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Catching up in Broadband - What Will it Take?

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FOREWORD

The OECD Secretariat has commissioned this report in order to test indicators and assess the roles of platform competition, pricing, geography, policy and regulation in the deployment and take-up of broadband and to assist in understanding how these help to explain the differences in broadband penetration across OECD economies. There are several empirical studies on OECD broadband penetration rates that precede the current paper. Much of the recent empirical work has aimed at understanding the role of local loop unbundling in driving broadband penetration rates. This paper provides more evidence in the debate on the role of policy and competition in broadband uptake. The paper is by John de Ridder, *Telecommunications Economist*, and does not necessarily reflect the official views of the Organisation or of the governments of its member countries.

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CATCHING-UP IN BROADBAND – WHAT WILL IT TAKE?

1. Introduction

Governments increasingly place a high priority on the availability of competitive broadband infrastructure and look to international benchmarks as one input to assess progress in meeting their policy objectives. These benchmarks include broadband penetration, pricing, availability and speeds. But, the benchmark most frequently cited is broadband penetration and this is the measure driving policy initiatives in many developed countries. In May 2006, for example, New Zealand cited its ranking in OECD broadband penetration as a factor in taking the decision to unbundle the local loop.

Can governments elevate their broadband performance rankings? This paper aims to identify the factors that are significant in driving broadband penetration. It develops and tests indicators to assess the roles of platform competition, pricing, geography, policy and regulation in the deployment and take-up of broadband and to assist in understanding how these help to explain the differences in broadband penetration across OECD economies.

2. Background

The broadband market is still at an early stage of its development and definitions of broadband are shifting as technologies improve and customer expectations rise. This paper seeks to explain the broadband adoption rates across countries reported by the OECD.[1]

There are several empirical studies on OECD broadband penetration rates that precede the current paper. Some of these are summarised in Table 1 alongside the findings of this paper. A “Yes” is reported in the table where the study reports the relevant variable to be statistically significant in explaining broadband penetration. These findings are discussed further below.

Much of the recent empirical work has aimed at understanding the role of local loop unbundling in driving broadband penetration rates (Garcia-Murillo & Gabel, 2003; Wallsten, 2006; Howell, 2006; Distaso *et al.*, 2006). This paper provides more evidence in the debate on the role of policy and competition in broadband uptake.

Descriptions of the model and data are presented in Sections 3 and 4. The presentation of estimates of the demand, supply and composite equations across three related data sets follows in Sections 5, 6, and 7. Suggestions for further research and policy implications conclude the paper.

Table 1: Drivers of broadband penetration in the OECD

Study	De Ridder (1)		Bauer et al	Cava-F. & Alabau-M.	Wallsten	Grosso	Garcia-M & Gabel	Turner
Period	2005	2003/05	2001	2000-02	1999-03	2001-04	2001	2005
N=	30	54	30	27-90(3)	179	117	36 (2)	30
Demand								
Income	No	No	No		Yes	Yes	Yes	Yes
Age	No	Yes						
Education	No	No		No				No
Price of broadband	Yes	Yes	No	No			Yes	No
Price of dial-up Internet	Yes	Yes	No					
Addressable market	Yes	Yes		Yes	Yes	Yes	Yes	
Weather	No	No						
Content				No			No	
Supply								
Urbanisation	Yes	Yes	Yes		Yes		Yes	No
Competition	No	Yes(4)	No	No		Yes	No	
Unbundling	Yes	Yes	No	No	Yes	Yes	No	
Best adjusted R-squared	0.85	0.86	0.46	0.41	0.35	0.98	0.91	0.58

Notes: (1) Results presented in this paper. Other studies cited in references below.
(2) ITU data but the sample of 36 is likely to be dominated by the OECD economies.
(3) Based on Tables 4, 5 and 7 which deal with broadband DSL penetration.
(4) Differenced data set only.

3. The model

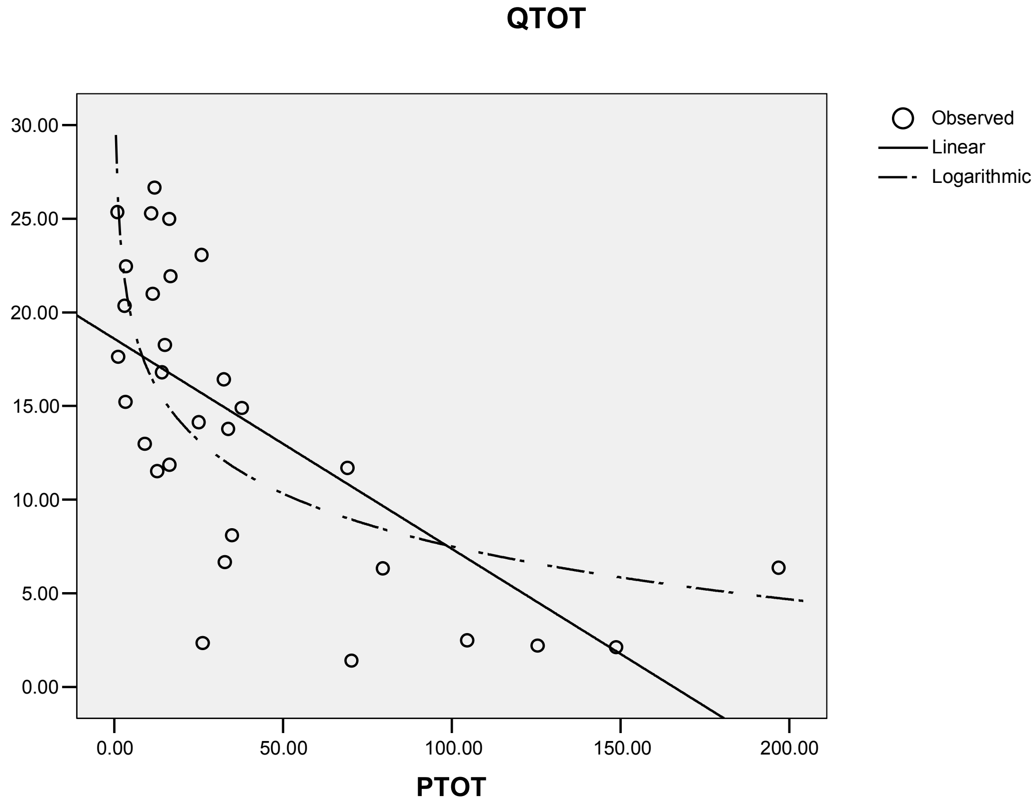
Broadband penetration is driven by both and supply factors. The *a priori* complete model consists of three equations:[2]

