link is capable of far more. This is presumably because of network latency and congestion elsewhere. The UK experienced a practical example of middle mile congestion with the launch of the iPlayer (the BBC's TV over-the-internet service). This caused a noticeable increase in traffic for the UK's ISPs, even in the launch phase when usage was still relatively low.[41] In turn, this required ISPs to increase their spend with BT for 'backhaul' (the link between the exchange and the ISPs' own networks).

Again, on the subscriber end, Bauer et al. have noted, "significant bottlenecks arise in home networks, end users' computers, and server side systems and networks".[42] For instance, "[t]he maximum rate of an 802.11b WiFi router (still a very common wireless router) is 11mbps. If wireless signal quality is an issue, the 802.11b router will drop back to 5.5mbps, 2mbps, and then 1 mbps. Newer wireless routers (e.g. 802.11g/n) have higher maximum speeds (e.g. 54 mbps) but will similarly adapt the link speed to improve the signal quality." Upgrading such a household's broadband to fiber will only have its full value if it also spends to upgrade its wireless router.

Put another way, if consumers are to get the full benefit of the bandwidth speeds made possible by upgrading to fiber to the home (or other forms of high speed access network) there are hidden costs which involve the need to upgrade other parts of the system as well. These costs need to be factored into the full benefit-cost analysis for fiber. Given the cost jump from broadband to FTTH is already far greater than those for previous evolutions of the network even excluding these expenditures, the incremental benefits of fiber need to be significant indeed to justify the investment.

[41] Aughton, 2008

[42] Bauer et al., 2010

Assessing the benefits of fiber

We will discuss below some of the specific types of benefit posited by fiber advocates, but in general fiber brings faster download speeds, much faster upload speeds, and greater consistency. To believe that the investment in fiber is worthwhile, one has to believe there will be considerable benefits from applications that are dependent on these capabilities of fiber –applications that basic broadband cannot deliver. This is because basic broadband is already available to the great majority of the population via the existing copper network or through wireless (at least in wealthy countries). DSL coverage across the OECD is 88%, and coverage is more than 95% in 18 of 30 OECD countries.[43]

It is problematic, then, that we will see much of the existing literature supporting FTTH uses the benefits of basic broadband applications to justify fiber rollout. Equally, the benefits of higher speed for businesses are sometimes used to make the case for fiber-to-the-home despite the fact that even if there is a case for rolling out fiber to businesses, this does not require building fiber out to residential neighborhoods.

For example, in 2009 Ovum published results of research undertaken in Swedish communities with fiber, which did find a number of benefits to health, education and other public services.[44] Joeri Van Bogaert, president of the lobby group Fiber To The Home Council Europe, commented, "This study provides even further depth to the business case for FTTH".[45] However, the study said in regard to fiber to the home that "to date, there is very limited evidence of any distinct social or economic benefit on any significant scale from fiber provision to individuals' *homes*. Today, there are virtually no services that can *only* be delivered over fiber based broadband" (emphasis in original).

With a focus on claims for applications that require superfast broadband, we now examine some of the potential benefits of fiber to the home in more detail.

[43] OECD 2010; figures generally for end 2008

[44] Ovum, 2009

[45] Lightwave, 2009 and Ovum, 2009

Fiber and the electricity industry

Some commentators have argued that fiber will enable 'smart grids' that allow electricity consumption to be smoothed, reducing peak demand and in turn the need for new power plants.[46] This argument is based on the premise that a smart grid will require significant upload speeds, beyond the capacity of basic broadband. However, the connectivity needs of smart meters are in fact far less than the capabilities of fiber. Typically, connectivity is provided either wirelessly (mesh networks based on ZigBee, for instance) or using broadband-over-powerlines.

The clearest evidence that fiber is not necessary for smart grids is that dozens of such grids have already been installed around the world, well in advance of any fiber roll-out. In Italy, under the Telegestore project, 30 million smart meters, requiring bandwidth of 2.4 Kbps, were installed between 2001 and 2005, primarily using existing copper or mobile networks for communication.[47] This smart grid has enabled peak shaving, energy efficiency and CO_2 reduction, all without requiring a single fiber connection.

Those who would base the case for fiber in part on the benefits to the electricity industry need to show how a high speed broadband network would deliver a better result than narrowband smartgrids such as Telegestore or basic broadband solutions. This seems a challenging case to make, given the inherently low data requirements for basic telemetry about electricity use. At least some of the belief that smart grids require fiber appears to based on a misreading of sources. Enck and Reynolds cite a figure of 100 Kbps needed for smart grids, but this is the requirement for a system of "several thousand meters", not a per household figure.[48] They also state "Some newer [smart grid] proposals have data requirements at 1 Mbit/s", but the source they provide refers to this as the theoretical upper limit of a communications protocol for smart grids, not a per household requirement.[49]

[46] Enck and Reynolds, 2009, Ezell et al, 2009

[47] Rogai, 2006 and Rogai, 2007

[48] Enck and Reynolds' source is p7 of Flynn 2007

[49] Mason et al., 2009

Fiber and healthcare

The FTTH Council Europe claim that "fiber-to-the-home empowers a new realm of services, content and applications" of which the first-mentioned is "remote surgery".[50] It is not completely clear what they have in mind – in-home surgery seems a somewhat distant dream.

