Quantifying differences between broadband penetration rates for Australia and other countries

The issue of broadband internet access is an important one for public policy makers in Australia and elsewhere. Broadband internet access has grown very rapidly in the last few years, however penetration rates appear to be very uneven across OECD countries. This has raised questions about the nature of the competitive, regulatory and policy environment in OECD countries and the possible influence on penetration rates.

The OECD has compiled a very useful data base on DSL and cable penetration rates for some 30 countries over the period 1997 to 2002. By compiling the data and making it available to us, the OECD has enabled us to examine patterns of broadband penetration and assess possible explanatory factors in more detail.

In particular, we have been able to use the OECD data to examine the following hypotheses:

(1) that Australian broadband penetration is low by OECD standards; and

(2) that a factor explaining low levels of broadband penetration in some countries is cross ownership of cable and copper networks by the incumbent telecommunications carrier.

The OECD data show that total broadband access per 100 inhabitants in Australia was 1.9 in 2002 compared to an OECD average of 4.9.[1] The OECD data also show a very broad range of penetration rates from near zero to 11.7 for Canada and 21.4 for Korea.

In examining the data it is important to recognise that broadband technology is in the very early stages in terms of the typical diffusion process that is observed with a new technology.

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1 OECD, 2003, *Broadband and Telephony Services Over Cable Television Networks,* Working Party on Telecommunication and Information Services Policies, Table 4, p.11.

2 OECD, 2003, p. 4.

Typically the take up of a new technology is often slow at first and then accelerates quickly before stabilising in the mature stage of the process – this pattern is often characterised by an S-type diffusion curve. A wide range of S-type patterns is possible depending on economic circumstances in each country and the inherent randomness that characterizes technology diffusion processes, particularly in the early stages of the process.

In understanding how these processes play themselves out, it is important to note that the nature and speed of diffusion will depend on a range of economic variables such as the age of the broadband service, per capita income levels and the supply of complementary goods (in this case, most importantly pay-TV penetration). We have estimated a simple statistical model that has confirmed the importance of these variables for up to 28 countries for each of the years 2000, 2001 and 2002.

The model was also used to test the two hypotheses as outlined above. The findings are as follows:

(1) when the influence of relevant basic economic variables is taken into account, Australia's broadband penetration rate is not significantly lower than the OECD average in a formal statistical sense; and

(2) cross ownership of the largest cable and copper networks by the incumbent carrier (in Australia, Denmark, Sweden and Portugal) does not have a statistically significant adverse impact on broadband penetration.

We have also been able to demonstrate that if the diffusion process for broadband services follows the typical S-type pattern over time, then given the very limited number of data points (that reflect the very early stages of the diffusion process) one cannot make reliable inferences of the outcomes in just a few years time. There is, in other words, no reason to believe that Australian levels of broadband take-up will not converge to high levels of penetration, as (after a relatively slow start) they have in other technologies such as mobile telephony.

Appendix: Empirical Assessment of Broadband Penetration Rates

1 Background and purpose

The OECD has provided data showing that total broadband access per 100 inhabitants in Australia was 1.9 in 2002 compared to an OECD average of 4.9.[3] The OECD data show a very broad range of penetration rates from near zero to 11.7 for Canada and 21.4 for Korea.

The OECD data base is a valuable source of information for assessing patterns of broadband penetration and underlying determinants. We have been able to use the data to examine possible factors that could explain the profiles of penetration rates and test a number of hypotheses.

The structure of this appendix is as follows. We start in section 2 by summarising some general results in the economic literature on the analysis of technology diffusion processes. This literature shows that diffusion processes are affected by a number of economic variables (such as income) that differ between countries. Assessments of whether rates of technology are 'high' or 'low' should normally be made taking these variables into account.

Given this background, in section 3 we present a model of broadband diffusion that explains well the international pattern reflected in the OECD data set. On the basis of this modelling, we show that Australian levels of broadband diffusion are not statistically lower than the OECD experience would lead one to expect.

In section 4, we then use the model to consider whether HFC/copper cross-ownership lowers broadband penetration rates. We find that this is not the case. Indeed, to the extent to which HFC/copper cross-ownership has any effect, it tends to increase broadband penetration levels.

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3 OECD, 2003, *Broadband and Telephony Services Over Cable Television Networks,* Working Party on Telecommunication and Information Services Policies, Table 4, p.11.

4 OECD, 2003, p. 4.

In section 5 we examine the effect of the aggressive 'pro-diffusion' policies adopted by Korea and Canada. We find that these countries have levels of penetration that are significantly higher than the OECD pattern would lead one to expect. However, this effect seems to be diminishing rapidly over time, as other countries catch up.

Finally, in section 6 we examine whether observed rates of broadband take-up in Australia reveal a pattern that, left to its own devices, would result in low levels of penetration. We demonstrate that if the diffusion process follows a typical S-type diffusion curve pattern, this inference would be highly unlikely.

Two annexes present the technical aspects of our methods and results in greater detail.