1. $Q_D = f(P, Y, A, E, S, W)$
2. $Q_S = f(P, U, G, C)$
3. $Q_D = Q_S$

The first two equations are for the demand and supply of broadband penetration. The price of broadband (P) appears in both equations. Income (Y), age (A), education (E), the addressable market (S) and weather (W) are the exogenous demand drivers. Population density (U), government policy (G) and competition (C) are exogenous supply shifters.

A priori, it is not clear if either the demand or supply equation or both can be estimated. Early estimation of demand curves in agricultural products was successful because shifts in the supply curve due to weather defined the demand curve. This seems to be the case in broadband too (see Figure 1 showing broadband penetration, Q_{TOT}, and the broadband price, P_{TOT}); although not because of weather which appears in this paper as a demand driver rather than supply shifter.

Figure 1. Figure 1: Scatter of Broadband Price and Penetration (December 2005)



It is clear from Figure 1 that the relationship between price and broadband penetration is non-linear. Scatters of all the main explanatory variables against Q_{TOT} are shown in Annexes 1a to 1e. Alternative curve fits were tested against every scatter but only price has a non-linear relationship with Q_{TOT} and this has been purged by taking the natural logarithm of the price variable; as depicted on the right-hand charts in Annex 1a.[3]

Bauer *et al*. (2003) recognise that broadband penetration is influenced both by demand and supply factors. Their reduced form model approach is followed with the composite equation estimates presented below.

Cava-Ferreruela and Alabau-Munoz (2006) follow Bauer *et al*. (2003) in specifying broadband demand and supply equations (for DSL and cable separately) but they define their dependent variables in the demand and supply equations differently. For DSL, demand is DSL penetration and supply is defined as the percentage of DSL-enabled loops[4]. The extent to which exchanges have been DSL-enabled seems less interesting from a policy perspective than the extent of broadband adoption which is the focus of this study.

The next section explores the data found to represent each of these concepts in the model and explains the choice of variables made to estimate the model.

4. The data

There are three data sets:

- December 2005; which has the widest range of variables for analysis.
- Panel data; which significantly improves the degrees of freedom and fit.
- Differenced data; which deals with country fixed effects.

The panel data comprises the December 2005 data plus December 2002 data. The third data set is the result of subtracting the values in the earlier data set from the corresponding values in the December 2005 data set.

All the variables described below are available for the December 2005 data set. So, this data set is mined to uncover the most useful measures of the variables required for the model. For example, six different measures of population density were considered.

The first level of filtering is consideration of the Pearson bivariate correlation coefficients[5] (Table 2). Since these measure linear correlations, the price variables are expressed in natural logarithms as discussed above. The more promising alternatives were then tested in models estimated using ordinary least squares (OLS) estimation.

The descriptive statistics for the variables used in estimation are presented in Table 3. For each variable, this shows the number of observations (countries), the range of values (minimum and maximum), the arithmetic mean and standard deviation.[6] The range of values across countries for each variable explaining broadband is quite wide which helps provide good estimates.

