Determinants of Broadband Penetration in OECD Nations

Marcelo Grosso*

Regulatory Development Branch

Australian Competition and Consumer Commission

e-mail: marcelo.grosso@accc.gov.au

Abstract

There have been a number of studies examining factors that drive broadband penetration. This paper attempts to add to the literature and empirically test what other possible factors may drive broadband penetration in the OECD. Using data from the OECD's database and 2005 Communications Outlook over the years 1999 to 2005, an empirical model is estimated using generalised least squares multiple regression analysis. Apart from the empirical testing conducted, government policies of several OECD nations over the past decade are outlined in the paper. Australia's broadband penetration has been compared to the rest of the OECD in recent years with several reports being released raising concerns over Australia's performance. The government has signalled to the Australian public its intention of making Australia a world leader in broadband. This has been further reinforced through the formation of the Broadband Advisory Group and the creation of the Higher Bandwidth Incentives Scheme. The aim of this paper is to analyse whether these concerns are valid and which factors are crucial in the development of broadband. Following the methodology used in previous work from the Network Economics Consulting Group and the Strategy and Policy Consultants Network, several conclusions are drawn. These are that broadband was estimated to be a superior good, competition increases broadband penetration, learning effects occur causing people to upgrade to broadband after discovering the benefits of the internet through narrowband subscription and finally that Australia performs well against the OECD average. Finally, it is noted that Australia's broadband penetration has reached a point of critical mass on the s-shaped diffusion curve and that continued government involvement and cooperation with industry will help to ensure that Australia maintains or improves its position in broadband penetration within the OECD.

JEL Classification: C33, H54, L96, O50

Keywords: broadband; internet; competition; diffusion curves; regulation; OECD

* I would like to thank Dr Robert Albon, ACCC staff and two anonymous referees for their assistance and comments during the drafting of this paper. Any views held in this paper are my own and should not necessarily be considered as the views of the ACCC.

Determinants of Broadband Penetration in OECD Nations

1. Introduction

Access to broadband facilities by businesses and consumers has been seen as a vital factor in the economic growth of a country in recent years. There is a general consensus that the deployment and adoption of broadband technologies will increase productivity levels in turn fuelling economic growth. This is re-enforced by the emergence and re-emergence of technologies such as video communications, downloadable content for consumers, voice over internet protocol (VoIP), online applications and many other examples that are bandwidth intensive. Since 2000 the Organisation for Economic Co-operation and Development (OECD) has been collecting broadband penetration statistics. The OECD views broadband connectivity as a key component in information communications technology (ICT) development, adoption and use. In October 2003 the OECD (2003, p. 1) released a paper titled 'Broadband Driving Growth: Policy Responses' which began by outlining the importance of broadband for economic and social development and states:

> It is of strategic importance to all countries because of [broadband's] ability to accelerate the contribution of ICTs to economic growth in all sectors, enhance social and cultural development, and facilitate innovation. Widespread and affordable access can contribute to productivity and growth through applications that promote efficiency, network effects and positive externalities, with benefits for business, the public sector, and consumers. Broadband networks are an important platform for the development of knowledge-based global, national, regional, and local economies.

In December 2005 Iceland, Korea, the Netherlands and Denmark led the OECD in broadband penetration, exceeding 25 subscribers per 100 inhabitants. During 2005 the strongest per capita subscriber growth came from Iceland, Finland, Norway, the Netherlands and Australia with an increase of more than six subscribers per 100 inhabitants. This paper examines a range of factors that have either driven or stalled broadband penetration in OECD nations.

The range of factors can be broken into three main categories; physical, economic and regulatory factors. Examples of physical factors that may affect broadband penetration include but are not limited to country specific characteristics such as land mass, population and density. In the case of economic factors, these would include income, competition levels, broadband pricing, factor costs, and the existence of substitutes and complements. Finally, regulatory factors tend to focus on such issues as the independence of a regulator, transparency and access regimes.

The paper is structured as follows. The following section reviews the background of the broadband penetration literature and policy work. From the previous work conducted, an econometric model is developed in the third section outlining the variables used, data sources and a priori expectations. Results and discussion follow in the fourth section and finally conclusions are made.

2. Background

The emergence of broadband technologies and their diffusion over the past five years has become an important issue for policy makers domestically and abroad. With the OECD releasing broadband penetration figures every six months, the media, academics and policy makers constantly use these figures as a gauge to see how their nation is performing. When a country drops in ranking questions about the nature of the competitive, regulatory and policy environment are inevitably raised.

2.1 OECD Broadband Policies

In October 2003 the OECD released a paper on the policies which should be used to guide broadband development. After receiving feedback and advice from OECD member nations, the OECD outlined principles that have demonstrated to assist in the development of broadband services. Some of the stated principles were:

- The need of promoting competition and liberalisation of infrastructure.
- The encouragement of investment and the provision of new technological infrastructure, content and service provision.
- The need of promoting technology neutral policies.
- Policies that encourage consumer and business confidence in the use of ICT.
- The introduction of demand aggregation policies in sparsely populated areas.
- The creation of access on fair terms and at competitive prices to all communities, irrespective of location.
- Assessment of the market-driven availability and diffusion of broadband services in order to determine whether government initiatives are appropriate and how they should be structured.

In general these policies have been taken up by the OECD member nations; one example is the unbundling of the local loop, with the exceptions of Mexico and New Zealand, to allow service based competition. This reduced the infrastructure requirements in order for new entrants to enter into the broadband market. Another area that governments from the member nations have been active in are the provision of subsidy schemes to encourage investment into areas without access to broadband.

2.1.1 Australia's Broadband Policies

The importance of broadband is well recognised by policy makers in Australia. In 2001 Accenture estimated that next generation broadband could produce economic benefits of $AUD12 billion to $AUD30 billion per annum to Australia.[1] The Victorian government recently released a report by ACIL Tasman examining the economic impacts of broadband in Victoria. It found that *'the average annual contribution of broadband to Gross State Product (GSP) growth over the period 2004 -2015 is predicted to be 0.82%'*[2]

---

[1] Refer to Broadband Advisory Group (2003), p. 5.

[2] Refer to Multimedia Victoria (2006).

In Australia the Broadband Advisory Group (BAG) was formed in March 2002 with the task of examining how Australia could become a *'world leader in the availability and effective use of broadband…'*[3] The BAG subsequently released a report in January 2003 with the group making 19 recommendations on how Australia could achieve the above vision. The recommendations covered issues ranging from the regulatory environment through to national strategies and implementation of those strategies. The National Broadband Strategy Implementation Group (NBSIG) was formed as a result of the BAG's report. NBSIG oversees the implementation of broadband strategy in Australia and is made up of both state and federal government representatives.

Another inquiry that was running at the same time as the Broadband Advisory Group's study was the Estens' Regional Telecommunications Inquiry. From this Inquiry the Higher Bandwidth Incentive Scheme (HiBIS) was created where broadband providers are given subsides to create services for regional and remote Australia. HiBIS has subsequently been replaced by the 'Broadband Connect' and the 'Metropolitan Broadband Connect' schemes where government has allocated $AUD928 million to connect households to broadband technologies.[4] KPMG and Alcatel released a report this year criticising Australia's position in relation to the rest of the world, in particular the fact that Australia compares poorly when in the higher bandwidth category.[5] However, these criticisms may be a little premature.

2.1.2 Canada's Broadband Policies

The Canadian government established the National Broadband Task Force in January 2001. The task force was to map out a strategy with the goal of ensuring that broadband services are available to businesses and residents in every Canadian community by 2004. Before mapping out the strategy, the task began by defining what was meant by broadband. The task force decided that given the rapid rate of technology improvements that bit rates were an inappropriate measure and therefore decided to measure broadband by what it could do for the Canadian public. The National Broadband Taskforce (2001, p. 7) defined broadband as:

> …a high-capacity, two-way link between an end user and access network suppliers capable of supporting full-motion, interactive video applications.

Given that Canada was already a world leader in the provision of broadband technology the task force decided that their focus could be best spent on developing strategies to make broadband services available to regional and remote geographical communities. It estimated, with the assistance of the carriers, that about three quarters of Canadian communities (one quarter of the population) did not have access to high-speed services. It decided that market forces alone will not be able to achieve coverage in these areas by 2004. The combined efforts of governments, the private sector and the communities themselves will be required to achieve this goal. Arising from the work conducted by the task force was the 'Broadband for Rural and Northern Development Pilot Program' and the 'National Satellite Initiative'.

---

[3] Refer to Broadband Advisory Group (2003), p. 5.