2 The analysis of technology diffusion rates

Rigorous economic analysis of the rate at which diffusion of technologies occurs has a long history, with the work of Griliches[5] in the late 1950's first clearly highlighting the fact that diffusion rates of new technologies are significantly affected by a range of variables that shape both the cost of and the return to innovation. Subsequent work by a wide range of authors has confirmed the importance of taking account of these factors in explaining differences between countries and within countries, as between regions, in the rate at which new technologies are taken up.[6]

This finding, which is uncontroversial in economics, implies that in assessing the OECD claims that Australia's performance, as reflected in broadband penetration rates, is well behind that of other countries it is important to take account of a number of basic economic considerations. More specifically, factors such as the age of the broadband service, recent changes to the technology that make it more accessible, GDP per capita, pay TV penetration and the availability or otherwise of substantial subsidies to broadband use, can all be

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5 Zvi Griliches (1957) "Hybrid Corn: An Exploration in the Economics of Technological Change." Reprinted in *Technology, Education, and Productivity* (1988). New York: Basil Blackwell.

6 E. M. Rogers (1995). *Diffusion of innovations* (4th ed.). New York: The Free Press.

presumed to influence the rate at which broadband technology is taken up. It is clearly important to take account of these variables in assessing whether Australia's diffusion rate is significantly behind that in the rest of the OECD as a result of the structure of cable ownership.

It is also relevant to recognise that the process of technology diffusion involves an inherent element of randomness, accentuated by errors (that can be substantial) in the measurement of take-up rates.[7] This implies that even the most completely specified model will not fully explain observed differences in diffusion rates. Importantly, however, it also implies that assessments of whether there is indeed a substantial lag in the Australian take-up of broadband need to consider whether any difference which there might be between take-up rates in Australia and those elsewhere are statistically significant. If they are not, then no conclusions can properly be drawn about whether take-up rates in Australia are lower, higher or equal to those elsewhere.

The random element in rates of diffusion is likely to be especially high in the relatively early stages of the diffusion process. Indeed, historical experience strongly suggests a mean reversion element in diffusion levels, in which countries whose institutional arrangements permit markets to function efficiently catch up with early leaders. Additionally, there is some evidence that at least as between the advanced market economies, catching up occurs sooner than it used too. All of this suggests that countries which may seem to have low diffusion rates at early stages in the technology life cycle may ultimately have penetration levels no lower, or even higher, than average.[8] As a result, an additional issue which warrants examination is whether the current levels of penetration in Australia are or are not consistent with a S-curve of diffusion which ultimately attains high levels.

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7 There can also be a systematic element in these errors. For example, Australia appears to define 'broadband' somewhat more narrowly than other countries and hence appears to have relatively lower penetration rates than would be shown in an 'apples for apples' comparison.

8 See for example John Cantwell (1995) "The Globalization of Technology: What Remains of the Product Cycle Model?" Cambridge Journal of Economics 19(1):155-74 and more generally Robert Barro and Xavier Sala-I-Martin (1999) *Economic Growth* Cambridge, MA: The MIT Press.

In short, economic analysis has shown over a period of many years that:

- the rate at which new technologies diffuse is affected by a range of basic economic factors. International comparisons of these rates need to take account of these factors in seeking to explain any individual country's performance;

- there is also a substantial element of randomness in diffusion rates, especially at the early stages of the diffusion process. Assessments of whether an individual country's diffusion rate is high or low relative to the international average also need to take account of this random element, and focus on whether observed differences are or are not statistically significant; and

- despite differences in diffusion rates at the earlier stages of the innovation process, historical experience points to the possibility of rapid catching up – as occurred in the 1990's, for example, with Australia's use of mobile telecommunications. Inferences about whether current penetration levels for broadband are a source of concern should therefore also consider whether they are or are not consistent with a diffusion process that ultimately leads to high levels of use.

3 Taking account of different technology vintages and relative income levels

So as to address these issues, a simple statistical model of broadband penetration was estimated based on data for up to 28 countries for each of the years 2000, 2001 and 2002.[9] The model, which is set out in **Annex A**, found that broadband penetration was explained by the age of the technology, real GDP per capita and the penetration of Pay TV.

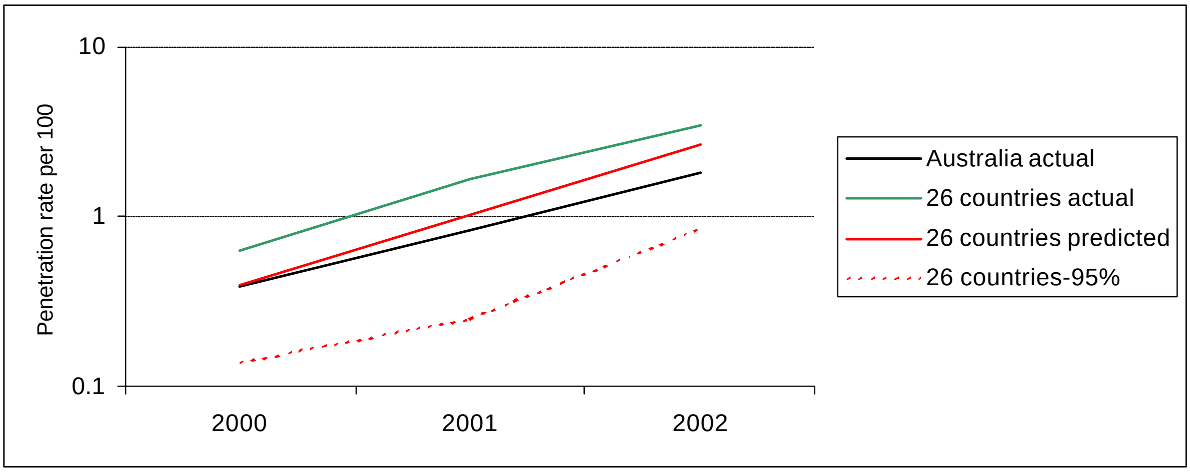
It is possible to use the model to demonstrate that the Australian broadband penetration rates are not significantly lower than the average of the countries in the OECD data base, when due account is taken of basic economic factors explaining penetration rates.