4.1 Dependent variable (Q)

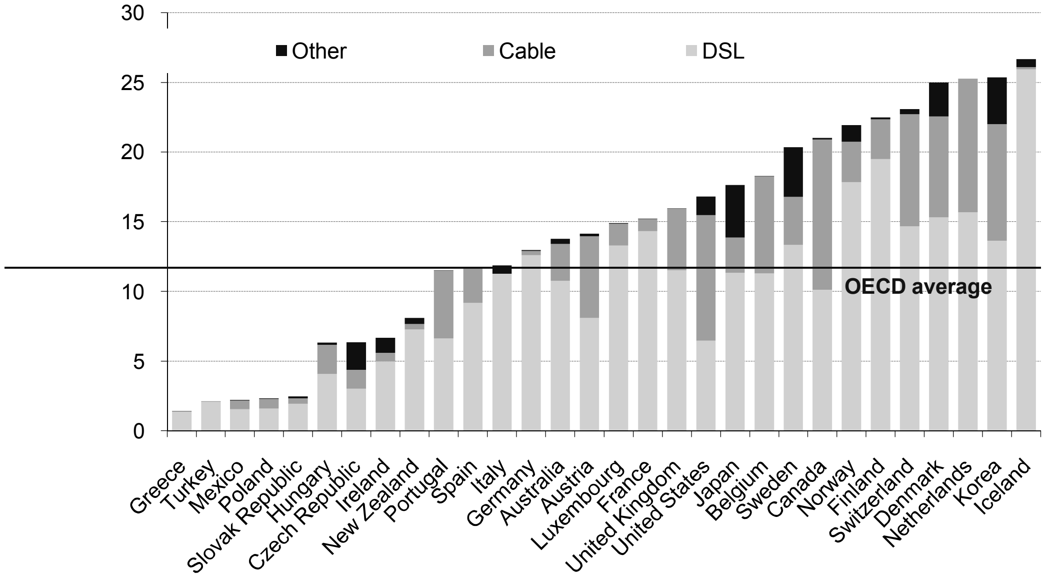
This paper seeks to statistically explain per capita broadband penetration rates at December 2005 and 2002 as sourced from the OECD. While both DSL and Cable per capita penetration rates are reported by the OECD, the focus of this paper is on the total penetration rate, Q_{TOT}. This is normally distributed with no outliers in the December 2005 data set. But, this is not the case with December 2002 data until Korea is eliminated from the sample as an outlier; as noted in section 6 below.[7]

4.2 Price variable (P)

Other studies have had difficulty finding a relationship between broadband prices and broadband penetration. This paper is more successful because it uses new price data obtained from the OECD.

The broadband price per Mbit/s is constructed using a method first suggested by the OECD (2001) and refined by the ITU (2003, A-56). It involves a two-step procedure: first, only plans that meet certain characteristics (*e.g.* download speed, data cap of around 1 GB per month and technology) are considered and then the best price per 100 kbit/s of advertised download speed is selected from those that remain. In this paper, prices and values are expressed at purchasing power parities rather than nominal USD.

Figure 2: OECD Broadband Penetration Rates, December 2005



Source: OECD

There are three variants of broadband price tested in this paper:

- Average price (P_{TOT}) is used only in the December 2005 data set as it is only available for the September quarter 2005. OECD data (provided directly to the author) for the prices for DSL and Cable were aggregated using the relative line shares of DSL and Cable as weights,

- P_{DSL} is the DSL price alone taken from the OECD for September 2005 and from the ITU (2003) for July 2003. Both P_{TOT} and P_{DSL} are expressed per Mbit/s in USD at purchasing power parities.

- P_{REL} is P_{DSL} divided by the total price of 20 evening hours per month of dial-up Internet access (excluding line rental). The dial-up costs are taken from the ITU (2006, Table 16) for August 2004[8] and from the OECD (2003, Table 6.2) for September 2002.

  Price relativity is considered to be potentially important as the most common application of Internet access is for e-mail which dial-up satisfies in many cases. There are eight countries where this relativity (P_{REL}) is greater than 2.0 and all but Spain have broadband penetration (Q_{TOT}) under 10% (see Annex 2). In these eight countries, dial-up is so cheap that it impedes the adoption of broadband.

All three price measures are significantly negatively correlated with Q_{TOT} (Table 2) with the natural log of each price used in estimation to remove their non-linear relationships with Q_{TOT} (see Annex 1a). Korea is the cheapest on all three measures of price and is second only to Iceland on broadband penetration (Annex 2).

4.3 Income variable (Y)

Income is measured as GDP per capita at 2004 and 2001 relative to the United States (Y_{INDEX}) and is sourced from the OECD. Some authors use median incomes and even poverty (Turner, 2005) as measures of income. As will be seen from the results below, GDP per capita may not be the best measure of income.

It could be argued that Y is endogenous. That is, that there is two-way causality between Q and Y. That may be true in future – it is why governments feel it is important to invest in broadband to increase economic prosperity and income. But the cross-section country samples in this study are taken at an early stage in the development of broadband. So, any feedback from Q to Y is likely to be very weak or absent at this point.

4.4 Age variable (A)

Age is measured as the share of the total population aged 35-44 as at 2004 and is used only in the December 2005 data set. The numbers by age group are sourced from OECD Labour Force Statistics. This source provides seven age cohorts by country (except Mexico). Surprisingly, the 15-35 and 25-34 groups were each negatively correlated with broadband penetration (overall and also for ADSL and cable separately). The 35-39, 40-44 groups were positively correlated with broadband penetration. Age groups over 55 show little correlation either way, as might be expected.

Table 2: Correlations with broadband penetration (Dec.2005)

Variable under study: Total broadband penetration (QTOT)							
Pearson correlation:	coeff. > 0.5		0.5 > coeff.> 0.4		0.4 >coeff. > 0.3		< 0.3
	Variable	Value	Variable	Value	Variable	Value	Variable
Demand							
GDP per capita	YINDEX	0.535**					
Age					AGE	0.385*	
Education	ETERT	0.650**					
	EYRS	0.517**					
Price (also supply factor)	LNPTOT	-0.692**					
	LNPDSL	-0.676**					
	LNPREL	-0.710**					
Saturation	SIP	0.833**					
	SGTOT	-0.706**					
	SBP	0.587**					
	SFTD	0.568**					
Weather					SUN	-0.363*	
					WET	0.348	
Supply							
Urbanisation	UURB	0.552**					USKM
Competition							CFAC
							CCAB
							CENT
Policy	GUYRS	0.555**			GOWN	0.351	GADSL
					GUTOT	-0.312	GBAR

Statistical significance at the 1 and 5% levels denoted by ** and * respectively.