[4] $AUD878 million is allocated to the regional scheme, while the $50 million is for metropolitan areas without ADSL access.

[5] Refer to KPMG report (2006), p. 7.

The pilot program was created to assist those communities without broadband access. Two rounds of business plan development funding ($CAD4.2 million) were followed by two rounds of business implementation funding ($CAD79 million). All submissions for funding were assessed by the National Selection Committee, a body which comprises of 24 members representing all regions of Canada and cross-section of professional backgrounds. For the programs to be funded they needed to meet the funding criteria set down by the program. Towns without access to DSL or cable[6] modems were eligible to receive funding with preference given to First Nations, northern, rural and remote communities. A 'community champion' is then assigned to gather information on a number of criteria and is asked to formulate a business plan in conjunction with community consultation, receiving $CAD30 thousand in funding. The second stage of the funding involves the implementation phase where the 'community champion' must prove that the funds provided by the government will be matched by the stakeholders in the project and that a number of other criteria are met.

The satellite initiative involved the provision of affordable satellite broadband services for regions in the far to mid-north of Canada. The initiative commenced in 2003 and was broken into three stages. The first stage awarded four applicants a total of 28 MHz of satellite capacity in the C-Band for 15 years at a cost of $CAD20 million. The second stage, currently in the process of being delivered, is the allocation of $CAD85 million to partly fund the acquisition of required infrastructure for a satellite service. The final stage of the program involves the Canadian Space Agency, to provide 11-years worth of capacity in the Ka-Band to deliver broadband to the far North.

2.1.3 European Union's Broadband Policies

In May 2002 the European Commission introduced the 'eEurope 2005' program. One of the explicit objectives of the program was the call *'for the stimulation of innovation and increased use of and investment in broadband communications'*. [7] An action plan was subsequently developed by the European Commission meeting in Lisbon during 2003. The action plan focused on developing a regulatory framework for wireless broadband, support for broadband in less-favoured areas, increased content provision by public authorities and the speeding up of the transition to digital television.

The EU15 member nations developed policies in response to the plan which could be broken up into supply-side and demand-side initiatives. Supply-side initiatives, one of the initiatives involved the provision of broadband to remote and regional Europe. 'The European Initiative for Growth' written in December 2003 instituted the 'Digital-Divide' and 'Quick-Start' projects where funding from the European Investment Bank could be used as long as the guidelines on investing in electronic communications were followed. Member nations have conducted mapping surveys to identify areas that have experienced 'market failures' and are being underserved, and follow-up by examining possible reasons for the failure. In general where investment into broadband infrastructure has occurred it has been supported by demand aggregation schemes. Other initiatives included the promotion of competition and convergence across alternative platforms, continued monitoring of markets and promoting the importance of research and development of next-generation broadband. On the demand-side,

---

[6] Cable is also referred to as Hybrid Fibre Coaxial or HFC.

[7] Refer to European Commission (2002), eEurope 2005 Section of European Commission website.

policies included demand aggregation, the deployment of broadband-enabled and interoperable applications and services for business and government, and the promotion of content creation through digital rights management. The 'eEurope 2005' program is currently in the process of being replaced by the 'i2010' program, which seeks to create a European Information Society.

2.1.4 Korea's Broadband Policies

Since the launch of broadband in Korea in 1998, Korea has quickly emerged as a leader in broadband adoption as the International Telecommunication Union (2003, p. 1) states:

> In 1995, Korea had less than one Internet user per 100 inhabitants. In 1999, it surpassed the developed nation average and by the end of 2002 was the world's fifth largest Internet market, with 26 million users. Korea has the third highest Internet penetration in the world and ranks top in Asia.
>
> Korea is the leading example of a country rising from a low level of ICT access to one of the highest in the world.

Several factors such as competition, population density, cultural attitudes[8], high education levels and interventionist government policy have all been attributed to the reasons of its success.

Korea's broadband policy has been tied in with its ICT policy, where the government has not only allocated funds to broadband but also to information technology provision and literacy programs. The Korean government set the early foundations of competition within the ICT industry by allowing free entry for facility-based service providers and resellers in the 1980s. In 1999 the Ministry of Information and Communications (MIC) launched the 'Cyber Korea 21' program. The program aimed '*to create the framework of a knowledge-based society and to improve national competitiveness and the quality of life to the level of the advanced nations.'*[9] The MIC acquired funds from the telecommunications companies which it then invested into upgraded the copper networks. In the same period the Korean government introduced the 'Cyber Building Certificate' system where apartments are rated upon their ability to access the internet and use other information technology. Along with the push to upgrade telecommunications networks the MIC also created laws to develop electronic signatures, and introduced computers and information technology in educational institutions and industry. By January 2000 almost all government ministries and agencies were online and connected to a high-speed backbone network.

In 2002 the MIC launched the 'e-Korea Vision 2006' program to continue the policies from the 'Cyber Korea 21' program. The key initiatives that arose from this program are covered under three areas:

1) 'Promoting national informatization'

---

[8] Refer to section 3.6, Wallsten (2006 p. 8) and Kanellos (2004) for examples of the popularity of online usage in Korean society.

[9] Refer to the Ministry of Information and Communications (1999).

- The continuation to improve literacy and internet usage (90 per cent target by 2006) within Korea.

- The further subsidisation of remote[10] and low-income regions.

- Increased provision of computers to schools (less than one computer per five students by 2006).

- The promotion of 'e-work' or teleworking, and e-business between both customers and businesses.

- The continued move to e-Government through computerising systems, offering e-commerce and the electronic storage of all documents and records.

2) 'Advancing the information infrastructure'

- A host of measures to promote the use and investment in information technology in industry.

- Continuing to promote the safety and reliability of Cyberspace through awareness programs and investment into improving systems to meet with technological developments.

- Universal access of broadband with minimum speeds of 1 Mbps by 2005.

- Continued investment into improving broadband infrastructure over the period.

- Investment for 'Next Generation Internet' and broadband technologies.

3) 'Strengthening International Cooperation for the Global Information Society'

- Establishing Korea as an East Asian business hub through mutual cooperation.

- Cooperating with the ITU and the OECD and to promote Korea as a global IT leader.

2.1.5 New Zealand's Broadband Policies

New Zealand has experienced rather slow broadband penetration relying on New Zealand Telecom and high cost satellite providers, resulting in a high concentration level within broadband provision. In May 2004, the New Zealand government accepted the recommendation of the Commerce Commission to introduce the unbundling of the bit stream at a limited speed. It was expected that it would lead to the co-operative development of an effective wholesale market and competition. Two targets were imposed on Telecom New Zealand in its provision of broadband services by December 2005. Telecom managed to meet the customer connection target of 250,000 connections but failed to ensure that a third of the connections were with wholesale customers.

---

[10] In excess of $USD300 million has been allocated to rural regions in Korea.

As a result of the failure to meet the second target the New Zealand government introduced a package of reforms to improve New Zealand's broadband performance. These reforms fell under three main categories – facilitating competition by improving access at the wholesale level, encouraging investment in infrastructure and adopting forward-looking policies and review processes. Some of the notable policies are:

- The introduction of local loop unbundling in 2006.
- The removal of constraints on the regulated Unbundled Bitstream Service, including providing for 'Naked DSL'.
- The implementation of accounting separation around Telecom New Zealand's wholesale businesses.
- A review of whether operational separation should be implemented will also be conducted.
    - Telecom New Zealand have subsequently pre-empted the New Zealand government's structural separation and announced that the wholesale and retail divisions will become separate units under the Telecom New Zealand banner.[11]
- Developing policies based on reviews of public sector infrastructure investment, and on whether Telecom New Zealand's ability to reduce local prices solely in response to new competing infrastructure investment should be constrained.
- Developing a rural package and expansion of the Digital Strategy Broadband Challenge fund in the 2007/08 Budget round.
    - $NZD24 million has been made available over four years under the Broadband Challenge to enable affordable broadband in rural and urban New Zealand.
    - The Broadband Challenge is also supplemented by the $NZD1.44 million PROBE Extension fund, which provides funding for broadband to be supplied at schools.
- Ensuring competitive access to spectrum for new wireless applications.
- Empowering the Telecommunications Commissioner to undertake strategic reviews of sector performance.
- Reviewing the Telecommunications Service Obligations, with a focus particularly on delivery of rural services.
- Continuing to develop and implement the Digital Strategy and encouraging the smart use of ICT.

[11] Telecom New Zealand has announced that the wholesale unit will provide non-discriminatory approach, providing a 'level playing field' to all broadband suppliers in the market.