The medical benefits discussed by FTTH advocates are in actuality those that would derive from higher speed connections for hospitals and medical centers. Enck and Reynolds' OECD report advocating fiber discusses the benefits of remote radiology, dermatology and cardiology, but (as the authors acknowledge) these benefits are primarily about linking medical practitioners at different sites, not about reaching the patient at home, and thus they are not relevant to the case for FTTH.[51]

The same OECD report discusses remote consultation and the positive results of a University of Minnesota trial of tele-homecare for the elderly. This is clearly potentially more relevant to the case for FTTH. However, what the Minnesota study found was that remote consultation *in addition* to home visits increased patient satisfaction (though it had no impact on mortality). While patient satisfaction is clearly valuable, if health care savings are to be delivered through FTTH (the premise of the OECD report), tele-homecare will have to substantially *substitute for* home visits, not be an addition.

And once again, it is also important to consider the incremental benefits of fiber. The Minnesota study dates from 2004, and does not appear to have used high speed connections. Similarly, a 2008 Australian study found that videophones could substitute for nurse home-visits in the area of medication management.[52] However, the study noted "Home installation of videophones has recently become possible and affordable in Australia for health care delivery due to the widespread availability of broadband connectivity, compression technology enabling good quality video over domestic grade broadband [and other factors]." In other words, it was perfectly possible to get the medical benefits in question using basic broadband, without any need for fiber.[53]

Another example of a failure to consider the *incremental* benefits of fiber is CTC Consulting's report for the City of Seattle on the direct and indirect

[50] see 0:50 of FTTH Council Europe, 2010

[51] Enck and Reynolds, 2009

[52] Wade, Izzo & Hamlyn, 2008

[53] While broadband speed was not a problem, the trial did have other technical challenges. In one case the patient's videophone "was reconfigured by a technologically semi-literate relative."

benefits of a municipal FTTP network in that city.[54] This estimates annual 'stakeholder savings' of $960m, of which the largest component is healthcare savings of $602m. This medical saving is based on a 30% reduction in the cost of treatment for chronic illness, a figure sourced to research by economist Robert Litan.[55] However Litan in turn sources this figure to a *McKinsey Quarterly* article that said: "disease-management programs combining a smart mix of technology and operational excellence would let insurers reap net savings of 10 to 30 percent for specific patient groups".[56] Putting aside the point that a 30% maximum in the McKinsey analysis has become a base case forecast in the CTC report, the key issue is that the McKinsey article dates to 2001. It is very unlikely that this estimate was predicated on widespread availability of highspeed fiber. Even if the 30% saving required widespread broadband (not self evident from the article), it was basic broadband at most. Thus the estimate of healthcare stakeholder savings of $602m for Seattle from fiber looks to be unfounded.

The CTC report supports its use of the Litan 30% figure using another report on a successful Veterans Administration trial of remote monitoring.[57] CTC suggest:

> "Based on a Veterans Administration study that reported a 63 percent reduction in hospital admissions and 40 percent cut in emergency room visits resulting from its remote home monitoring system, remote monitoring facilitated through broadband availability might have avoided 33,754 of Seattle residents' inpatient admissions during 2009." [58]

The VA study was conducted in 2000-2002. It did not use broadband. It used dial-up access and instamatic cameras. Once again, estimate of the benefits of dial up or basic broadband are being used to justify an investment in fiber.

Given the relatively limited roll-out of fiber to the home, it is not surprising that there are few (or any) trials of the benefits for telemedicine over FTTH. What is more puzzling is that there has been so little effort to suggest even in the abstract what valuable telemedicine applications might critically depend on fiber to the home and be

[54] CTC, 2009

[55] Litan, 2005

[56] Adomeit et al., 2001

[57] Meyer et al., 2002. Note that (as with the McKinsey study) CTC refer to this paper indirectly. They cite Neuberger, 2007which in turn refers to the VA study

[58] CTC, 2009, p. 61

impossible on DSL, particularly since remote health is frequently cited as one of the justifications for fiber roll out.

It is also worth noting that there are likely to be considerable barriers to the use of fiber to the home to reduce health expenditures that are unconnected with network costs. On the consumer side, for example, remote home health care is primarily for the elderly. However, this is one of the demographics least likely to be online. Even in the US, only 31% of those aged over 65 have home broadband, reflecting the fact that the elderly as a group are some of the least comfortable with the new technologies of the Internet. [59] If the elderly are to use applications like fiber-based home health care, it is not only the costs of otherwise unwanted connectivity –perhaps $650 for a house on a street already passed by fiber—that need to be taken into account.[60] It is also the costs of familiarization, training and considerable ongoing technical support.