4.5 Education variable (E)

Education measures are for 2003 sourced from the OECD (2005a). The two measures selected for exploration in this study are:

- The average number of years in formal education, E_{YRS} (OECD, Table 1.4).
- The share of the population aged 25-64 that has received tertiary education, E_{TERT} (OECD, Table 1.3a).

Both seem promising based on previous studies and the correlations reported in Table 2. But since E_{YRS} is highly correlated with $Y_{INDEX,}$ this paper uses E_{TERT}.[9]

The panel data simply repeats the December 2005 data for the second (earlier) period as it is unlikely that the values would have shifted much.

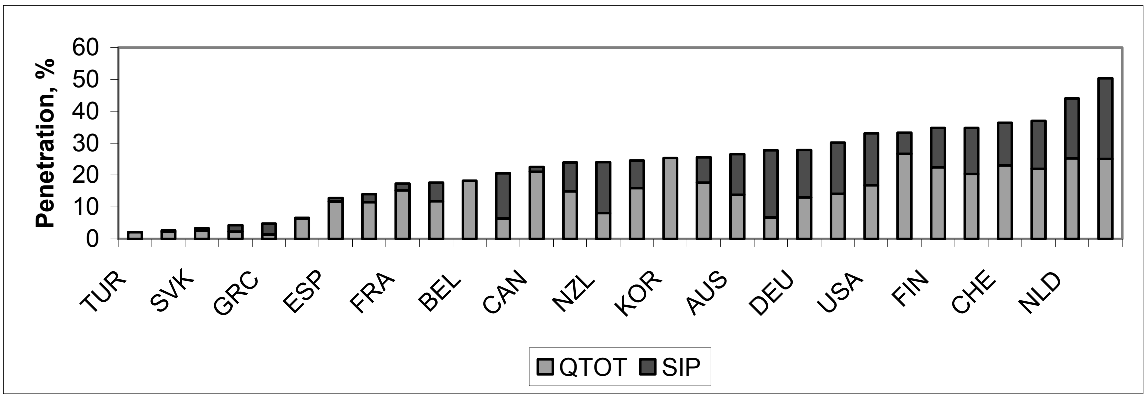
4.6 Saturation variable (S)

There are four measures of saturation or market potential which are all correlated with Q_{TOT} (Table 2):

- S_{IP} is total Internet subscribers as a percent of population and is the measure chosen for estimation. It represents the addressable market which should be positively correlated with broadband penetration. OECD data was used for 2002 and ITU data for 2004 unless it was lower than the 2003 figure reported by the OECD; in which case the latter was used with population data for the same year.[10] One exception to this procedure is Portugal where the OECD's implied penetration rate of 69% is replaced with 14% sourced from the country regulator (www.icp.pt).

  The variation of S_{IP} across countries (Figure 3) also suggests possible variations in the asymptotic limits of their respective broadband adoption curves. The greatest potential for broadband growth by substitution of dial-up is in the seven countries where dial-up customers exceed the number of broadband customers: led by Denmark and followed by Ireland, Austria, New Zealand, Germany, the Czech Republic and Greece.

Figure 3: Broadband and Internet Penetration, December 2005



Source: OECD and ITU.

- S_{GTOT} is the ratio of broadband penetration (Q_{TOT}) at December 2005 to December 2004. If countries climb an "S-curve" characteristic of new services, a high growth rate will signify a lower point on the curve and a low level of penetration.

- S_{BP} is the share of total Internet subscribers (obtained from the ITU for 2004) accounted for by broadband. As much of the demand for broadband comes from the migration of dial-up Internet customers, a positive correlation between S_{BP} and broadband penetration should be expected.

- S_{FTD} is fixed telephone density at 2004. This is a limiting factor in what ADSL per capita penetration is possible so it should be positively correlated with broadband penetration. ADSL accounts for over 50% of broadband penetration in every country (except for the Czech Republic) and averages over 60% across the OECD.

4.7 *Weather variable (W)*

Weather could be a factor explaining Iceland's high take-up of broadband. Two annual average measures of weather were extracted from monthly data for the capital city in each country:[11]

- SUN is the daily average number of sunlight hours.

- WET is the daily average number of wet (over 0.25mm) days.

Iceland has less days of sun and more days of rain than the sample mean. As expected from the hypothesis, Q_{TOT} is negatively correlated with SUN and positively correlated with WET and the weather variables are highly correlated with each other. SUN is used in estimation, although WET could have been used instead.

Table 3: Descriptive statistics (Dec. 2005)

	N	Minimum	Maximum	Mean	Std. Deviation
QTOT	30	1.41	26.66	14.1443	7.91954
LNPTOT	30	-.16	5.28	2.9749	1.34488
LNPDSL	30	.07	5.60	3.0736	1.36888
LNPREL	30	-3.00	2.23	-.1841	1.37475
YINDEX	30	.17	1.60	.6690	.27462
AGE	30	23.0	32.1	28.527	1.6954
ETERT	30	10	44	24.07	9.421
SIP	30	2.10	51.23	23.7557	12.47569
SUN	30	3.5	8.3	5.497	1.2995
UURB	30	56.2	97.2	74.960	11.0733
CFAC	30	.91	61.47	26.9357	16.92989
GUYRS	30	0	10	4.97	2.965
Valid N (listwise)	30				

4.8 *Urbanisation variable (U)*

Urbanisation and population density are recognised supply factors for broadband penetration. City states like Hong Kong, China and Singapore should find it cheaper to wire-up their populations than other countries. In addition, wiring high-rise buildings has lower unit costs than connecting low rise buildings to broadband.