2.1.6 United State's Broadband Policies

The Telecommunications Act 1996 directed the Federal Communications Commission (FCC) to conduct inquiries *'into whether "advanced telecommunications capability" is being deployed to all Americans in a reasonable and timely fashion.'* [12] Congress has defined an 'advanced telecommunications capability' as a *'high-speed, switched, broadband telecommunications capability that enables users to originate and receive high-quality voice, data, graphics, and video telecommunications using any technology.'* [13] The FCC was ordered by Congress under the Act to complete the inquiry within 180 days and take any necessary actions to promote broadband if it is not being deployed in a timely fashion.

The FCC's policy approach to broadband has relied in general on the promotion of facility based competition, stimulation of demand, and incentives for investment. The reports released by the FCC from 1999 to 2004 have found that in general the deployment of broadband technologies has been satisfactory. Some of the policies used by the FCC to further achieve their goal over the period were:

- The creation of the E-Rate program where schools are subsidised 20 to 90 per cent of the broadband cost depending on several criteria.[14]
- To promote competition and provide access to rural areas, several steps were taken to increase the promotion of wireless services, such as:
- Making available and auctioning of (Radio and satellite, C and Ku-bands) spectrum to ensure wireless services.
- The promotion of next generation mobiles in 1999 as another means to accessing broadband services.
- The re-examination of 45 MHz CMRS spectrum cap in 1999 on wireless telecommunications providers.
- The international harmonisation of spectrum allocations, products and technical standards.
- Promoting the provision of licences for wireless broadband facilities.
- A Federal-State Joint Conference was held on broadband in 2000.
- The introduction of collocation in incumbent local exchange carriers' exchanges for competitive local exchange carriers.
- The unbundling of DSL services and the high frequency portion of the local loop.
  - In 2003, the FCC's decision for unbundling of the local loop for broadband services was vacated by the courts.

[12] Refer to FCC (2006).

[13] Refer to FCC (2006).

[14] Broadband providers have also made philanthropic donations to assist in the program.

- Promoting competition in international submarine cable market.

- Creating universal service provisions for rural, low-income and indigenous people modified plus other incentives to get carriers to serve and deploy broadband facilities in these regions. Initiatives in this area include:

  - Encouraging investment in high-cost infrastructure areas via the five-year Rural Task Force plan through support to rural carriers and additional investment.

  - Modifying universal service and charge rules so that rural rate-of-return carriers have certainty and stability by ensuring that rate structure modifications do not affect overall recovery of interstate access costs.

  - Allowing small and rural carriers to set rate-of-return at 11.25 per cent.

On the whole the United States has relied upon industry to promote the deployment of broadband with exception of the above policies.

2.2 Previous Work on Broadband Penetration

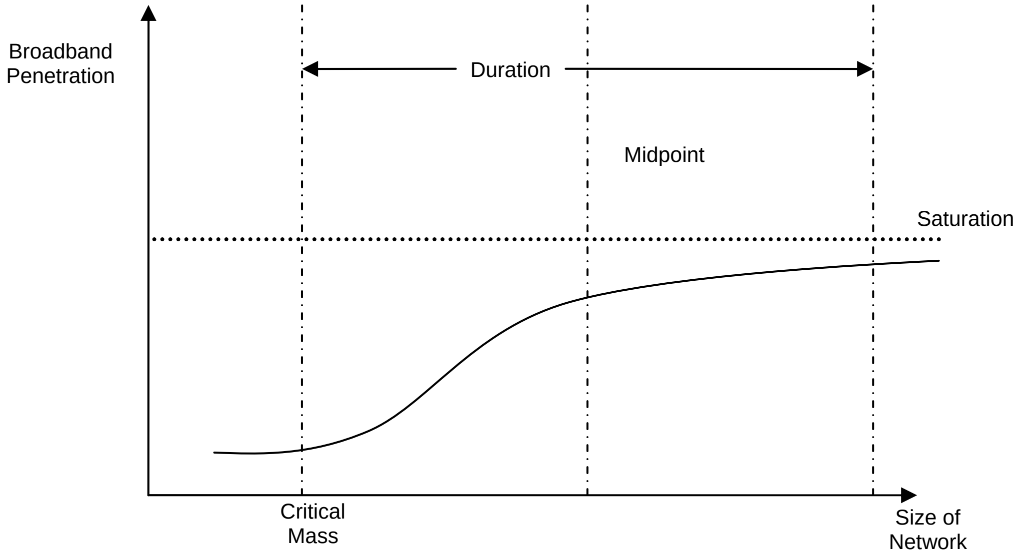
In July 2003 the Network Economics Consulting Group (NECG) released a paper titled 'Quantifying differences between broadband penetration rates for Australia and other countries'. The purpose of the paper was twofold. Firstly, it examined whether Australia's broadband penetration was low by OECD standards. Secondly, it examined whether cable-copper cross-ownership would have an adverse effect on broadband penetration levels. The general conclusions made by the NECG were based upon a regression of OECD nations' broadband penetration and factors such as GDP per capita and cross ownership of broadband platforms by incumbents. The NECG found that Australia's penetration levels were not below average as claimed by several critics. On the contrary, Australia's current broadband penetration levels were found to fall within the confidence intervals of the predicted levels of OECD broadband penetration. The NECG also found that cable-copper cross-ownership was an insignificant determinant of broadband penetration. The NECG also pointed out that technologies such as broadband tend to follow an S-shape curve.

This curve is known as a diffusion curve that is generally observed when the technology is introduced to the mass market.[15] This curve can be broken up into three segments. The first segment of the curve is usually made up of early adopters and sees relatively small growth in the uptake of the technology. The second stage occurs when a technology reaches critical mass, where the technology is seen as viable in the long-run by the mass market, and then attracts many adopters. The NECG defined this (duration) period beginning at 10 per cent and concluding at 90 per cent of the saturation level. The final stage is a slow down in the technology diffusion due to the effects of congestion and the fact that there will be no take-up among those in the population who do not value the technology highly enough – this is also known as the point of saturation.

The following diagram illustrates what a diffusion curve may look like:

[15] The diffusion of technology is generally long and drawn out, and can be split into three stages (including the mass market diffusion stage). For more information on the topic of technology diffusion, refer to Ortt (2005).

Figure 1: Technology Diffusion Curve



By using cable penetration and changing the parameters of the potential size of the network, the time it takes to get from critical mass to saturation and the midpoint in technology diffusion curve, the NECG illustrated that Australia, like other OECD nations, is in the pioneering stage of the diffusion process. The NECG therefore concluded that it was too early to tell which country will potentially become a world leader in broadband, let alone which policies will be the most successful in promoting broadband. It must be assumed that the forecast over of cable penetration taking the s-shape diffusion process has failed to materialise as DSL has become the dominant platform in the provision of broadband services in most OECD nations.

Another country-wide empirical study into broadband penetration rates was conducted by Cadman and Dineen (2006), their study focused on European Union Nations. They developed a generalised least squares model with fixed effects in the constant term of the model. Cadman and Dineen regressed penetration against a pseudo Herfindahl-Hirschman Index (HHI) consisting of the country's incumbent share of the market and the shares of other platforms used in the country for broadband.[16] The other platforms used in the model were wholesale bitstream (OLO), unbundled local loop (LLU), cable and other methods. Cadman and Dineen found that their model explained 82 per cent of the variation in broadband across 21 European nations could be explained by the HHI. From the regression results they concluded that *'a 1% decrease in HHI will lead to a 1.66% increase'*[17] in broadband penetration.

In the same paper they conducted the same regression for the EU13 and found the relationship between the HHI and penetration to be 2.86 per cent. Cadman and Dineen compared this result with a regression they had conducted in the past and found the coefficient had increased from 2.83 per cent but the R-squared in the model had fallen 13 per cent. Cadman and

[16] For further explanation of the HHI, please refer to section 3.2.

[17] Refer to Cadman and Dineen (2006), p. 7.

Dineen then proceeded to use the 1.66 per cent coefficient, using Sweden as a benchmark, to show that if all European Union countries decreased their HHI to Sweden's level, the number of broadband users in the EU would increase by 20 million. These results are likely to be overly optimistic as calculations assume a constant return to improvements in the HHI and the model only considers two factors in determining broadband penetration. These factors are the fixed cross-sectional effect and the HHI of a country. In addition to the factors used by Cadman and Dineen, impacts of other factors on broadband penetration within the 30 OECD nations will be examined.

3. Model, Methodology and Data

The model will follow the approach used by Cadman and Dineen a log-log model using generalised least squares with cross-sectional fixed effects, and cross section weights. By using a log-log model it allows us to view the elasticities of the different variables in the model. The following is an explanation of each of the variables used in the model.