On the supply side, when assessing the net benefits of fiber to healthcare, it is of course essential to take into account the required changes within the healthcare system itself. Even if fiber were available, a massive investment and change in behavior would be required of healthcare providers. In this regard, it is worth noting that healthcare has struggled badly with transforming IT investments. For example, even today only 20% of doctors and 10% of hospitals in the US use electronic medical records.[61] This despite the fact that savings from moving to electronic records were estimated at $142-$371bn five years ago.[62] Similarly, the UK's digital medical record project ('NPfIT') was started in 2002 and cost £12.7bn but is now "close to imploding".[63] Thus to believe that FTTH would enable a successful transformation of medical practices and IT systems is, to say the least, assuming a great deal.

[59] Pew Internet,2010

[60] Thonis, 2008

[61] Adamy, 2010

[62] Hillestad et al, 2005

[63] Bowers, 2010

Fiber and education

Sadly, education is another area where fibre advocates have misquoted their sources. The UK Government's publication "Britain's Superfast Broadband Future" claims:

> "Superfast broadband can help improve the quality and delivery of public services to people in more rural and remote areas, helping them become more skilled, productive and earn a higher wage. Australia is an excellent illustrative example of where this is actually happening. According to DCITA, higher speed broadband has led to the creation of virtual classrooms which help to deliver a better quality of service and enables teachers to engage with students as a group through video conferencing." [64]

However, the report cited discusses a 2002 trial, [65] comparing the use of satellite (low speed) broadband to two-way radio. It is absolutely not an "excellent illustrative example" of how superfast broadband can help. Moreover, the report goes on to sound a note of caution about the incremental benefits of even basic broadband over dial-up:

> "It is likely … that in a world without broadband, e-learning tools of some form would have emerged to take advantage of the bandwidth available. Just how functional these might have been compared to the tools that have actually emerged is a matter of conjecture, but it would be wrong to attribute to broadband all the benefits of e-learning aids."

As we have already seen, the evidence for benefits from broadband rollout on educational outcomes is mixed at best, but even if broadband access in schools, and in particular higher speeds, were known to be positive for educational attainment, this does not justify a wide-spread fiber to the home program. Once again, it is not necessary to wire up entire residential neighborhoods to provide high speeds to schools. Indeed, in the UK in 2009, the average secondary school already had internet access at 19.2 Mbps, suggesting that they had found ways to secure high speed access (for instance, via a business connection) even without a widespread fiber roll-out.[66] Again, even if new infrastructure is required, it can be built in a targeted manner. For instance, in New Zealand approximately NZ$200m is being earmarked specifically for improving schools' access. Korea has completed a 'FTTS' program,

[64] BIS & DCMS 2010

[65] Collins et al, 2007

[66] NERP, 2009

connecting all 11,414 schools with at least 10 Mbps, with one third of funding coming from the Ministry of Education.[67]

Within the home, as with other claimed benefits of fiber, it is important to consider the *incremental* benefits of high-speed broadband to educational outcomes. For instance, university lectures can be delivered over fiber to students at home, but equally they can be delivered over copper. As of March 2010, the Youtube EDU library had over 65,000 videos and 350 full courses.[68] YouTube had over 300 partner universities (including Cambridge, Yale, Stanford, MIT, Chicago and The Indian Institutes of Technology) and courses in 7 different languages across 10 countries. Several of the lectures have had over a million views, presumably not all by people on fiber. It is possible to imagine certain lectures that will be dependent on very high resolution video, but the vast majority of educational material can be delivered perfectly well over copper.

[67] Lee, 2010

[68] Youtube, 2010

Fiber and transportation

FTTH advocates argue that fiber will enable much greater teleworking, with associated benefits for the traffic congestion and the environment. For example, in 2008 the FTTH Council of Europe commissioned a study from PricewaterhouseCoopers subsidiary Ecobilan which suggested that fiber's effect on teleworking rates would result in a 330 kg eq. CO_2 reduction per user.[69]

However, key to this outcome appears to be an assumption that (as a result of the availability of fiber) "10% of European working population telework 3 full days per week." The basis for this assumption was the fact that some Nordic countries already had 17% of the population teleworking. In turn, the source for this 17% figure was a report from 2000.[70] However, if 17% penetration for teleworking was possible in some countries in 2000, when fiber penetration had not begun, it is not clear why fiber is necessary to bring the rest of Europe to a 10% figure.

The same report on the Nordic experience listed some of the barriers to teleworking. These were data security concerns, doubts about return on investment, misgivings about supervision of remote workers, demands of day-to-day business, implementation issues, inertia and cultural distance. Bandwidth was not mentioned as a concern.[71]

There is some more recent data from a US survey that does suggest households upgrading to fiber telework more – one extra day per month.[72] However, it isn't clear whether this result is dependent on fiber, or whether those upgrading to cable broadband would have given a similar answer. It is also possible that those quickest to switch to fiber are precisely those keenest on home working (and are switching for that reason), and once fiber spreads into the mass market this apparent impact will diminish.