9 The number of countries varied for each year depending on data availability.

For example, the statistical model shows that for 2002 the lower bound estimate predicted by the model for the average of 26 countries would be a penetration rate of 0.9. If the Australian penetration rate was less then this lower bound, one would conclude, based on formal statistical criteria, that it was not possible to reject the proposition that Australia's broadband penetration rate was significantly less than the average in the OECD data base. In 2002 Australia's broadband penetration rate was 1.8, twice the estimate of the lower bound. Thus although the actual average for 26 countries was 3.5[10] in 2002, one cannot conclude, based on a simple economic model and formal statistical criteria, that the Australian penetration rate is significantly lower than this average.

The result can also be shown graphically. The actual and predicted levels of broadband penetration for the average of 26 countries and associated 95% lower bound estimate along with the actual broadband penetration rate for Australia are depicted in Figure 1.

Figure 1: Actual, predicted average and predicted lower bound broadband penetration for 26 countries and actual broadband penetration for Australia



Clearly the actual estimate for Australia lies well above the lower bound confidence interval estimate and is close to the predicted estimate for 26 countries from the model. To reiterate,

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10 This excludes Canada and Korea which had extreme values, but similar conclusions hold even if these countries are included.

the interpretation of this result is that, when due account is taken of basic economic factors and the early stages of the diffusion process in a simple statistical model, one cannot conclude that Australian penetration rates are lower, in a statistically significant sense, than the average in the OECD data base.

4 The role of HFC/Copper cross-ownership

The model can also be used to test whether broadband penetration rates are lower in those countries where cable networks are owned by the incumbent telecommunications carrier or where the incumbent carrier is considered to be a significant player.

The OECD identifies Australia, Denmark, Sweden and Portugal as the countries where the incumbent telecommunications carrier owns the largest cable network.[11] It also identifies 12 countries in which incumbent telecommunications carriers were significant players in cable markets in 2002.[12]

We used the model to test whether cross-ownership affected broadband penetration correcting for the other factors that affect broadband take up rates. The statistical tests confirmed that dummy variables for ownership of the cable network by the incumbent telecommunications carrier in Australia, Denmark, Sweden and Portugal are not significant. The same result was confirmed for dummy variables for the role of the incumbent carrier in these and 8 other countries identified by the OECD where the incumbent carriers were significant players in cable markets.

Although technically the dummy variables for ownership or influence of the incumbent carriers are not considered to be statistically significant, it is of interest to note that the coefficients on these variables are all positive. This direction of influence implies that divestiture or removal of the influence of the incumbent telecommunications carrier would

11 OECD, 2003, paragraph 26.

12 OECD, 2003, Table 7, p. 21 – Denmark, Australia, Portugal, Sweden, Norway, Finland, France, Hungary, Turkey, Germany, Luxembourg, Iceland.

lead to **lower**, not higher, penetration. This is shown by the results in the last column of Table 1.

Table 1: Significance of ownership of cable and PSTN or influence of incumbent telecommunications carrier

Extent of joint ownership of cable and PSTN or influence of incumbent telecommunications carrier	Year	Significance level of P-value	Coefficient	% change in penetration rate if divestiture occurred
Dummy variables for Australia, Denmark, Sweden, Portugal	2000	55%	0.29	-0.29%
	2001	60%	0.33	-0.33%
	2002	72%	0.18	-0.18%
Dummy variables for Australia, Denmark, Sweden, Portugal, Finland, Hungary, Germany, Iceland, Norway, France, Luxembourg and Turkey	2000	54%	0.23	-0.23%
	2001	10%	0.69	-0.69%
	2002	11%	0.55	-0.55%

5 The impact of policy

Canada and Korea have levels of broadband penetration that are well above average. These reported levels may be affected by error in measurement, as there is no standard definition of broadband take-up, and there are reasons to believe some countries include a wider range of connections in the data they report than do others. However, it is also well known that Canada and Korea have implemented policies that have strongly encouraged broadband deployment.

To test the impact of these policies, the model was re-estimated with these countries included (as outliers they were excluded from the original modelling) and with associated dummy variables. The results, which are set out in detail in Annex A, Table A5, show that the dummy variables were statistically significant. However, the impact of these dummies on penetration rates diminished through time from 3% in 2000 to 2.5% in 2002.

One possible interpretation of these dummies is that the policy interventions have provided a diminishing "lead" to Korea and Canada in terms of broadband penetration relative to the other countries in the sample. While it would be foolish to view broadband penetration as an objective worth pursuing in its own right, this implies that policy measures aimed at aggressively promoting broadband diffusion may have effects that are relatively short lived.

This is simply the flip side of the familiar observation that where markets are allowed to work, technology diffusion processes across countries tend to converge.