3.1 Broadband Penetration

The broadband penetration figure measures the number of broadband users within each country per 100 people. Households with access to the internet at speeds of at least 256 kilobits per second are considered to have broadband access. The penetration data were obtained from the OECD Communications Outlook 2003 database and the Information and Communications Technology Section of the website. The OECD publishes data on broadband penetration rates every six months. Given the fact that the other variables are only released on an annual basis yearly data were used starting in 2000 through to 2005.[18]

Apart from being the dependent variable in the model, the model uses lagged penetration levels in order to capture technology adoption effects. In other words, potential broadband consumers base part of their decision to consume broadband upon previous penetration levels. It is therefore expected that previous broadband penetration levels will have a positive effect on penetration. This is especially the case as the use of broadband technologies is relatively new for the majority of the general public and therefore problems associated with congestion are unlikely.

3.2 Herfindahl-Hirschman Index

The HHI is traditionally used as a measure of firm concentration, where the market share of each firm in the industry is squared and then summed together. The HHI is usually expressed as follows, $HHI = \sum_{i=1}^{f} S_i^2$, where f represents the firms and S are the shares. The HHI strictly falls between zero and one, for example; a pure monopoly has a share of 100 per cent and therefore the HHI will be one, a perfect duopoly has a HHI of 0.5 and perfect competition has a HHI near zero.[19] Following the work conducted by Cadman and Dineen, and given that the data about broadband firm shares across all 30 OECD nations are not readily available, the

[18] In 2000 Luxembourg, Poland and the Slovak Republic did not record any broadband penetration figures, therefore there are no values in the HHI or broadband penetration for these years.

[19] For mathematical examples please refer to the appendix 1.

shares of different access types were used. The share data were obtained from the OECD Communications Outlook 2003 database and the Information and Communications Technology Section of the website.[20] Instead of multiplying the HHI by 10,000 as in Cadman and Dineen, the HHI was multiplied by 100 in order to maintain consistency between the HHI and the penetration variables. The OECD publishes the share data alongside the broadband penetration data.

As with Cadman and Dineen it is expected that the HHI will have a negative relationship with broadband penetration. Despite the HHI not being used in its traditional sense, it may still be used as a pseudo measure for competition, as incumbents tend to own the copper network of a country. In other words, a large share of DSL technologies over cable may reflect a highly concentrated market. Increased concentration implies that there is a dominant firm that may choose to price broadband products higher and stall investment, as a result broadband penetration will decrease in concentrated markets.

3.3 Real Gross Domestic Product per Capita

The GDP per capita is used as a measure of a country's level of income and is measured in US dollars, based on both exchange rates and on purchasing power parities (PPPs). The data for GDP per capita were taken from the OECD Reference series which contains a database of economy wide statistics, starting from 1999 through to 2004.

GDP per capita is commonly used as an income variable in countrywide studies and as the model takes the log-log form, the coefficient can be interpreted as an income elasticity. Given that broadband could be viewed as a 'luxury item', broadband is likely to be a superior good and therefore it is expected the coefficient in the model will be greater than one – therefore as consumers' disposable income increases, their consumption increases at a greater rate. This is as opposed to a normal good with the coefficient being between one and zero, or an inferior good where it is less than zero.

3.4 Fixed Internet Penetration

There are two differences in the way fixed penetration is measured compared with broadband penetration. Firstly dial-up users are included in the penetration figures and secondly mobile broadband users are excluded from this figure. The measure covers the number of fixed internet users within each country per 100 people. The data for fixed internet penetration were gathered from the OECD communications outlook 2003, starting from 1999 through to 2003.

The fixed internet penetration variable is lagged in the model in order to capture learning effects. It is expected that there will be a positive relationship between broadband and fixed internet penetration. As more consumers use the internet they learn about the different benefits and services the internet has to offer. Examples of these benefits may include, but are not limited to, internet streaming services, relatively inexpensive forms of communication (VoIP, video and chat), international news and publications, and, access to new sources of

[20] The difference between this data, and, Cadman and Dineen's data is that the EU data is that the incumbent's share is separated from the share data and that bitstream and ULL are treated separately. The OECD data use DSL as a category instead.

information and public opinions (blog sites like myspace® and MSN space, and wiki sites such wikipedia). In order to utilise the benefits from the internet fully, consumers will upgrade from dial-up to broadband services.

3.5 Unbundled Local Loop Dummy

Given that the HHI is not a perfect measure of competition and does not split up the incumbent's share of the market as in Cadman and Dineen, the model uses a dummy to capture further effects of competition from the unbundling of the local loop. Unbundling ensures *'that new facility-based entrants and Internet service providers can compete with incumbents in offering broadband access and services'*[21]. It achieves this through reducing barriers to entry by lowering entry costs into the broadband market. The dummy variable equals one when local loop unbundling is available to access seekers, otherwise it is zero. The information on when local loop unbundling occurred was obtained from the OECD's Communications Outlook database and from a paper generated by the OECD's working party on telecommunication and information services policies.

Given that allowing access to the local loop is likely to promote competition and investment into broadband by other firms, it is expected that there will be a positive relationship between the unbundled local loop dummy and broadband penetration.

3.6 Fixed Effects and Covariance Methods

In order to capture different country effects such as land mass, rural urban mix and other country specific effects, a fixed cross-section specific effect was used in the model. This follows the approach used by Cadman and Dineen and each of the country's coefficients in the model are reported in the appendices. A good example of a country effect in the case of broadband is referred to in a paper by Freiden (2005, p. 604). He stated that:

> Geographically small nations, with little rugged terrain and high incomes can achieve ubiquitous digital network access on a timely and efficient basis, perhaps even without having to create a sizeable fund for subsidising service to rural and low-income residents. Similarly, with a population skewed to youthful, urban apartment dwellers, telecommunications carriers can more readily introduce new services and achieve comparatively higher penetration rates than what carriers in other nations would achieve.

Other examples of differences between countries that may be captured by fixed effects are the different countries attitudes towards broadband. For example in Korea there is a pervasive online culture with video on demand, online gaming and other activities involving broadband are commonplace in Korea. Successful online gamers are given celebrity status and large tournaments for prize money are commonplace.[22]

White's cross-section standard errors and covariance were calculated to factor for correlation in the residuals between countries.[23] Due to the lack of time periods in the model White's period standard errors and covariance were not used.

---

[21] Refer to OECD Working Party, p. 4.

[22] Refer to Wallsten (2006), p. 8 and Kanellos (2004).

[23] Refer to Appendix 2 to see correlation in residuals between cross-sections.

3.7 Statistical Model and Other Considerations

Using the above variables, the statistical model is specified as follows:

$$\log(PEN_{it}) = c_i + \beta_1 \log(HHI_{it}) + \beta_2 \log(GDPPC_{it}) + \beta_3 \log(FINT_{it-1}) + \beta_4 \log(PEN_{it-1}) + \beta_5 (ULL_{it}) + \varepsilon_{it}$$

Where, subscript *i* denotes the country, *t* denotes time, *c* is the constant, PEN is the level of penetration, HHI is the concentration index, GDPPC is GDP per capita and FINT is fixed internet penetration. Subscript *t*-1 denotes that the variable has been lagged by one period.

Due to the short time period and unbalanced nature of the data, tests for non-stationarity were unable to be performed. It must be noted that it might be possible that the GDP per capita, broadband penetration and fixed internet penetration data suffer from non-stationarity. When more data becomes available further conclusions on the stationarity of data could possibly be drawn.

Given there is a lagged dependent variable model, it may also be possible that the model takes the form of a partial adjustment model. A partial adjustment infers that there is an optimal level of broadband penetration in the long run and that an adjustment is made to meet the optimal level. This arises from the fact that adjustment costs will constrain consumers from reaching the optimal level of penetration in the current period. Therefore in this case realised values of broadband penetration would *'be used as a "backcast" of what the rational decision maker had expected.'*[24] If this is the case, a possible model specification would be:

$$\begin{aligned}\log(PEN_{it}) = {} & \lambda c_{it} + \lambda\beta_1 \log(HHI_{it}) + \lambda\beta_2 \log(GDPPC_{it}) + \lambda\beta_3 \log(FINT_{it-1}) + \lambda\beta_4 (ULL_{it}) \\ & + (1-\lambda)\log(PEN_{it-1}) + \varepsilon_{it}\end{aligned}$$

where $(1-\lambda)$ measures the rate at which a country adapts to the optimal level of broadband penetration over the single lagged period.