What is clear is that teleworking has been increasing rapidly even without fiber. For instance, between 2000 and 2005, the portion of teleworkers in the EU15 grew from 5.3% to 8.4%, and the figure is presumably higher today.[73] Between 2004 and 2008 (again before fiber), the portion of UK

[69] Ecobilan, 2008. The Ecobilan study appears to have ignored the offsetting negative CO_2 consequences of teleworking, caused by the need to heat or cool homes that would otherwise have been unoccupied during the day

[70] empirica, 2000

[71] empirica, 2000

[72] RVA, 2010

[73] Third and Fourth European Working Conditions Survey

employers offering teleworking rose from 11% to 46%.[74] In the US, the number of people telecommuting at least 1 day per month doubled from 17m to 34m between 2001 and 2008. In each case these substantial shifts pre-dated the material deployment of fiber. Conversely, in Korea, which *has* had fiber for some time, the current telecommuting rate is less than 1%.[75]

Thus while fiber may contribute to teleworking, it is neither necessary nor sufficient, and great caution must be taking in ascribing teleworking's benefits to FTTH.

[74] CBI, 2008

[75] Youkyung, 2010

Fiber as a TV platform

In almost every prediction of the applications that will fill the fiber access network, TV looms large. It is also an important part of operators' business models. Verizon in the US, Hong Kong Broadband Network and Iliad in France all place great emphasis on their TV offers.

As we have seen, DSL is already more than sufficient for moderate quality video. That is clear because there's already massive use of the Internet for video downloads today – Nielsen[76] reports that 136m users in the US watched 75 video streams each in June 2010, when there were less than 10m households with fiber in the US.[77] The success of Hulu in the US and iPlayer in the UK demonstrate that millions of consumers are quite happy to consume their TV over current networks. This suggests that while fiber might improve the viewing experience, consumers are perfectly willing to watch video online without it. Again, in the UK, DSL typically delivers around 4 Mbps.[78] Standard definition TV in the UK is typically broadcast over the air at around 2 Mbps.[79] This doesn't mean that we can move all TV online – the backbone capacity isn't there – but it does mean that the replacing the copper access network with fiber will not make any great difference to our ability to watch standard definition TV over the internet.

High-definition TV and the ability to stream multiple programs to the household at once might add to the case for fiber, but even here there are limits. Firstly, the bandwidth of the human eye is only 9 Mbps.[80] It is certainly possible to deliver more than this to the home, but there are likely to be diminishing returns. The argument for up to 100 Mbps (as opposed to the 40 Mbps that could be delivered once fiber reaches the cabinet), is uncertain.

Secondly, there are many other mechanisms for delivering TV (even HD TV) to the home, including terrestrial broadcast, satellite broadcast, cable, DVDs and so on. On-demand HD is often cited as a key advantage of fiber, but cable is capable of this too, and cable coverage is high in many countries: 96% of households in the US and 97% in Canada for instance.[81] Moreover, as DSL2+ is rolled out, more and more households will be able to receive HD TV over ADSL. Value Partners (in a report for

[76] Nielsen, 2010

[77] Primarily 3.8m FiOS customers plus 2.6m AR&T U-verse customers. Verizon, 2010 and AT&T, 2010

[78] Ofcom, 2009

[79] See www.dttmuxes.co.uk

[80] Koch et al, 2006

[81] OECD, 2010

the BBC) estimate that 74% of households will be able to stream HD TV by 2015, for example, many over copper-based broadband.[82]

Broadcast methods are a far cheaper way to distribute popular content (HD or SD), and increasing availability of digital video recorders (in 44% of households in the UK, for instance) means that this broadcast content can easily be time-shifted.[83] It is also worth noting here that demand for time-shifting appears to be exaggerated – it accounts for only 12% of total viewing in households with digital video recorders. Similarly, demand for video on demand (VOD) may be limited. In the UK, the market for VOD delivered to the TV set is actually shrinking – down from £114m in 2008 to £108m in 2009.[84] Moderate desire for on-demand and time-shifted TV, alongside other tools to deliver these services does not imply that there is *no* incremental benefit to fiber, merely that it is limited.

Third, the need for *simultaneous* video streams is often cited as the justification for higher speeds. For instance, in making the case for fiber, Motorola describes a household simultaneously using two HD TV streams, two SD TV streams, and a picture-in-picture stream, all while uploading a large number of photos.[85] This is a very busy home. Given average household size in Europe and the US is 2.4 and 2.6 people respectively, it implies considerable multitasking.[86] Even this scenario only requires 30 Mbps, far below FTTH's capability, and well within the capacity of Fibre-to-the-cabinet (FTTC) or cable.

In practice, households generally don't watch different TV programs simultaneously. In the UK only 62% of homes have more than one TV set, and even in these households, only 59% (or 38% of all households) actually watch TV on more than one set in a typical week. The great majority of viewing in these households still happens on one set at time (according to BARB data). Just 7% of viewing in these households (or 3% of total UK viewing) takes place on a second set whilst the first set is also in use. Finally, simultaneous streaming capacity is only relevant for the remaining 3% if the two streams in question must come over the Internet. If one of the two programmes being watched is arriving by

[82] Value Partners, 2009

[83] Personal Video Recorders, such as Tivo in the US and Sky+ in the UK. Also known as Digital Video Recorder

[84] Film Council, 2010. Note that this contraction of TV VOD, was offset by a slightly larger growth in VOD to the PC, which grew from £6m to £16m. However, given that this usage will almost certainly have had a lower picture quality than TV VOD, the migration of the market to the PC suggests that HD picture quality (as enabled by fibre) may not be of paramount importance to consumers

[85] Motorola, 2007. Corning justifies the need for 36 Mbps with an even busier family, using two HD TV streams, two SD TV streams, one video-on-demand stream, two phone lines, teleworking, online gaming and internet access simultaneously. See Kunigonis, 2005. NBNCo paints a similar picture in NBNCo, 2010b

[86] Iacovou, 2010, US Census Bureau 2007

satellite, or by terrestrial broadcast, or by cable, the ability of fiber to have parallel streams is again irrelevant, since the Internet will only be used for one.