The separate house on the quarter acre block is the most popular type of dwelling in Australia, making up 78.1% of total dwellings in the year to June 2001. Flats, units and apartments accounted for just 11.3% and the rest was made up of semi-detached, row or terrace houses (ABS, 2005). Unfortunately, there do not appear to be internationally comparable data on the proportion of the population that live in high rise dwellings.[12]

A number of internationally comparable indicators of population density could be used in this study.[13] The main alternatives are:

- U_{SKM} is population per square kilometre. This is the standard measure, and
- U_{URB} which is the percent of the population that is urbanised from the United Nations (2004).

The latter, U_{URB}, is more highly correlated with broadband penetration than the traditional measure of U_{SKM} (see Table 2 and Annex 1b).

4.9 Government variable (G)

Governments can try to stimulate broadband penetration with subsidies or regulation. For example, in May 2006 the New Zealand government decreed unbundling of the local loop as a direct result of its poor ranking on broadband penetration rates. This study considered six measures of policy:

- G_{UYRS} is the number of years that unbundled local loop (ULL) has been available and is derived from the OECD (2005, Table 2.10). Half of the panel data for the earlier period is derived by subtracting three years from each value in the December 2005 data set.

  Of course, dates can be problematic – availability will lag legislation. But this measure is no less precise than using a dummy to reflect whether ULL is available or mandated, as some studies do (*e.g.* Grosso, 2006 and Garcia-Murillo 2003). In fact, G_{UYRS} turns out to be the most useful of the proxies for government policy considered here.

  Wallsten (2006) used segmented information on unbundling for OECD countries, but he used a vector of three dummy variables (full unbundling, bit-stream and sub-loop) based on the regulatory environment at 2001 reported in Umino (2004). There are also dummies for price regulation and collocation policies and practices. In fact, the only continuous independent variables are for the demand shifters of fixed teledensity and GDP per capita.

  Cava-Ferreruela and Alabau-Munoz (2006) tried using both a dummy to test the effect of the existence of ULL and also the number of ULL lines. Only the latter is used in the estimation of broadband penetration and it is small and insignificant. A 10% increase in unbundled local loops leads to only a 1.25% increase in broadband penetration on their estimates.

  G_{UYRS} has a statistically significant and positive relationship with Q_{TOT} (*i.e.* ULL promotes broadband penetration) and a negative relationship with P_{TOT} (*i.e.* ULL is associated with lower broadband prices). On this measure, the United States has had ULL available for longer than other countries except Finland, but this has done more for Finland than the United States.

  The other four measures of government policy discussed below have much lower correlations with Q_{TOT} (Table 2 and Annex 1c).

- G_{ADSL} is another measure of regulatory intent. It is defined as the sum of entrants' retail ADSL lines expressed as a percent of incumbent total ADSL lines and available at December 2005. The European data is sourced from ECTA.[14] The paper also uses the author's estimates for Australia, New Zealand and the United States.[15] This still leaves eight missing observations for Canada, Iceland, Japan, Korea, Mexico, Norway, Switzerland and Turkey.

- G_{UTOT} is a measure of service-based competition defined as entrants' lines based on incumbent copper (*i.e.* G_{ADSL}) as a percent of the total broadband market. This measure is negatively correlated with Q_{TOT} (see Table 2) which seems inconsistent with finding a positive relationship for G_{UYRS} and is counter-intuitive as it suggests that service based competition does not assist broadband penetration. There are, however, seven missing values.

  G_{ADSL} and G_{UTOT} both have a statistically significant and positive relationship with U_{URB}. That is, a high share of entrants in the ADSL market is associated with high population density, as we would expect.

- G_{BAR} is an "entry barrier" index where a higher number reflects lower barriers. It is based on nine indicators collected in 1998 and aggregated through principal components analysis (Gual & Trillas 2006). There are 8 missing values.

  Bauer *et al.* (2003) tried a similar approach when they tested the importance of policy variables on broadband penetration. They used cluster analysis across unbundling policies, cross cable-telco ownership restrictions and government funding for broadband to assign countries to one of three policy groups (Bauer, Table 2). But, this procedure was not very successful so this categorisation is not used here.

- G_{OWN} measures government ownership in the main fixed telephone operator. After reviewing the literature on the effects of ownership and competition on investment, Garcia-Murillo and Gable (2003) hypothesise that broadband subscription is positively correlated to the privatisation of the incumbent carrier. Of course, privatisation is usually associated with market liberalisation so this measure could be a proxy for competition. Neither G_{OWN} nor the competition variables defined below are significantly correlated with $Q_{TOT.}$

Although regional and remote areas might be expected to impact government policy, the relevant measure of policy in this context is not G_{UYRS} (because full local loop unbundling will not be used in country areas) but either mandated wholesale access to some form of unbundled bit-stream access and/or subsidy arrangements. It has not been possible to identify cross-country data on subsidy programmes.