[24] Refer to Kennan (1979), p. 1,453.

4. Results and Discussion

The following table sets out the results from the regression analysis:

Table 1: Regression Results

Dependent Variable: LOG(PEN)
Method: Panel EGLS (Cross-section weights)
Sample (adjusted): 2001 2004
Cross-sections included: 30
Total panel (unbalanced) observations: 117
Linear estimation after one-step weighting matrix
White cross-section standard errors & covariance (degrees of freedom corrected)

Variable	Coefficient	Std. Error	t-Statistic	Probability
C	-55.22632	2.441571	-22.61917	0.0000
LOG(HHI)	***-0.184164	0.054943	-3.351936	0.0012
LOG(GDPPC)	***5.571821	0.250062	22.28174	0.0000
LOG(FINT(-1))	***0.159914	0.018469	8.658306	0.0000
LOG(PEN(-1))	***0.501104	0.017231	29.08167	0.0000
ULL	***0.322922	0.016541	19.52305	0.0000
Effects Specification	Cross-section fixed (dummy variables)[25]			
Weighted Statistics				
R-squared	0.988487	Mean dependent variance	3.271768	
Adjusted R-squared	0.983713	S.D. dependent variance	4.889144	
S.E. of regression	0.44892	Sum squared residuals	16.52538	
F-statistic	207.0648	Durbin-Watson statistic	1.984766	
Probability (F-statistic)	0.000000			

*, **, *** statistically significant at the 10%, 5% and 1% levels, respectively.

As can be seen from the above table, all the variables in the model are statistically significant, with all the variables being significant at the one per cent level except the concentration measure. While the adjusted R-squared is 98 per cent, it should also be noted that the model contains a lagged dependent variable, which more than likely contributes to the high R^2. The following five subsections analyse each of the variables individually with all other things being equal in the model.

4.1 Broadband Penetration

The previous year's penetration level has a positive effect with a one per cent increase leading to a 0.5 per cent increase in the next year's penetration level. This would suggest, as expected, that the use of broadband is a relatively new technology to the general public. In other words broadband is at the pioneering stage of the technology diffusion curve. If a partial adjustment model is assumed, the coefficient would mean that there is a 0.5 adjustment

[25] Refer to Appendix 3 for country specific coefficients, residuals graph and fixed effects testing.

occurring to meet the optimal level of broadband penetration. As a result, the other coefficients in the model would be adjusted upwards accordingly in the model. The adjusted figures will be noted in parentheses.

4.2 Herfindahl-Hirschman Index

Cadman and Dineen found a coefficient of 1.66 between concentration and broadband penetration. Although the measure used in Cadman and Dineen's work had data on incumbent shares and covered EU nations, this model only finds the effect to be of the order of magnitude of 0.184 (0.092). The model finds that a one per cent decrease in concentration will lead to a 0.18 per cent increase in broadband penetration. Apart from using a slightly different measure, this could also be explained by the use of other explanatory factors in the model and that some of the effects of competition are captured by the dummy variable.

4.3 Real Gross Domestic Product per Capita

A one per cent increase in GDP per capita leads to an increase in broadband penetration of 5.5 (2.75) per cent. As explained earlier, a coefficient larger than one would suggest that broadband is a superior good and consumption of broadband is likely to increase at a greater rate than an increase in income. The above result confirms the *a priori* expectations of the relationship between income and broadband penetration.

4.4 Fixed Internet Penetration

As expected the coefficient for fixed internet penetration is positively signed suggesting that learning effects exist. For a one per cent increase in fixed internet penetration in the previous year there is a 0.16 (0.08) per cent increase in broadband penetration. It must be noted that this variable might also be capturing part of the technology diffusion effect as part of the variable includes fixed broadband.

4.5 Unbundled Local Loop Dummy

In countries where the local loop had been unbundled penetration levels were found to be 0.32 (0.16) per cent higher than in countries where the local loop was not unbundled in a given period. This dummy is capturing part of the effects of competition. As previously mentioned, unbundling the local loop reduces barriers to entry by lowering entry costs into the broadband market. The increased number of firms in the market creates competition and therefore lower prices, which increases the level of demand for broadband services.

In the data only two countries – New Zealand and Mexico – did not unbundle their local loop over the recorded period. As of December 2005 the broadband penetration in these countries is 8.1 and 2.2 respectively which is well below the OECD average of 13.6. As mentioned previously in section 2.1.5, New Zealand relied upon satellite broadband and constrained unbundled bitstream in 2004 as the main forms of competition in broadband. As for Mexico, it has a dominant carrier in Telemex which has argued that local loop unbundling is not feasible at this point in time.[26]

[26] Refer to Adams (2006).

4.6 Limitations of the Model

As previously mentioned the concentration measure used in this model is slightly different from Cadman and Dineen's concentration measure and therefore this may explain partly why the effect of concentration is reduced in the model. It is unlikely that it explains such a large difference between the figure reported in Cadman and Dineen's paper. Before discussing the results further, some other limitations of the model must be pointed out. These limitations arise mainly due to the unavailability of data as a result of the relatively short period of time broadband services have been in existence and the lack of data for other explanatory variables. For example fixed internet penetration figures could only be obtained up to 2003. Despite broadband penetration figures being released every six months, variables such as GDP per capita measured in US dollars at PPP are only released on a yearly basis. Finally, there were variables such as the average price of broadband services, substitutes, the costs of providing broadband services and other regulatory variables which may have been useful in explaining broadband penetration but the data were unavailable.

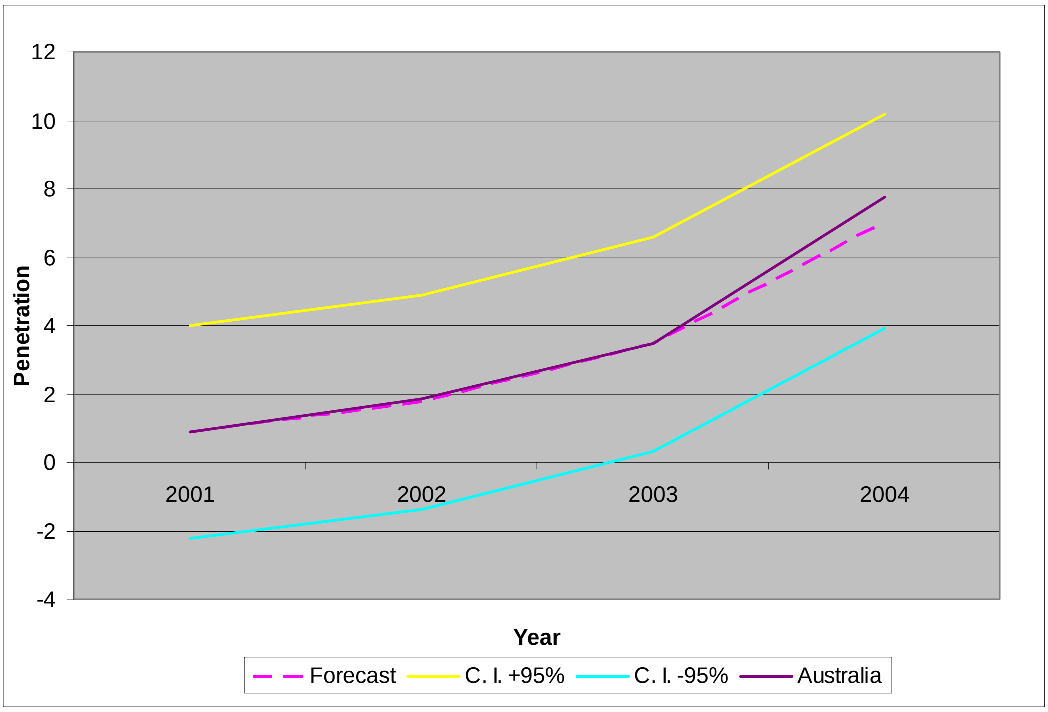
In the case of the model used in this paper, the effects of pricing are likely to be captured in the HHI and unbundled local loop variables of the model. As the HHI and unbundled local loop dummy variables were used to measure competition within OECD nations, it can be implied that broadband prices are lower in countries that have less concentration and have unbundled their local loop. Other regulatory variables which would be helpful in studying determinants of broadband penetration include broadband and complementary[27] subsidy schemes, the existence of any arbitration/litigation in the area of broadband, and whether governments apply light or heavy-handed regulations on providers.

5. Australia's Performance

By following similar methodology used in the NECG report the following findings were made in relation to Australia. The following figure illustrates Australia's actual broadband penetration plotted against the forecast level of broadband penetration derived from the results of the model.