This means that the simultaneity benefit delivered by fiber is irrelevant for more than 97% of TV viewing in the UK. In some households, people will be watching video on their computers while the TV is on in another room --but not in all that many. For example, while the BBC's iPlayer has been hugely successful, with 1m TV users per day in June 2010, [87] iPlayer consumption over the internet represented just 1.7% of the BBC's viewing that month. [88] This suggests limited appetite for planned, rather than passive (scheduled) TV consumption.

To be clear, we are not saying that TV is irrelevant to the business case for fiber. Fiber operators will undoubtedly benefit from being able to offer triple play services (TV, internet, and telephony services together). What we are saying is that the benefits to society (and indeed individual consumers) from TV delivery over fiber are likely to be underwhelming as a justification for rollout.

[87] Maynard 2010

[88] Authors' analysis of BARB and BBC data. 30 mins of viewing per iPlayer stream assumed.

Fiber as a 'future-proof' solution

One of the arguments made for FTTH is that it is 'future-proof' - that is, it is a technology that is not going to be made obsolete (unlike, say, FTTC, which could be made obsolete if 40 Mbps turns out to be insufficient for the typical household).[89] Certainly it would be wasteful to install a given infrastructure if you knew you were going to have to rip it out and replace it with something different in the near future. However, there are a number of limits to this argument.

Firstly, it implicitly assumes that nothing better than FTTH will come along, that might render fibre to the home obsolete. Certainly we don't know of anything technically better for delivering fixed bandwidth today, but of course the future is inherently uncertain. Twenty six years ago ISDN was being referred to as the 'ultimate' network.[90] Today it is a largely forgotten and obsolete standard, and it is at least possible that FTTH suffers the same fate. Twenty six years from now is when the financial return on Australia's NBN (its government-funded FTTH network) will start to exceed its cost of capital.[91]

Secondly, even if FTTH remains the best technical solution, it only makes sense to invest now if one knows there is are likely future benefits from the incremental capacity. As we have discussed elsewhere, these future benefits are far from certain, and if there is risk, it often makes sense to keep options open. Beginner pianists don't buy grand pianos (though it would be future-proof to do so) because they don't know for sure that they will need one.

Thirdly, a future-proof solution isn't necessarily the right answer immediately, even if it will be in time. It may be that a cheaper interim solution is right (for instance FTTC), depending on how long it is before the future-proof solution is essential, and on how much of the cost of the interim solution is wasted when it becomes time to upgrade. Young couples don't immediately by a large family home, even if they fully expect to need one later, because they can make better use of the money in the short term than paying a mortgage for mostly empty rooms.

To put all this another way, the 'future proof' argument only has validity (given the substantial incremental costs of FTTH over alternatives such as FTTC) if the incremental benefits of FTTH are substantial, relatively certain and not too distant. It is an argument that tends to amplify a case for FTTH that is already good, rather than one that stands independently.

[89] See for instance FTTH Council North America, 2010

[90] Edwards 1984

[91] Authors' analysis of NBNCo, 2010b

Fiber and consumer demand

The somewhat disappointing benefits of superfast over basic broadband are reflected in recent estimates of consumer willingness to pay for faster speeds. An inexact estimate based on recent surveys in the US conducted for the Federal Communications Commission suggests that the average household would be willing to pay about $45 per month to move from 'slow' to 'fast' speeds – approximately equivalent to moving from dial-up to broadband—but only $3 per month to move from 'fast' to 'very fast' speeds.[92] Willingness to pay tends to grow as consumers become accustomed to better quality services, but this is a very low base from which to start.

Pricing in the European market suggests a similar, sobering, level of consumer willingness to pay. In order to attract customers, in 6 out of 9 European countries with FTTH available, fiber broadband prices were the same or less than those of ADSL2+ services.[93] While aggressive pricing is not unusual for products entering a market, it is much less usual for something that is in theory a much-superior product. According to WIK Consult: "pricing strategies [that] regard fiber access as a premium service seem to fail".[94]

Adoption tells a similar story. In Korea, despite many years of investment, substantial government support and a minimal price premium for fiber, (just) more than half of all households with broadband are still connecting via cable or ADSL.[95] In Europe, as of July 2009, the portion of homes passed by fiber who had connected was 15.5%.[96] (In the UK in particular, a service offering up to 50Mbit/s available to around half of UK households since the end of 2008 had only 74,000 subscribers at the end of June 2010.[97]