4.10 Competition variable (C)

Competition should drive broadband penetration. The number of suppliers is important but it is not usually reported. However, it may be even more important to distinguish between platform (primarily cable) and service- (unbundling and resale) based competition. The debate over the efficacy of ULL in promoting broadband adoption is also about which end of the facility versus service-based competition spectrum is best for broadband uptake.

Cava-Ferreruela and Alabau-Munoz (2006) found significant effects from "technological" (platform) competition. They use a dummy variable to "indicate the existence of competition between technologies". Since there was no OECD country that relied entirely on DSL for broadband access at December 2005, some threshold must apply[16] or else their dummy is the same for all countries. They also find the number of 3G mobile operators to be a significant measure of competition for broadband coverage.

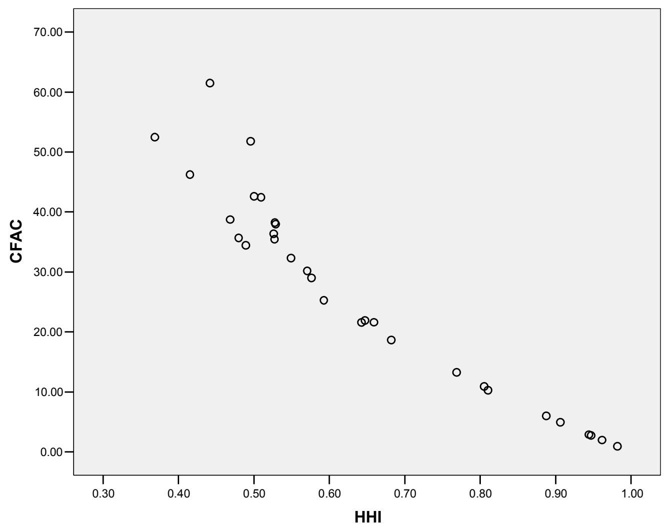
- C_{FAC} is measured as the share of non-DSL lines in $Q_{TOT.}$ The higher this ratio is, the nearer the country is to the facilities-based end of the competition spectrum. Only three countries have a share higher than 50%: the United States, Canada and the Czech Republic (Annex 2). As expected, this measure is positively correlated with Q_{TOT}.

  A variant of this measure is the Herfindahl-Hirschman Index of concentration using the shares of broadband access types instead of firm market shares (Cadman and Dineen, 2006; Grosso, 2006). As shown by Figure 4, there is not much difference between this index (based on OECD data) and C_{FAC}.

- C_{CAB} is narrower in scope than CFAC being the share of cable in $Q_{TOT.}$

- C_{ENT} is 1 minus the share of the broadband market accounted for at the retail level by the incumbent fixed carrier. The main source is ECTA (which reports only European countries) supplemented by the author's estimates for Australia, Canada, Korea, Norway and the United States with Iceland, Japan, Switzerland and Turkey treated as missing observations.

Figure 4: The HHI and CFAC compared (December 2005)



While all these measures are positively correlated with Q_{TOT} (see Table 2 and Annex 1d), the correlations are very weak despite some tautology (all the measures are significant components of Q_{TOT}). However, C_{FAC} does seem important in the country commentary (Table 5) and is significant in the differenced data set (Table 7).

5. December 2005 data set

The data set for December 2005 tests the suitability of a large range of possible explanatory variables. The maximum sample size is only 30 but it appears to yield better results than other samples of the same size (*e.g.* Bauer *et al.* 2001 and Turner 2005).

The first three columns of Table 4 show results for demand and supply equations estimated independently while the last two columns are results for a composite equation.

The estimated equations give some comfort that just a few key variables can explain much of the variation in broadband penetration rates.

Table 4: Results of some OLS estimations (Dec. 2005)

Dependent variable: total broadband penetration (QTOT)		1	2	3	4	5
Demand						
Price	LNPTOT	-1.980				
		(2.96)**				
	LNPDSL		-1.865			
			(2.84)**			
	LNPREL			-1.978	-2.366	-3.572
				(3.27)**	(4.88)**	(6.19)**
GDP per capita	YINDEX	0.261	0.079	-1.099		
		(0.07)	(0.02)	(0.31)		
Age	AGE	0.534	0.598	0.725	0.521	0.917
		(1.11)	(1.24)	(1.57)	(1.47)	(1.93)*
Education	ETERT	0.084	0.092	0.131		
		(0.80)	(0.88)	(1.37)		
Saturation	SIP	0.352	0.352	0.338	0.296	
		(3.94)**	(3.90)**	(3.87)**	(4.94)**	
Weather	SUN	-0.173	-0.197	-0.007		
		(0.27)	(0.31)	(0.01)		
Constant		-4.798	-6.751	-17.321		
		(0.0.33)	(0.47)	(1.34)		
Observations		30	30	30		
Adjusted R-squared		0.770	0.765	0.784		
Supply						
Price	LNPDSL	-2.790				
		(3.76)**				
Urbanisation	UURB	0.316	0.349	0.354	0.194	0.302
		(4.09)**	(3.71)**	(3.81)**	(3.41)**	(4.17)**
Competition	CFAC	0.057	0.043			
		(1.12)	(0.70)			
Policy	GUYRS	0.574	1.285	1.333		
		(1.65)	(3.60)**	(3.84)**		
Constant		-5.348	-19.592	-19.019	-22.724	-35.332
		(0.77)	(2.73)**	(2.69)*	(2.24)*	(2.61)**
Observations		30	30	30	30	30
Adjusted R-squared		0.672	0.507	0.517	0.852	0.720

Note. Absolute value of t statistics in parentheses.