[27] For example computer subsidy schemes in Korea as mentioned in section 2.1.4 have been noted as a possible factor in Korea's world-leading broadband performance.

Figure 2: Australia's Actual Penetration Plotted Against Forecast Penetration



As figure 2 illustrates, Australia's performance in broadband penetration is on par with the rest of the OECD and falls well within the confidence intervals. When compared to the point forecast, Australia has begun to out perform the OECD average. These results are similar to those of NECG in 2003 and would suggest that it is a little too early to be concerned with Australia's broadband penetration performance. It must be noted that the NECG's report focused on cable penetration in Australia, as at the time copper-cable ownership was an important issue due to the incumbent owning both types of networks. As can be seen by Australia's latest penetration figures, cable is no longer a technology which dominates the broadband market in Australia.[28] When comparing the shape of the above curve and penetration size to figure 1, it can be seen that the current rate of broadband fits well within the early stages of technology diffusion as the following figure illustrates.

[28] As of December 2005 cable only holds 20 per cent of the broadband market compared to the 75 per cent it held back in 2000.

Figure 3: Possible Australian S-shaped Diffusion Curves

Following from the NECG report, the s-shaped diffusion equation[29] was used to illustrate potential diffusion paths for broadband penetration in Australia.[30] This was achieved by setting saturation levels at current internet penetration levels,[31] with a 20 per cent upper and lower bound, and then solving for the duration and midpoint in the equation in order to fit the broadband penetration data used in the model. As can be seen from the above figure, Australia's current broadband penetration, illustrated by the dotted line, is likely to have reached critical mass and is entering into a strong growth period.

However it must be noted that the NECG report assumed that no government intervention would occur and that therefore broadband penetration is driven by other factors. In the context of Australia this has not occurred as the government has introduced the already-mentioned subsidy schemes and continued to regulate access pricing.

6. Conclusions

The estimated model is useful in drawing some conclusions about the factors that drive broadband penetration across OECD nations. All of the variables in the model are statistically significant and therefore it would seem that the variables all have a role to play in determining broadband penetration.

The main conclusions that can be drawn from the analysis are:

---

[29] Refer to NECG (2003), p. 26.

[30] Refer to Appendix for table and parameters used.

[31] Refer to Miniwatts Marketing Group (2006).

6.1 Broadband is a Superior Good

The model estimated that broadband is a superior good, where broadband is viewed as a luxury item by consumers.[32] An increase in GDP per capita of one per cent, all other things being equal, will increase broadband penetration by 5.57 per cent. GDP per capita is by far the strongest driving force of broadband penetration estimated in the model.

6.2 Competition Increases Broadband Penetration

The magnitude of the effect of concentration on broadband penetration is relatively small when compared to Cadman and Dineen's work (0.18 compared to 1.66). Several reasons may explain why the magnitude was lower in this paper, including the presence of other explanatory variables, the way the shares were split up and the fact that the ULL dummy captures some of the effects of competition.

Unbundling the local loop further reinforces the idea that competition assists with broadband penetration. By allowing entrants to have access to the local loop, the model estimates that broadband penetration increases by 0.32 per cent from the point of unbundling. Therefore a reduction in concentration or an increase in competition generally increases broadband penetration.

6.3 Learning Effects Exist between Dial-up and Broadband

Consumers are switching from dial-up to broadband as they learn about the benefits of the Internet and wish to fully maximise the value of internet usage. As estimated in the model, all other things being equal, a one per cent increase in fixed internet penetration in the previous year leads to a 0.16 per cent increase in broadband penetration.

6.4 Australia's Broadband Penetration is Above the OECD Average and is Reaching Critical Mass

Following a similar methodology to NECG's paper, Australia's broadband penetration levels are well within the expected OECD average according to the estimated model. It is likely that concern about Australia's poor broadband performance has been exaggerated. By looking at several examples of S-shaped diffusion curves it would appear that Australia's current broadband levels are reaching or have reached the critical mass stage of technology diffusion.[33]

However the limitations of the study as noted earlier mean that the results should be treated as preliminary work, with a view to a more comprehensive study being conducted as more data become readily available. Despite the promising results that arose from the analysis with regard to Australia's performance compared to the OECD, it appears that continued government involvement and cooperation with industry will help to ensure that Australia maintains or improves its position in broadband penetration within the OECD.

---

[32] For an explanation of a superior good please refer to section 3.3 on page 13.

[33] For an explanation of critical mass please refer to section 2.2 on page 10.

Appendices

Appendix 1: HHI Calculations

Appendix 2: Correlation in Residuals

Appendix 3: Cross-country Constants, Residuals and Fixed Effects Testing

Appendix 4: S-shaped Broadband Diffusion Curves

Appendix 1: HHI Calculations

Remember that the HHI is calculated as $HHI = \sum_{i=1}^{f} S_i^2$, here are some examples of how the index may vary:

1. Perfect Monopoly

$1^2 = 1$

2. Perfect Duopoly

$0.5^2 + 0.5^2 = 0.25 + 0.25 = 0.5$

3. Perfect Triopoly

$$\left(\tfrac{1}{3}\right)^2 + \left(\tfrac{1}{3}\right)^2 + \left(\tfrac{1}{3}\right)^2 = \tfrac{1}{9} + \tfrac{1}{9} + \tfrac{1}{9} = \tfrac{1}{3}$$

4. Ten firms with equal share

$0.1^2 + 0.1^2 + 0.1^2 + 0.1^2 + 0.1^2 + 0.1^2 + 0.1^2 + 0.1^2 + 0.1^2 + 0.1^2 = 0.01 + 0.01 + 0.01 + 0.01 + 0.01 + 0.01 + 0.01 + 0.01 + 0.01 + 0.01 = 0.1$

5. One dominant firm with nine smaller firms

$$\left(\tfrac{7}{10}\right)^2 + \left(\tfrac{1}{30}\right)^2 + \left(\tfrac{1}{30}\right)^2 + \left(\tfrac{1}{30}\right)^2 + \left(\tfrac{1}{30}\right)^2 + \left(\tfrac{1}{30}\right)^2 + \left(\tfrac{1}{30}\right)^2 + \left(\tfrac{1}{30}\right)^2 + \left(\tfrac{1}{30}\right)^2 + \left(\tfrac{1}{30}\right)^2 =$$

$$0.49 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 + 0.001 = 0.49\dot{9}$$

(Note that the result here is approximately the equivalent of a perfect duopoly)

Appendix 2: Correlation in Residuals

	AUS	AUT	BEL	CAN	CHE	CZR	DNK	ESP	FIN	FRA	GBR	GER	GRE	HUN	ICE	IRE
AUS	1.0000	-0.8749	-0.8995	-0.8927	-0.5141	0.5709	-0.8521	-0.7224	-0.0417	0.3256	-0.0092	-0.5973	0.6057	-0.7852	-0.9788	0.5861
AUT		1.0000	0.9736	0.9987	0.4705	-0.1238	0.9850	0.9614	-0.3545	-0.2259	-0.0679	0.8937	-0.8620	0.7595	0.7921	-0.8272
BEL			1.0000	0.9695	0.6553	-0.1593	0.9923	0.8859	-0.1524	-0.4390	0.1512	0.7838	-0.7260	0.6404	0.7973	-0.6776
CAN				1.0000	0.4502	-0.1698	0.9774	0.9546	-0.3448	-0.2053	-0.0945	0.8854	-0.8621	0.7879	0.8192	-0.8309
CHE					1.0000	-0.0300	0.6059	0.2927	0.4913	-0.9654	0.8441	0.1370	0.0051	-0.1046	0.3643	0.0862
CZR						1.0000	-0.0567	0.0811	-0.4918	0.0281	0.1388	0.1897	-0.0774	-0.4937	-0.7037	-0.0386
DNK							1.0000	0.9303	-0.2630	-0.3778	0.0994	0.8474	-0.7861	0.6402	0.7417	-0.7375
ESP								1.0000	-0.5928	-0.0346	-0.2241	0.9823	-0.9545	0.7446	0.6364	-0.9258
FIN									1.0000	-0.6638	0.7083	-0.7330	0.7659	-0.4418	0.0564	0.7850
FRA										1.0000	-0.9481	0.1207	-0.2648	0.3259	-0.1889	-0.3427
GBR											1.0000	-0.3484	0.5006	-0.6096	-0.1239	0.5751
GER												1.0000	-0.9828	0.7260	0.5198	-0.9623
GRE													1.0000	-0.8209	-0.5647	0.9959
HUN														1.0000	0.8423	-0.8487
ICE															1.0000	-0.5630
IRE																1.0000
ITA																
JAP																
KOR																
LUX																
MEX																
NED																
NOR																
NZL																
POL																
POR																
SVR																
SWE																
TUR																
USA																