6 Future penetration levels

The adoption of a new technology is a phenomenon that typically exhibits an S-shaped pattern over time. This pattern is characterised by slow adoption in the early stages followed by an increasing rate of adoption and eventually a saturation stage. A final issue worth considering is whether current levels of broadband diffusion in Australia suggest that, left to its own devices, this process would not ultimately attain high levels of penetration.

In examining this question, it is important to note that the diffusion process for broadband services is generally in the very early stages of the typical pattern. Reflecting this fact, the behaviour to date could be consistent with a very large number of S-type patterns for Australia and other countries. For example, Figure 2 shows the current penetration rates for cable for Australia. The formula and characteristics of typical S type curves (which are discussed in greater detail in Annex B) were then used to derive three very different S curves for Australia given the data for the first 5 years of the process. These curves are depicted in Figure 3.

Figure 2: Cable penetration for Australia

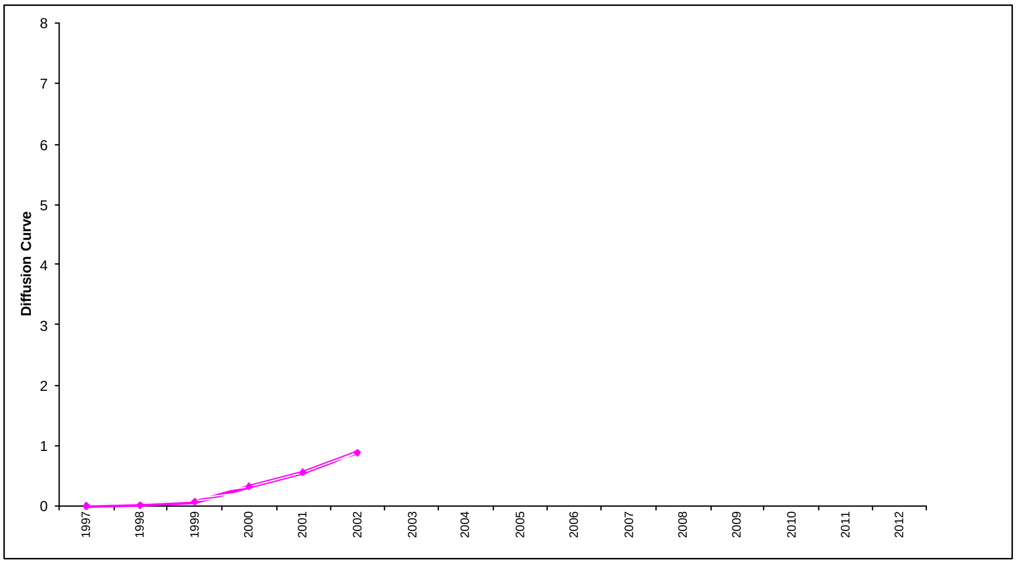
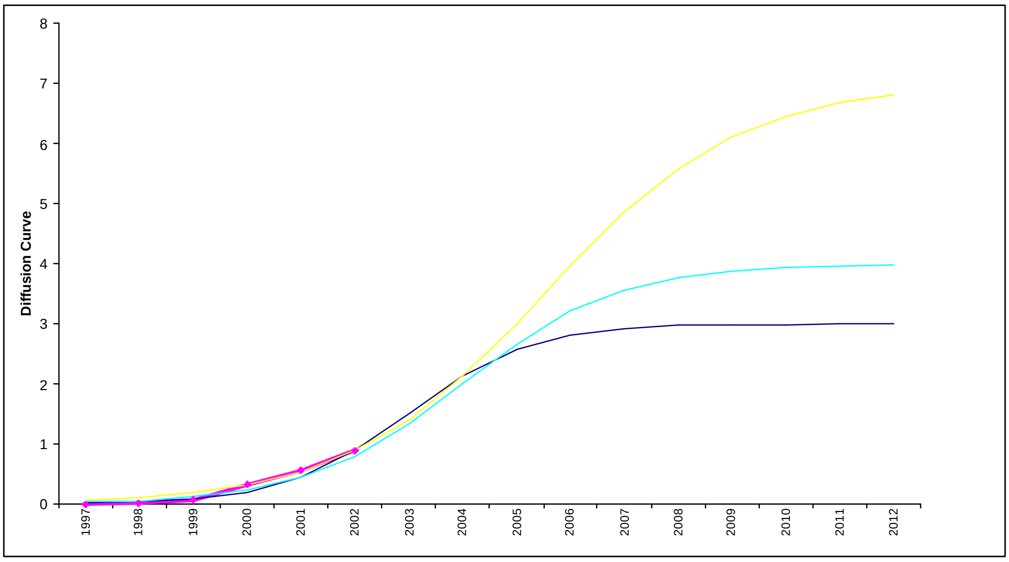


Figure 3: Possible diffusion curves for cable penetration for Australia



Statistically, no one diffusion curve is statistically better than the others in explaining the actual data from 1997 to 2002, and the large variations in the predictions demonstrate that no meaningful inference about likely outcomes in the next ten years could reasonably be made from the current penetration of cable in Australia. Similar results would hold for DSL penetration and for other countries for both technologies.

As a result, it would be incorrect to infer from the behaviour to date that Australian penetration rates are not tending towards high levels. Indeed, the acceleration in broadband take-up over the course of the last year suggests that the diffusion process is moving into the stage where penetration rises rapidly. This pattern – a relatively slow start, followed by rapid growth – would be consistent with the Australian experience in other technologies, including facsimile service and mobile telephony.