Statistical significance at the 5 and 1% denoted by * and **.

In Table 5, those countries that are more than one standard deviation from the mean broadband penetration rate are identified at the top of the table. About one third of OECD countries are in this category, shown as "worst and best performers". Using this country selection, Table 5 then goes on to report which of these countries is greater than one standard deviation from the mean of the key explanatory variables identified. If a country has such a deviation on a variable that would promote broadband penetration (*e.g.* low prices), it is shown in the "advantaged" column. If the deviation would have the opposite influence (*e.g.* high prices) the country is shown as "disadvantaged".

Table 5: Macro-correlations - the best and the worst (Dec. 2005)

	Worst performers (1)		Best performers (1)	
B'band Penetration (2)				
	GRC	Greece	DNK	Denmark
	HUN	Hungary	FIN	Finland
	MEX	Mexico	ISL	Iceland
	POL	Poland	KOR	Korea
	SVK	Slovak Republic	NLD	Netherlands
	TUR	Turkey	NOR	Norway
			CHE	Switzerland
	Disadvantaged (1)		**Advantaged (1)**	
Price (LN forms)	HUN, MEX, SVK, TUR		FIN, KOR	
Income (YINDEX)	HUN, MEX, POL, SVK, TUR		NOR	
Education (ETERT)	MEX, POL, SVK, TUR		DNK, FIN, NOR	
Weather (SUN)	GRC, KOR (3), MEX		ISL, NLD	
Saturation (SIP)	GRC, HUN, MEX, POL, SVK, TUR		DNK, NLD, NOR, CHE	
Urbanisation (UURB)	GRC, FIN (3), POL, SVK		DNK, ISL	
Policy (GUYRS)	MEX, SVK, CHE (3), TUR		DNK, FIN, NLD	
Competition (CFAC)	GRC, ISL (3), TUR		KOR	

Notes: (1) Further than one standard deviation from the mean.
(2) Only these countries are considered in the remainder of the table.
(3) These are "disadvantaged" countries which have high penetration.

None of the "worst performers" have any advantages. Mexico and Turkey are the most disadvantaged with six citations each across the eight explanatory variables. The most advantaged country is Denmark which is cited against four variables with no negative citations.[17]

While neither Australia nor New Zealand is among the countries just discussed, both lie more than one standard deviation from the mean on some of the explanatory variables. Australia is disadvantaged on weather (the sun creates its famous outdoor culture) and advantaged on urbanisation (which could be due to poor measurement of urbanisation as noted earlier). New Zealand is advantaged on the education measure and disadvantaged on policy (ULL is only now being introduced) and competition (DSL accounts for almost 90% of broadband access).[18]

6. Panel data set

The panel includes the December 2005 data except that the price variable relates only to DSL prices because only DSL prices are available for both periods in the panel data set. The panel dummy variable set to 1 for December 2005 data and set to 0 for the earlier corresponding data.

The earlier panel data is for December 2002 with the following exclusions:

- The penetration rate for Korea has been treated as a missing value. Korea's penetration rate is more than twice as high as the next highest country (Canada) and including it would have skewed the distribution of Q_{TOT} making OLS estimation results unacceptable.

- The Internet penetration rate (SIP) for Portugal in the early period has been treated as a missing value given the reporting issues discussed above.

- DSL prices for Turkey in the early period are excluded. Turkey's DSL prices in that period are more than treble those of the next highest prices (Mexico).

- There are also three missing DSL price points in the early period for the Czech Republic, Greece and the Slovak Republic. None of them had broadband service in July 2003.

The OLS estimation results are presented in Table 6. The first three columns show results for demand and supply equations estimated independently while the last two columns are results for a composite equation.

Not surprisingly, the panel dummy variable is highly significant showing a mean jump in broadband penetration of around 7 percentage points between the two periods.

Comparing Table 6 with Table 4 shows no surprises. The demand equations show again the importance of price and the size of the addressable market (SIP) with support for AGE. But GDP per capita is not significant as a measure of income.

Comparing Table 6 with Table 4 on the supply side, the price variable is again incorrectly signed suggesting that the observed relationship between broadband penetration and price is tracing-out the demand curve. The level of urbanisation is again a highly significant supply factor and strong support is found for ULL (GUYRS) as a key explanatory variable. The role of platform competition (CFAC) is still difficult to confirm.