	ITA	JAP	KOR	LUX	MEX	NED	NOR	NZL	POL	POR	SVR	SWE	TUR	USA
AUS	0.8127	-0.8806	-0.9223	0.3228	-0.2183	0.9592	0.8274	-0.3560	0.1923	0.6100	0.2312	-0.7796	0.6074	-0.9452
AUT	-0.8907	0.6094	0.9907	-0.0374	0.6599	-0.8791	-0.9952	0.5339	-0.2572	-0.5750	-0.2759	0.9723	-0.7965	0.7177
BEL	-0.9665	0.7336	0.9609	0.0331	0.5440	-0.9502	-0.9686	0.6648	-0.4134	-0.7438	-0.4355	0.8947	-0.8758	0.8118
CAN	-0.8776	0.6257	0.9963	-0.0812	0.6340	-0.8845	-0.9890	0.4977	-0.2273	-0.5572	-0.2479	0.9712	-0.7694	0.7347
CHE	-0.8186	0.7279	0.4279	0.3907	0.0480	-0.7283	-0.4846	0.8998	-0.8127	-0.9921	-0.8284	0.2705	-0.8288	0.6783
CZR	0.0554	-0.6697	-0.2517	0.7445	0.5931	0.4111	0.0269	0.3719	-0.2545	0.0701	-0.2065	-0.0291	-0.2327	-0.6513
DNK	-0.9529	0.6438	0.9611	0.0821	0.6438	-0.9043	-0.9891	0.6699	-0.3959	-0.6969	-0.4127	0.9295	-0.8869	0.7341
ESP	-0.7829	0.3677	0.9336	0.0322	0.8314	-0.7150	-0.9734	0.4671	-0.1602	-0.3997	-0.1671	0.9935	-0.7386	0.4998
FIN	0.0011	0.5039	-0.3109	-0.0541	-0.8450	-0.1327	0.3934	0.1231	-0.3448	-0.4202	-0.3701	-0.5584	0.0777	0.3604
FRA	0.6407	-0.6439	-0.1858	-0.4190	0.1623	0.5558	0.2399	-0.8231	0.8130	0.9269	0.8263	-0.0103	0.6709	-0.5563
GBR	-0.3930	0.3938	-0.1230	0.5346	-0.2714	-0.2629	0.0395	0.7350	-0.7869	-0.7703	-0.7888	-0.2665	-0.4883	0.2769
GER	-0.6634	0.1914	0.8590	0.0469	0.9014	-0.5721	-0.9136	0.3720	-0.0606	-0.2433	-0.0603	0.9680	-0.6460	0.3359
GRE	0.5653	-0.1692	-0.8484	0.1009	-0.8457	0.5284	0.8686	-0.2020	-0.0903	0.1100	-0.0871	-0.9566	0.5108	-0.3226
HUN	-0.4238	0.4388	0.8248	-0.5529	0.3904	-0.6031	-0.7088	-0.1406	0.3167	-0.0184	0.2887	0.8112	-0.2130	0.5668
ICE	-0.6763	0.8535	0.8637	-0.4803	0.1043	-0.8859	-0.7291	0.1609	-0.0355	-0.4631	-0.0785	0.7118	-0.4322	0.9185
IRE	0.4994	-0.1366	-0.8224	0.1636	-0.8162	0.4846	0.8286	-0.1124	-0.1675	0.0311	-0.1636	-0.9342	0.4324	-0.2932
ITA	1.0000	-0.7441	-0.8576	-0.2059	-0.4812	0.9316	0.8988	-0.8254	0.5947	0.8814	0.6130	-0.7742	0.9554	-0.7904
JAP		1.0000	0.6614	-0.2413	-0.1711	-0.9087	-0.5564	0.4358	-0.3866	-0.7749	-0.4304	0.4259	-0.5474	0.9870
KOR			1.0000	-0.1512	0.5778	-0.8962	-0.9727	0.4434	-0.1870	-0.5376	-0.2111	0.9597	-0.7260	0.7689
LUX				1.0000	0.3422	0.0991	-0.0419	0.6256	-0.7275	-0.3384	-0.6863	-0.0621	-0.4404	-0.2720
MEX					1.0000	-0.2558	-0.7177	0.4220	-0.1183	-0.1188	-0.0964	0.7728	-0.5916	-0.0412
NED						1.0000	0.8509	-0.5994	0.4224	0.8051	0.4562	-0.7479	0.7833	-0.9519
NOR							1.0000	-0.5853	0.2960	0.5850	0.3102	-0.9732	0.8329	-0.6654
NZL								1.0000	-0.8236	-0.8975	-0.8199	0.4047	-0.9362	0.4248
POL									1.0000	0.7823	0.9983	-0.1101	0.6919	-0.3346
POR										1.0000	0.8005	-0.3834	0.8708	-0.7430
SVR											1.0000	-0.1220	0.6960	-0.3778
SWE												1.0000	-0.6968	0.5587
TUR													1.0000	-0.5863
USA														1.0000

Appendix 3: Cross-country Constants, Residuals and Fixed Effects Testing

Dependent Variable: LOG(PEN?)
Method: Pooled EGLS (Cross-section weights)
Date: 05/26/06 Time: 11:37
Sample (adjusted): 2001 2004
Included observations: 4 after adjustments
Cross-sections included: 30
Total pool (unbalanced) observations: 117
Linear estimation after one-step weighting matrix
White cross-section standard errors & covariance (d.f. corrected)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-55.22632	2.441571	-22.61917	0.0000
LOG(GDPPC?)	5.571821	0.250062	22.28174	0.0000
LOG(HHI?)	-0.184164	0.054943	-3.351936	0.0012
LOG(FINT?(-1))	0.159914	0.018469	8.658306	0.0000
LOG(PEN?(-1))	0.501104	0.017231	29.08167	0.0000
ULL?	0.322922	0.016541	19.52305	0.0000
	Fixed Effects (Cross)			
AUS--C	-1.322236			
AUT--C	-1.241045			
BEL--C	-0.673119			
CAN--C	-0.855652			
CHE--C	-1.275757			
CZR--C	1.069554			
DNK--C	-1.060861			
ESP--C	0.22151			
FIN--C	-0.722651			
FRA--C	-0.646478			
GBR--C	-1.036866			
GER--C	-0.476468			
GRE--C	-0.516411			
HUN--C	2.696306			
ICE--C	-0.629982			
IRE--C	-2.63003			
ITA--C	-0.547072			
JAP--C	-0.484763			
KOR--C	1.942777			
LUX--C	-4.302373			
MEX--C	4.722492			
NED--C	-1.010658			
NOR--C	-2.289807			
NZL--C	0.341472			
POL--C	3.643208			
POR--C	1.249794			
SVR--C	2.576802			
SWE--C	-0.789802			
TUR--C	6.704722			
USA--C	-2.177195			

Effects Specification

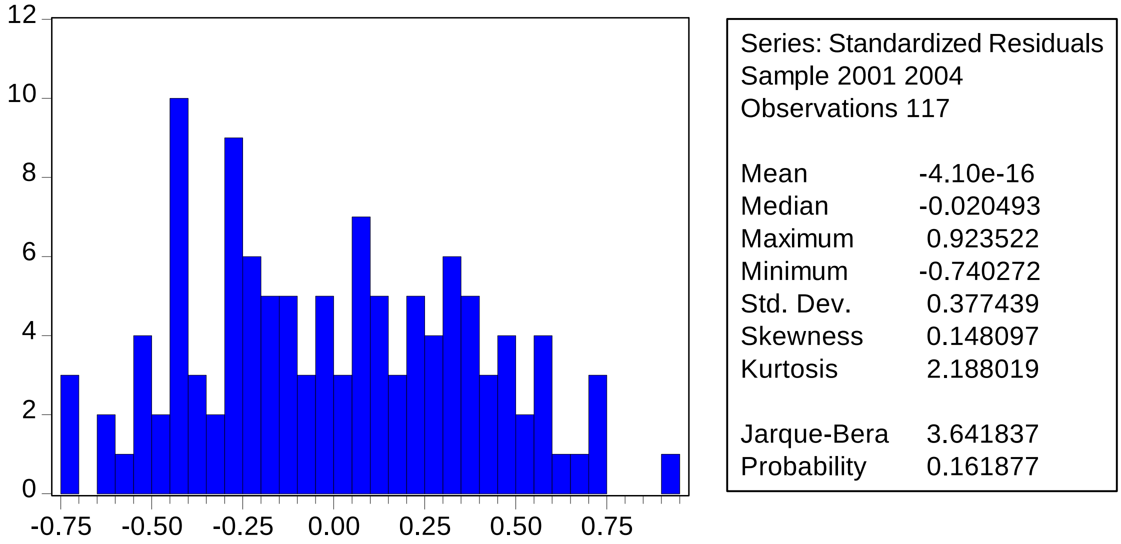
Cross-section fixed (dummy variables)