[92] Rosston, Savage and Waldman, 2010. The survey evidence is inexact because slow, fast and very fast were defined by respondents within parameters given by surveyors –so "fast" is "similar to a high speed Internet connection… great for music, photo sharing and watching some videos" while "very fast" is "really great for gaming, watching high-definition movies, and instantly transferring large files." It should also be noted the same study suggested a willingness to pay for increased reliability, telehealth services, videophone capability and movie rental online of $19.88, $4.39, $5.06 and $3.29 respectively (though as we have discussed elsewhere, telehealth is possible over DSL, as are videophones). A second study suggests similar results –moving from dial-up to broadband is associated with a considerable value in the mind of the average consumer while moving between broadband technologies with different capacities –in this case cable versus DSL—has little perceived value (Rappoport et. al., 2002).

[93] Tariff Consultancy, 2009

[94] Neumann, 2010

[95] OECD 2010, data for December 2009

[96] Neumann, 2010

[97] Ofcom, 2010

In Australia, where the government's NBN Co has started to roll out fiber in Tasmania, and reportedly only half of premises have agreed to allow the necessary access to their property, even though this stage of the install is free and carries no obligation to take high speed services. As a result NBN Co has extended its deadlines for response, and the government is considering a switch from a 'contract-in' to a 'contract-out model.[98]

Of course adoption of any new service takes time, but these data points do not suggest overwhelming and widespread preference for fiber over other technologies.

[98] Ars Technica, 2010 and NBNCo 2010a

Other high-speed infrastructures

We have argued that many of the applications used to make the case for fiber, such as smart grids and home monitoring, can in fact be delivered over lower-speed ADSL networks. However, even applications that do require higher speeds than ADSL can provide may not necessitate fiber. This is because there are other higher-speed infrastructures out there, or coming soon.

Most obvious is cable broadband. Cable modem coverage was 43% in the EU at the end of 2008,[99] and much higher in some counties (well over 80% in Belgium, the Netherlands and Portugal, for instance). In both the US and Canada, it is over 90%.[100] By upgrading their networks to DOCSIS 3.0, cable operators are starting to offer access speeds of over 100 Mbps (German operators Kabel Deutschland, Kabel BW and Unity Media have all done so, for instance.[101] It is also appreciably cheaper than fiber – US estimates are in the range of $100 per home.[102] Fiber advocates argue that FTTH is preferable because it is capable of speeds of 1,000 Mbps or more;[103] however, given that the applications that require 100 Mbps are unclear, the incremental benefits of going from 100 to 1,000 Mbps are even more speculative. DOCSIS 3.0 is being rolled out by cable operators on a purely commercial basis – it does not require subsidy. At least within cable coverage areas, this makes the case for subsidized fiber particularly hard to make.

Even outside cable coverage areas there are cheaper alternatives to fiber-to-the-home. Fiber to the curb or fiber to the node (also known as fiber to the cabinet) bring fiber closer to the consumer without going all the way to the house. Both can considerably increase the speed of broadband services, if not to the level that FTTH can provide. At the same time, because they don't require replacing connections all the way to the home, but only to boxes serving multiple households, they are considerably cheaper.[104] FTTC can be one fifth the cost of FTTH.[105]

[99] IDATE, 2009

[100] OECD 2010

[101] Garlick and Polyviou, 2010

[102] Higginbotham, 2009

[103] FTTH Council North America, 2008

[104] In New Zealand the government is spending $NZ1.5bn to support fiber roll-out, although the incumbent is already committed to providing 84% coverage for FTTN by 2011, which will be capable of speeds of at least 10 Mbps (and, for most households, much more) (Telecom New Zealand, 2010). The government there must be very confident of the externalities associated with speeds of more than 10 Mbps to justify a complete overlay FTTH network.

[105] Telecommunications and Internet Federation, 2010

The third type of high speed network (besides FTTH) being rolled out globally is wireless. Mobile operators are in the process of implementing LTE, the next generation of mobile network, which will enable typical speeds of 10 Mbps (and a theoretical maximum of 100 Mbps). While these networks will not be well equipped to support widespread and steady usage at 10 Mbps (for instance for viewing HDTV), they can well support less widespread applications often cited to support the case for fiber. For instance, LTE might be well suited for home monitoring of chronically ill patients (a relatively small percentage of total households).

Although the above technologies deliver many of the same applications as fiber may, with very few exceptions, they are not receiving subsidies. Indeed in many markets wireless operators are paying substantial spectrum charges to enable their services. Yet there are innovative potential subsidy responses likely to achieve considerably higher returns in some of these areas. Take, for example, a mandate that duct and dark fiber be installed alongside trunk roads when they are being built or repaired (if fiber competition does not already exist on that route).[106] In the US, 90 percent of the population lives within five miles of the national highway system. Installing fiber during road construction adds about one percent of total construction costs. Each year, about fifteen percent of the network is constructed, upgraded or rehabilitated, suggesting the potential to rapidly roll out a wide-reaching backbone that would greatly improve the quality and reach of wired and wireless broadband alike at a total cost of between $1.6 and $4.9 billion --which could be recouped from private operators.