Annex A: Estimating a broadband penetration model

DSL data relate to the period 1999 to 2002 but for some countries, the start date was later than 1999. Cable penetration data relate to the period 1997 to 2002 but for some countries, the start date was later than 1997. Broadband penetration is equal to the sum of DSL and cable penetration.[13] Pay TV penetration data relate to the years 1997 to 2001. Data were available for up to 28 countries in the OECD data base, depending on when services started.

Given that the diffusion of broadband services is at a relatively early stage for a new technology it is not possible to estimate a full S-type diffusion curve using regression analysis. However, including variables, in polynomial form, for the age of the broadband network approximates the early stages of an S-shaped curve.[14]

It is posited that networks that are built late benefit from a number of factors (e.g. standards developed by early builders, marketing spill-overs, etc.) that were not available to early builders at the same network age. In particular those countries that introduced cable early are considered to be likely to have experienced a disadvantage relative to those that introduced cable from late 1999, when less expensive cable modems became available.[15] These effects were recognised, by assuming a minimum cable network age of 1999. Given the limited time series data and the difficulties in capturing these vintage effects, the model was estimated separately for each of 2000, 2001 and 2002. As Korea and Canada are considered to be outliers in the sample they were excluded from the regressions.[16]

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13 It is assumed that households purchase either cable or DSL broadband services and not both.

14 The age of the broadband network is taken to be the lesser of the age of the DSL and cable networks.

15 Around August 1999 the Data Over Cable Service Interface Specification (DOCSIS) modem was introduced to the market. This innovation reduced the cost of rolling out services to subscribers.

16 The conclusions are the same if Korea and Canada are included in the data for the regressions.

An alternative to separate estimation for each of the three years would have been to pool the data for all time periods and countries. This was attempted but there was evidence of serial correlation in the residuals, caused by the time series component of the pooled data, which would in turn bias the estimation of the confidence intervals. A maximum likelihood pooled regression estimator was not able to be overcome the problem because of problems with degrees of freedom and establishing a global maximum. In light of these difficulties it was considered that the benefits of pooling in terms of achieving statistical efficiency gains were not justified.

As higher income countries are generally likely to facilitate earlier and more rapid adoption of broadband services, the log of real GDP per capita (in 1995 $US terms) was also included as an explanatory variable in the regression.

The log of Pay TV penetration was included in the model, with a 1 year lag, to account for the proposition that cable networks with low Pay TV penetration will also have relatively low cable modem penetration.

The following model was estimated using OLS and found to explain the data reasonably well. There was no heteroscedasticity present in the error terms.

Log [Broadband penetration rate] = a + b*Log[Age]^2 + c*Log[Age]^3 + d*Log[real GDP per capita] + e*Log[Pay TV penetration lagged one year] + u

The results are presented in Tables A1, A2 and A3.

Table A1: Broadband penetration OECD regression, 2000

Variable	Coefficient	t-Statistic
Constant	-10.21	-1.73
Log Age^2	10.61	4.75
Log Age^3	-6.16	-4.20
Log GDP/capita	0.57	0.89
Log Pay TV	0.31	2.14
Degrees of freedom	12	
Adj. R-squared	0.78	

Table A2: Broadband penetration OECD regression, 2001

	Coefficient	t-Statistic
Constant	-21.40	-4.29
Log Age2	6.58	3.77
Log Age3	-2.99	-2.63
Log GDP/capita	1.75	3.33
Log Pay TV	0.12	0.83
Degrees of freedom	21	
Adj. R-squared	0.70	

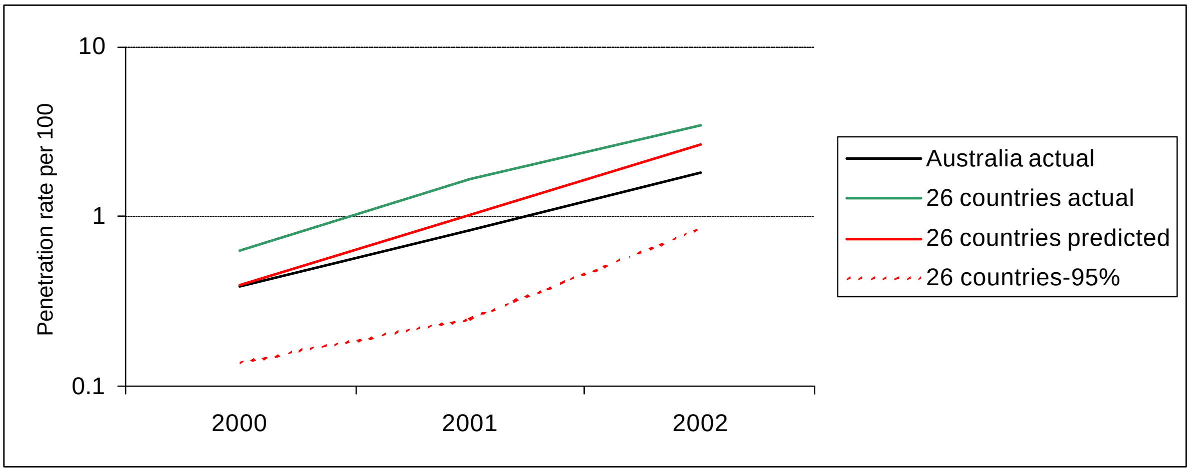
Table A3: Broadband penetration OECD regression, 2002