Weighted Statistics

R-squared	0.988487	Mean dependent var	3.271768
Adjusted R-squared	0.983713	S.D. dependent var	4.889144
S.E. of regression	0.44892	Sum squared resid	16.52538
F-statistic	207.0648	Durbin-Watson stat	1.984766
Prob(F-statistic)	0		

Unweighted Statistics

R-squared	0.986356	Mean dependent var	0.910184
Sum squared resid	19.58393	Durbin-Watson stat	2.275952



Equation: EQ01
Test cross-section fixed effects

Effects Test	Statistic	d.f.	Prob.
Cross-section F	3.839903	(29,82)	0

Cross-section fixed effects test equation:
Dependent Variable: LOG(PEN)
Method: Panel EGLS (Cross-section weights)
Date: 05/31/06 Time: 11:41
Sample (adjusted): 2001 2004
Cross-sections included: 30
Total panel (unbalanced) observations: 117
Use pre-specified GLS weights
White cross-section standard errors & covariance (d.f. corrected)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.31706	0.585816	-3.95527	0.0001
LOG(HHI)	0.006859	0.07363	0.093154	0.9259
LOG(GDPPC)	0.27497	0.067743	4.05899	0.0001
LOG(FINT(-1))	0.071595	0.024577	2.913139	0.0043
LOG(PEN(-1))	0.705135	0.021756	32.41069	0
ULL	0.267031	0.043959	6.074585	0

Weighted Statistics

R-squared	0.971944	Mean dependent var	3.267801
Adjusted R-squared	0.97068	S.D. dependent var	4.743947
S.E. of regression	0.591104	Akaike info criterion	-0.16361
Sum squared resid	38.78387	Schwarz criterion	-0.02196
Log likelihood	15.57101	F-statistic	769.0684
Durbin-Watson stat	1.389089	Prob(F-statistic)	0

Unweighted Statistics

R-squared	0.979054	Mean dependent var	0.910184
Sum squared resid	28.95449	Durbin-Watson stat	2.072428

Appendix 4: S-shaped Broadband Diffusion Curves

Year	Curve 1	Curve 2	Curve 3
2000	0.26715874	0.295049	0.345904
2001	0.60713416	0.661825	0.759495
2002	1.37249238	1.474669	1.652573
2003	3.06636381	3.238111	3.527138
2004	6.67781164	6.893121	7.237952
2005	13.7999993	13.8	13.8
2006	25.9089095	24.83333	23.3806
2007	42.0944688	38.4723	34.07165
2008	57.9614598	50.85766	42.94766
2009	69.4295332	59.3263	48.67935
2010	76.0206567	64.05588	51.80415
2011	79.3204	66.40319	53.35204
2012	80.8583	67.49997	54.08242
2013	81.5512	67.99797	54.41913
2014	81.8586	68.22115	54.5727
2015	81.9941	68.32058	54.64239

Duration	5.32615355	5.403501	5.533661
Saturation	82.1	68.4	54.7
Mid	6.93830992	6.691176	6.368115

References

Adams, G. (2006), 'Why Mexican phones cost a bundle', *New Zealand Herald*, URL: http://subs.nzherald.co.nz/category/print.cfm?c_id=27&objectid=10377782, Accessed on: 3 August 2006.

Broadband Advisory Group (2003), *Australia's Broadband Connectivity*, National Office for the Information Economy.

Cadman, R. and Dineen, C. (2006), Broadband Markets in the EU: The importance of dynamic competition to market growth, Strategy and Policy Consultants Network Ltd.

Coham, J. (2006), DSL Forecast: Sustaining Bandwidth and APRU, Ovum Limited.

Department of Communications, Information Technology and the Arts (2006), *Connect Australia*, Telecommunications Branch, URL: http://www.dcita.gov.au/tel/connect_australia, Accessed on: 5 July 2006.

European Commission (2006), *Activities of European Union – Summaries of Legislation*, Information Society Section, URL: http://europa.eu/scadplus/leg/en/s21012.htm#eEurope, Accessed on: 18 July 2006.

Federal Communications Commission (2006), *Section 706 Advanced Services Inquiry*, Broadband Section, URL: http://www.fcc.gov/broadband/706.html, Accessed on: 25 July 2006.

Frieden, R. (2005), 'Lessons from Broadband Development in Canada, Japan, Korea and the United States', *Telecommunications Policy*, 29, 8, pp. 595-613.

Gray, V., Kelly, T. and Minges, M., (2003), *Broadband Korea: Internet Case Study*, International Telecommunication Union.

Grubesic, T. (2003), 'Inequities in the Broadband Revolution', *The Annals of Regional Science*, 37, 2, pp. 263-289.

Kanellos, M. (2004), *Consumers: Gaming their Way to Growth*, CNET Article, URL: http://news.com.com/Consumers+Gaming+their+way+to+growth+-+Part+3+of+South+Koreas+Digital+Dynasty/2009-1040_3-5239555.html, Acessed on: 11 September 2006.

Kennan, J. (1979), 'The Estimation of Partial Adjustment Models with Rational Expectations', *Econometrica*, 47, 6, pp. 1,441-1,456.

KPMG report (2006), Fostering Investment in Broadband Infrastructure – the Need for Regulatory Certainty, KPMG and Alcatel.

Miniwatts Marketing Group (2006), 'Internet World Stats – Countries with the Highest Internet Penetration Rate', URL: http://www.internetworldstats.com/top25.htm, Accessed on: 1 June 2006.

Ministry of Information and Communications (1999), URL: http://www.mininnovazione.it/eng/intervento/banda_larga/corea_cyber.htm, Accessed on: 2 August 2006.

Ministry of Information and Communications (2002), *e-Korea Vision 2006*, MIC News, URL: http://www.ipc.go.kr/ipceng/policy/vision_2006.jsp, Accessed on: 2 August 2006.

Multimedia Victoria (2006), *Economic Impacts of Broadband in Victoria*, Broadband Access Office, URL: http://www.mmv.vic.gov.au/broadband/Economicbenefits, Accessed on: 22 May 2006.

National Computerization Agency paper (2002), *Broadband in Korea - Korea Information Infrastructure*, Informization Promotion Committee.

New Zealand Government (2006), *Government Moves Fast to Improve Broadband*, Press release on New Zealand government's Beehive website, URL: http://www.beehive.govt.nz/ViewDocument.aspx?DocumentID=25636, Accessed on: 1 August 2006.

OECD paper (2003), *Broadband Driving Growth: Policy Responses*, Directorate for Science, Technology and Industry – Committee for Information, Computer and Communications Policy.

OECD Telecommunications Database (2005), *OECD Communications Outlook 2005*, OECD.

OECD Working Party (2002), *Developments in Local Loop Unbundling*, OECD Working Party on Telecommunication and Information Services Policies.

OECD Working Party (2004), *The Development of Broadband Access in Rural and Remote Areas*, OECD Working Party on Telecommunication and Information Services Policies.

Ortt, J. (2005), 'Chapter 7 – Development and Diffusion of Breakthrough Communication Technologies', *Managing Technology and Innovation: An introduction*, Abingdon, Oxon; New York: Routledge, pp. 130-148.

Papacharissi, Z. and Zaks, A. (2006), 'Is Broadband the Future? An Analysis of Broadband Technology Potential and Diffusion', *Telecommunications Policy*, 30, 1, pp. 64-75.

Telecom New Zealand (2006), 'Telecom to Separate Wholesale and Retail Operations', *Australian Stock Exchange Announcement*, URL: http://www.asx.com.au/asx/research/CompanyInfoSearchResults.jsp?searchBy=asxCode&allinfo=on&asxCode=TEL&companyName=&principalActivity=&industryGroup=NO#headlines, Accessed on: 14 August 2006.

Wallsten, S. (2006), *Broadband and Unbundling Regulations in OECD Countries*, AEI-Brookings Joint Centre for Regulatory Studies, Working Paper 06-16, June 2006.