Broadly, if governments are interested in supporting the rollout of more advanced Internet services to more of their populations, there are considerably more equitable approaches with higher benefit-cost ratios than rolling out FTTH. Working on filling out basic broadband access to more rural areas and strengthening middle-mile capacity are two such approaches. It is worth noting in this regard that there is considerable divergence in the focus of broadband initiatives in OECD countries between the focus on superfast and a focus of equitable broadband – plans in Australia, France and Portugal concentrate on FTTH rollout while those in Spain, Canada and the US appear more concerned with universal (basic) broadband access. A few countries - notably Finland - look to be pushing a universal fiber access model.[107] On the basis of present evidence, a focus on equitable broadband access appears the most rational approach of the three.

[106] See Lennett and Meinrath, 2009 for a more detailed discussion

[107] National broadband target priorities from Table One of Qiang, 2009

Competing to stay atop the league table

The rationale for fiber investment is often couched in national competitive terms. For instance, in announcing NBN Co (his government's investment in fiber), Australian Prime Minister Kevin Rudd said: "Slow broadband is holding our national economy back ... Australia is in the bottom half of the OECD countries for broadband take up; 16 out of 30 in 2008 ... Years of failed policy have left Australia as a broadband backwater".[108]

Until the case is made that fiber is worth the cost, concerns about positioning on a league table are premature. As Plum Consulting put it in their review for the Broadband Stakeholder Group of the costs and benefits of fiber in the UK:

> "[i]nvesting in something simply because others have does not make economic sense. The case for investment should rest on the resource cost and expected returns within the UK. If others invest in next generation broadband, the UK is not necessarily getting left behind in terms of economic and social progress, because others may be investing prematurely or for reasons that make sense locally". [109]

Moreover, even if fiber may turn out to be a worthwhile investment in the long term, that does not mean that urgency is required. Rushing to invest in new risky technology, particularly for reasons of national competitiveness, often ends badly.[110] The UK government invested over £1bn into its share of the Anglo-French Concorde supersonic transport aircraft between 1956 and 1987.[111] This Concorde program prompted the Soviet Union to build in its own supersonic passenger plane, the Tu-144, which was withdrawn from service after just 55 passenger flights and two crashes. The US also responded to Concorde. In 1963 President Kennedy launched a program to develop an American rival: "It is my judgement that this Government should immediately commence a new program in partnership with private industry to develop at the earliest practical date the prototype of a commercially successful supersonic transport, superior to that being built in any other country in the world." (Language echoed

[108] Rudd, 2009. Worrying about internet rankings is nothing new. In 2004 President Bush said of America's basic broadband ranking: "Tenth is ten spots too low". Hazlett (2009)

[109] Plum, 2008

[110] Note that we do not mean to imply that fiber has material *technology* risk – it is in fact a well tested technology. Rather, we perceive substantial risk that the mooted benefits from fiber access (social and economic) do not appear

[111] Butcher, 2010. All financial figures in this paragraph in money of the time.

by many current political statements in favour of FTTH).[112] The program was defunded by Congress eight years later, after spending $864m, without even completing a prototype.[113]

Supporters of FTTH argue that the benefits of the network will not be apparent until fiber reaches many homes and so there is the incentive to produce applications to run on it. Some go on to make the case for government support for applications development, to ensure demand for the network. Such an approach has apparently met with limited success in the Netherlands over the past few years –where developers have failed to uncover the 'killer application' for fiber.[114] In the circumstances, it is likely to be the lower-risk approach to allow applications to develop organically alongside the commercial rollout of fiber, rather than attempt to subsidize both supply and demand for superfast at the same time. Following rather than leading in the superfast race will also allow countries to benefit from the applications innovations of other economies. If those applications create a domestic demand for FTTH, rollout of a fiber network becomes a considerably less speculative investment. The great majority of fiber's potential benefits, for healthcare, education and so on, will in no way be reduced if another country rolls out access first. Admittedly such an approach sacrifices the opportunity to be a world-leading applications developer, but in practice this is not a realistic goal for most economies. Again, Korea has had fiber for many years, but it is hard to think of a single high speed service that has been exported from Korea as a result.

It is a fool who predicts the future of information and communications technologies with any certainty – given the massive rollout of new devices and applications over the past fifteen years, the future may hold a powerful application that requires FTTH. That application may even carry significant network externalities. If so, the case for fiber rollout will become more compelling. At that point, perhaps, it might be worth subsidising access beyond the market. Luckily, it is likely at that point the market demand will have gone up and the cost of supply will have gone down – and so the need for subsidies will be lower. The evidence in favour of the idea that late adopters will never catch up should such an application appear is threadbare. And, of course, the 'killer application' requiring FTTH may not appear at all.