	Coefficient	t-Statistic
Constant	-28.97	-6.86
Log Age2	8.07	3.80
Log Age3	-3.41	-3.04
Log GDP/capita	2.34	5.51
Log Pay TV	0.13	0.93
Degrees of freedom	21	
Adj. R-squared	0.78	

It is possible to use the model to test whether the Australian broadband penetration level is significantly lower than the average of the 26 countries in the OECD data base. This was done by estimating the mean forecast for the 26 countries and establishing a lower bound range for the OECD average at a 95% confidence level. Formally, if the Australian actual broadband penetration rate is below this lower bound one could not reject the null hypothesis that the Australian penetration rate is lower than the average in the OECD data base. However if the Australian penetration rate is above this lower bound, one would reject the hypothesis that Australian penetration is less than the average in the OECD data base.

The actual and predicted levels of broadband penetration for the average of 26 countries and associated 95% lower bound confidence interval along with the actual penetration rate for Australia are depicted in Figure A1.

Figure A1: Actual, predicted average and predicted lower bound broadband penetration for 26 countries and actual broadband penetration for Australia

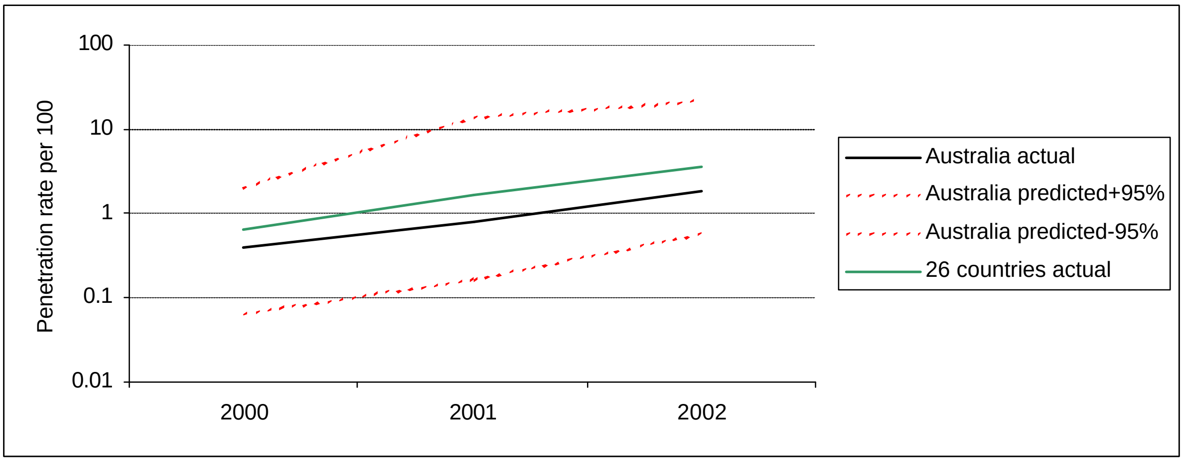


Clearly the actual estimate for Australia lies well above the lower bound confidence interval estimate and is close to the predicted estimate for 26 countries from the model. The interpretation of this result is that, when due account is taken of basic economic factors and the early stages of the diffusion process in a simple statistical model, one cannot conclude that Australian penetration rates are lower, in a statistically significant sense, than the average in the OECD data base.

An alternative way of considering the results is to predict the range of estimates that would arise if other countries had Australia's characteristics. The actual, predicted average and predicted normal statistical range for broadband penetration for Australia and the actual average for 26 countries is shown in Figure A2.

The Australian actual broadband penetration rate is well within the predicted confidence intervals for Australia based on the model. The interpretation of this result is that if the 26 countries had Australia's characteristics they would have exhibited a range of penetration rate outcomes consistent with what Australia has achieved. For comparison purposes, the actual average penetration rate for the 26 countries is also well within the predicted range, although there is no formal statistical interpretation of this result.

Figure A2: Actual, predicted average and predicted range for broadband penetration for Australia and actual average for 26 countries



The model can also be used to test whether broadband penetration rates are lower in those countries where cable networks are owned by the incumbent telecommunications carrier or where the incumbent carrier is considered to be a significant player.

The OECD report identifies Australia, Denmark, Sweden and Portugal as the countries where the incumbent telecommunications carrier owns the largest cable network.[17] It also identifies 12 countries in which incumbent telecommunications carriers were significant players in cable markets in 2002.[18] However statistical tests confirmed that dummy variables for ownership of the cable network by the incumbent telecommunications carrier in Australia, Denmark, Sweden and Portugal were not significant at the normal levels of statistical significance (5%). The same result was confirmed for dummy variables for the role of the incumbent carrier in these and the 8 other countries identified by the OECD.

17 OECD, 2003, paragraph 26.

18 OECD, 2003, Table 7, p. 21 – Denmark, Australia, Portugal, Sweden, Norway, Finland, France, Hungary, Turkey, Germany, Luxembourg, Iceland.