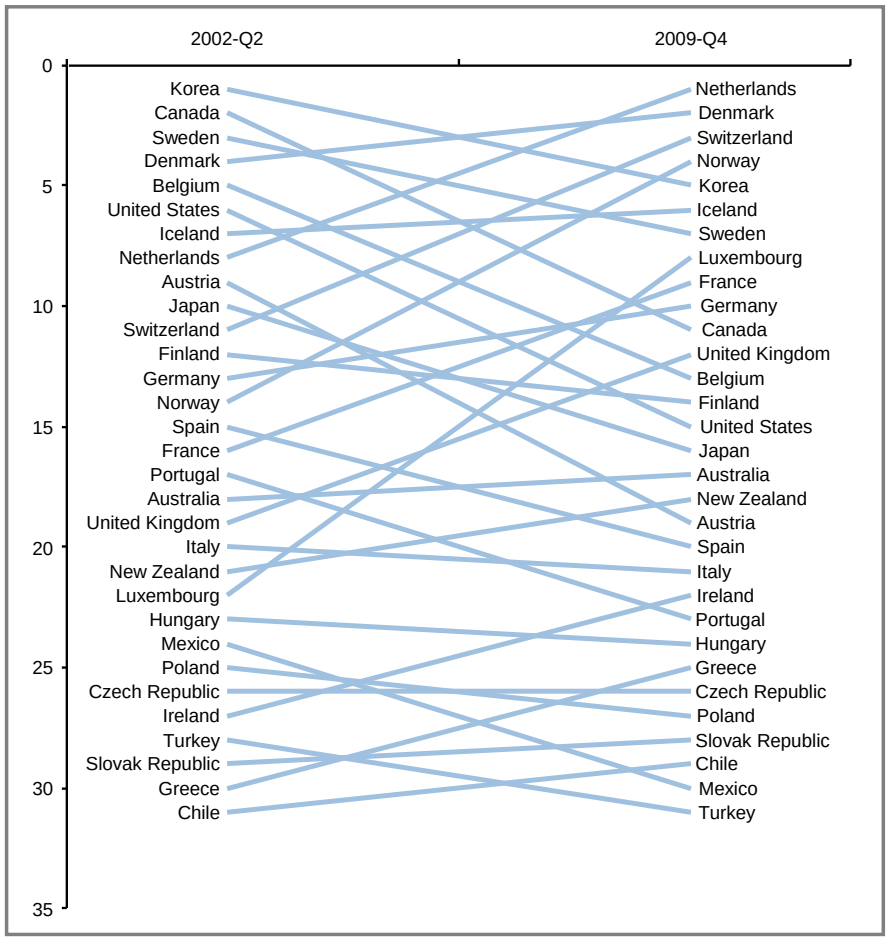
[112] Time, 1967, quoting a speech to the US Air Force Academy on 5 June 1963

[113] Time, 1971. The history of supersonic transport also shows that just because the first generation of a technology is good (propeller flight), and the second better (jet flight), it doesn't follow that a third generation (supersonic) is worth the money.

[114] Howell and Grimes, 2010

A final argument for waiting is that even if it is important to lead the league tables, it is easy to gain places later. Figure One shows how broadband rankings have changed over time – as is evident, quite substantial movement up and down the rankings is not just possible, but common.

Figure One: Broadband penetration rankings, Q4 2009 vs Q2 2002[115]



[115] OECD, 2010 and authors' analysis

Conclusion

Supporters of fiber subsidies note that the market is not rushing to install ubiquitous fiber networks – that telecoms companies are waiting until they better understand the business model and the extent of regulatory technical and operational risks. Governments should be wary of stepping where telecoms companies fear to tread. These are, after all, firms that have happily rolled out access in war-torn Afghanistan and Iraq. Risk is hardly an alien concept to them. Perhaps their caution is well-founded.

If governments subsidise rollout enough, surely at some point the fibers rolled out will fill with data traffic. If consumers don't have to pay more to get it, they'll sign up to superfast, and companies will provide enough bandwidth-hogging applications to light the fibers. The question is, will the subsidies have been worthwhile? Will the applications be valuable enough to justify such a large investment? Given what we know to date, the answer appears to be no.

The argument for government subsidy at this point looks particularly threadbare because it is unclear the compelling market failure that the subsidy would overcome. Multiple streaming TV on demand is not a technology that creates 'network externalities' like a telephone or email account. I benefit from my ability to email or call you. I don't benefit from your (little-exercised) ability to watch the Olympics in high-definition while the kids are streaming Toy Story III in the basement. Fiber advocates have claimed externalities such as improved healthcare or reduced electricity consumption. As we have seen, these benefits are frequently based on crediting fiber with applications that can work on basic broadband (or even dial-up), or from benefits from taking fiber to business premises, not homes.

When there is no apparent need to rush into investments in an unproven technology, the answer is to wait. If money must be spent on connectivity, we would suggest resources flow to widening access to basic broadband; or coaxing those not yet online to take the broadband services already available to them; or invest in freeing up spectrum to meet the burgeoning demand for mobile data services, or improve the capacity of the middle mile.

At the turn of the last decade, telecommunications companies lost billions of dollars of private investment by spending on long-haul fiber networks that turned out to be far beyond what was needed for many years thereafter. At the turn of this decade, governments risk doing the same thing with tax-payer dollars by overinvesting in fiber in the access network. Hi-def TV on demand is no way to guarantee short term economic recovery or long term prosperity.

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