The results are shown in Table A4. The P values show the lowest level of significance where the null hypothesis (that there is no influence from the particular variable) can be rejected (or alternatively the probability of committing a Type I error of rejecting that there is no influence when in fact there is no influence). Although technically the dummy variables for ownership or influence of the incumbent carriers are not considered to be statistically significant, it is of interest to note that the coefficients on these variables are all positive. The interpretation is that divestiture or removal of the influence of the incumbent telecommunications carrier would lead to lower penetration. This is shown by the results in the last column of Table A4.

Table A4: Significance of ownership of cable and PSTN or influence of incumbent telecommunications carrier

Extent of joint ownership of cable and PSTN or influence of incumbent telecommunications carrier	Year	Significance level of P-value	Coefficient	% change in penetration rate if divestiture occurred
Dummy variables for Australia, Denmark, Sweden, Portugal	2000	55%	0.29	-0.29%
	2001	60%	0.33	-0.33%
	2002	72%	0.18	-0.18%
Dummy variables for Australia, Denmark, Sweden, Portugal, Finland, Hungary, Germany, Iceland, Norway, France, Luxembourg and Turkey	2000	54%	0.23	-0.23%
	2001	10%	0.69	-0.69%
	2002	11%	0.55	-0.55%

Canada and Korea were considered to be outliers, with their broadband penetration rates being to a large extent explained by special policy and institutional factors, and so the basic model excluded them. To test the impact of including them, the model was re-estimated with these countries included and with associated dummy variables. The results are shown in Table A5. The dummy variables were statistically significant and indicated an impact on penetration rates that diminished through time from 3% in 2000 to 2.5% in 2002. An alternative interpretation of the significance of these dummies is that Korea and Canada are influential observations on the results i.e. outliers.

Table A5: Influence of special policy factors in Canada and Korea

Influence of special policy or institutional factors in Canada and Korea	Year	Significance level of P-value	Coefficient (% impact on penetration rate)
Dummy variables for Canada and Korea	2000	0%	3.08
	2001	1%	2.78
	2002	1%	2.49

Annex B: Estimation of an S-type diffusion curve

The econometric estimation of the data for up to 28 countries for 3 years showed that one cannot conclude that Australia's penetration rates for DSL and cable broadband are generally outside the normal confidence intervals of a function that explains the data reasonably well.

An alternative approach, based on the estimation of possible S-type diffusion curves for Australia, demonstrates that it is not possible to draw meaningful conclusions about the extent to which current broadband penetration in Australia is such that the outcome in a few years will be significantly different from the S-type diffusion curve outcomes in other countries, once the process is given a reasonable time to mature.

The adoption of a new technology is a phenomenon that typically exhibits a S-shaped curve. Indeed, empirically, it is quite common to observe a diffusion process characterised by:

- an increasing adoption rate at the early stage;
- a peak in the diffusion of the technology per unit of time;
- a decrease in the rate of growth; and
- a saturation stage.

The S type pattern that often characterises a diffusion process can be reflected in what is called a logistic function. The logistic function is:

- widely-accepted for modelling S-shaped curves; and
- readily interpretable, as its three parameters can readily describe the characteristics of a diffusion process.

The mathematics of the logistic function, as well as its precise definition and interpretation are provided in Annex B1.

This section estimates several possible diffusion curves given the data for cable penetration in Australia. It is suggested that similar conclusions would hold for DSL penetration and for both types of broadband in other countries.

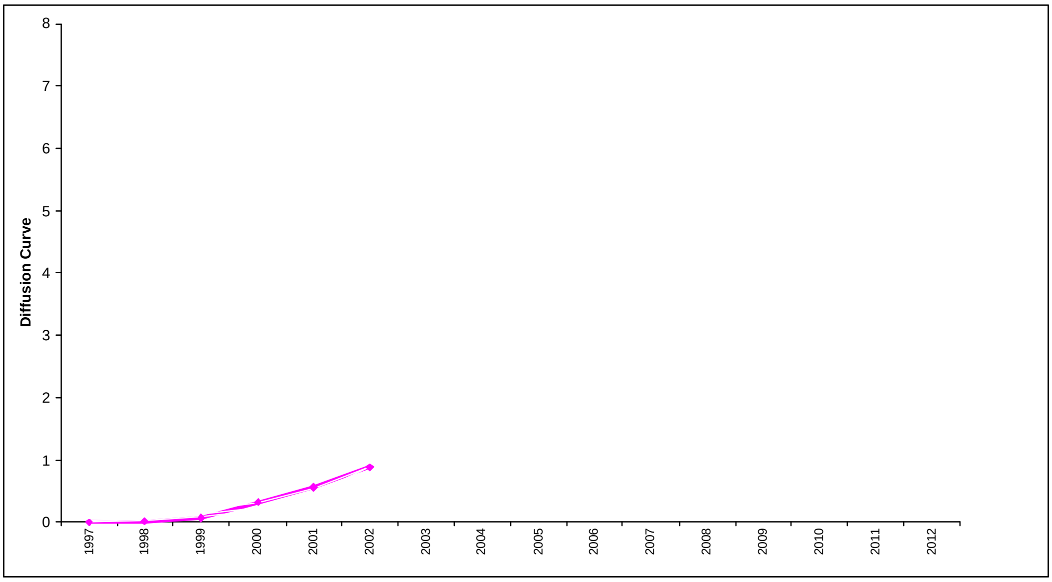
The data for the Australian rate of penetration of cable are summarised in Table B1:

Table B1: Cable penetration rates for Australia

Year	1997	1998	1999	2000	2001	2002
Data	0.00527	0.0264	0.0738	0.3341	0.56454	0.8889

The data are plotted in Figure B1.

Figure B1: Cable penetration for Australia



The task is to calibrate a logistic function (i.e. a diffusion curve) so that it replicates as closely as possible the available data.

This is done by changing the parameters (saturation, midpoint and duration)[19].

19 As explained in the appendix, these parameters define the position of a logistic curve.

However the difficulty is that given the limited data, a nearly infinite number of curves could do the job.

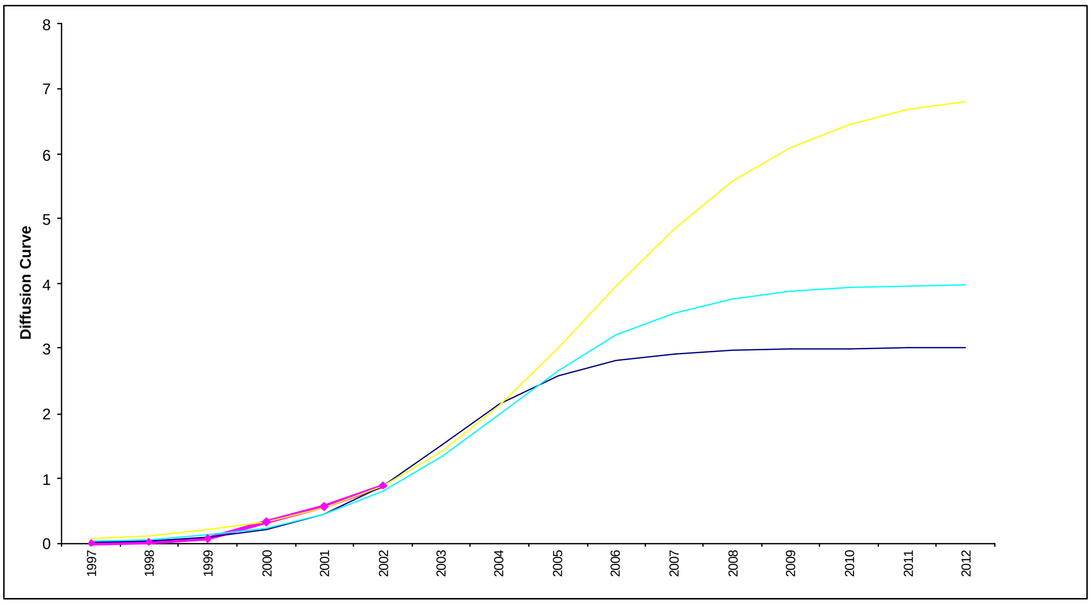
For example, based on the same data set, we generated three different sets of parameters that define a logistic curve that could fit the actual observations from 1997 to 2002 very well. The parameters are summarised in Table B2.

Table B2: Diffusion curve possible parameters for Australia

	Diffusion Curve 1	Diffusion Curve 2	Diffusion Curve 3
Saturation	3	7	4
Duration	5	8	6.3554
Midpoint	5.9841	8.5096	7.0000

The fitted results are plotted in Figure B2.

Figure B2 Possible diffusion curves for cable penetration for Australia



Clearly each function explains the actual observations very well but subsequently there can be very large differences in final penetration outcomes over the latter part of the fitted period.

No diffusion curve is statistically better than the others in explaining the actual data and the large variations in the predictions demonstrate that no meaningful inference about likely outcomes in the next ten years could reasonably be made from the current penetration of cable in Australia. Given the nature of the data and the fact that saturation has not been generally observed, similar results would hold for DSL penetration and for other countries for both technologies.

Annex B1: Technical details for estimating a logistic function

To start with, assume that the number of subscribers grows exponentially. Let N(t) be the number of subscribers at time t, and a the rate of growth.

Formally, N(t) satisfies the following differential equation:

(1) $$\frac{dN(t)}{dt} = a.N(t)$$

One solution of (1) has the following form:

(2) $$N(t) = ß.e^{at}.$$

The logistic equation is based on the exponential growth model but with a "negative feedback factor" as the number of subscribers approaches its upper limit.

This negative feedback is introduced by multiplying (1) by $\left(1-\frac{N(t)}{L}\right)$ with L the upper limit.

Indeed, when the number of subscribers is small compared to L, the term is close to unity and hence does not significantly affect the rate of growth in the early stage of the service provision. At the other extreme, when nearing saturation levels, the rate of growth mechanically decreases, and ultimately tends to zero.

(3) $$\frac{dN(t)}{dt} = a.N(t).\left(1-\frac{N(t)}{L}\right).$$

The solution of the logistic differential equation (3) is:

(4) $$N(t) = \frac{L}{1+\exp(-a(t-ß))}$$

This equation is the logistic equation that produces an S-shaped curve.

There are three parameters in this function, each of which has an interesting interpretation.

- L is the maximum value or saturation point for the number of subscribers;
- a relates to 'd' the "characteristic duration" of the mechanism. This is the time required for the number of subscribers to grow from 10% to 90% of the upper limit, L. Some algebra shows that $d = \frac{\ln(81)}{a}$;
- Finally, the parameter ß can be shown to be the time at which the number of subscribers reaches half of the upper limit. It is called the midpoint.

For illustration, consider a theoretical logistic function is presented in the Figure below.