7. Differenced data

While the variables considered in this paper can explain some of the difference in broadband penetration rates across countries, it must be recognised that there may be country-specific factors that will affect broadband uptake and which are not captured by the variables examined in this study. But, there is a simple technique which washes-out country fixed effects. That is, assuming that the excluded, unique country factors do not vary between the two periods in the panel data set, subtracting the values in the earlier period from those in the later period yields a new differenced data set where country-specific factors have been eliminated.[19]

Table 6: Results of some OLS estimations (Panel data)

Dependent variable: total broadband penetration (QTOT)						
		1	2	3	4	5
Demand						
Price	LNPDSL		-2.017	-1.993	-2.023	-2.233
			(5.69)**	(5.49)**	(5.84)**	(5.43)**
	LNPREL	-1.549				
		(3.94)**				
GDP per capita	YINDEX	-1.44				
		(0.59)				
Age	AGE	0.505	0.522		0.440	0.652
		(1.56)	(1.90)*		(1.71)*	(2.15)*
Education	ETERT	0.117				
		(1.76)*				
Saturation	SIP	0.247	0.277	0.302	0.215	
		(4.20)**	(6.89)**	(7.71)**	(4.69)**	
Weather	SUN	-0.085				
		(0.21)				
Dummy	DUMMY	7.610	7.349	7.286		
		(7.33)**	(7.90)**	(7.64)**		
Constant		-15.368	-8.481	5.823		
		(1.70)*	(1.09)	(2.93)**		
Observations		55	54	54		
Adjusted R-squared		0.816	0.839	0.831		
Supply						
Price	LNPDSL	-2.131				
		(5.05)**				
Urbanisation	UURB	0.255	0.249	0.295	0.134	0.218
		(5.44)**	(4.58)**	(4.48)**	(3.20)**	(4.81)**
Competition	CFAC	0.033		0.030		
		(1.52)		(0.99)		
Policy	GUYRS	0.596	0.970		0.094	0.469
		(3.17)**	(4.82)**		(0.54)	(2.51)*
Dummy	DUMMY	7.215	7.488	11.054	7.288	6.732
		(5.98)**	(5.68)**	(7.13)**	(7.87)**	(6.13)**
Constant		-9.447	-16.704	-19.740	-15.075	-23.006
		(2.07)*	(4.05)**	(3.53)**	(2.01)*	(2.63)*
Observations		54	54	58	54	54
Adjusted R-squared		0.794	0.683	0.557	0.862	0.802

Note: Absolute value of t statistics in parentheses.
Statistical significance at the 5 and 1% denoted by * and **.

Of course, differencing means that some key factors from Tables 4 and 6 such as education, weather and urbanisation which do not vary between periods are differenced out of the equations. And, the GUYRS policy variable drops out too because the difference in years of unbundling takes the same value (*i.e.* 3) for all countries.

The estimated results for the demand, supply and composite equations are presented in Table 7. Comparing these results with Tables 4 and 6, price and market size (SIP) are still significant and platform competition (CFAC) becomes highly significant.

Table 7: Results of some OLS estimations (Difference data)

Dependent variable: total broadband penetration (DQTOT)		1	2	3
Demand				
Price	LNDPREL	-0.473		
		(0.21)		
	LNDPDSL		-1.053	-1.456
			(1.08)	(2.04)*
GDP per capita	DYINDEX	-47.619	-41.613	
		(1.31)	(1.20)	
Saturation	DSIP	0.798	0.740	0.733
		(1.754)*	(1.79)*	(2.38)*
Constant		6.686	5.710	
		(3.40)**	(2.74)**	
Observations		24	25	
Adjusted R-squared		0.095	0.144	
Supply				
Price	LNDPDSL	-1.785		
		(2.38)*		
Competition	DCFAC	0.119		0.120
		(4.11)**		(4.48)**
Constant		10.128		7.728
		(7.35)**		(4.74)**
Observations		25		24
Adjusted R-squared		0.427		0.523

Note: Absolute value of t statistics in parentheses.
Statistical significance at the 5 and 1% denoted by * and **.

8. Conclusions

There is a consistent pattern across all the results presented here in terms of what drives broadband penetration. The new pricing data in this study yield more significant price effects than some previous studies (Table 1). The size of the addressable market (S_{IP}) and age profile of the population were also found to be significant demand drivers.

Surprisingly, GDP per capita was not found to be statistically significant.[20] Future research should consider whether a broader set of internationally comparable income data yield the same results.

Weather is not a variable that has been considered before in any broadband penetration study. Although statistically significant coefficients were not found for SUN, Tables 2 and 5 suggest weather could be a demand driver and should be considered in future studies; perhaps testing rain and temperature as alternative weather variables.

On the supply side, urbanisation proved to be significant, as expected. However, it was difficult to establish strong competition effects. However, as broadband mobile and wireless Internet platforms become more widely deployed, it should be possible to revisit the impact of facilities based competition on broadband.[21]

While the number of years that ULL has been available (G_{UYRS}) proved significant, it is a rather simplistic measure of government policy. Unfortunately, the wealth of data on different forms of unbundling and alternative broadband platforms that is published by ECTA for European countries is not yet available for the rest of the OECD countries.

This paper has not been able to look at other government policies, such as subsidies and taxes. These could affect the deployment and uptake of broadband. These factors may be more easily addressed through country case studies than international comparisons due to the paucity of comparable data.

Data is available to examine DSL and Cable penetration rates separately. The former is the dominant form of supply currently. Any research on the impact of unbundling policies should focus on DSL rather than overall broadband penetration.

The results of this paper suggest that the key variables driving broadband penetration rates are either exogenous (*e.g.* urbanisation) or they are general economic factors (*e.g.* market size and education). The analysis also supports the contention that unbundling (as measured by G_{UYRS}) is currently more significant than platform competition in explaining broadband penetration. This fact suggests that if platform competition does not materialise, government or regulatory policy aimed at increasing broadband penetration rates should focus on determining the appropriate pricing structure for the unbundled local loop or consider the use of subsidies to increase broadband infrastructure or penetration rates.

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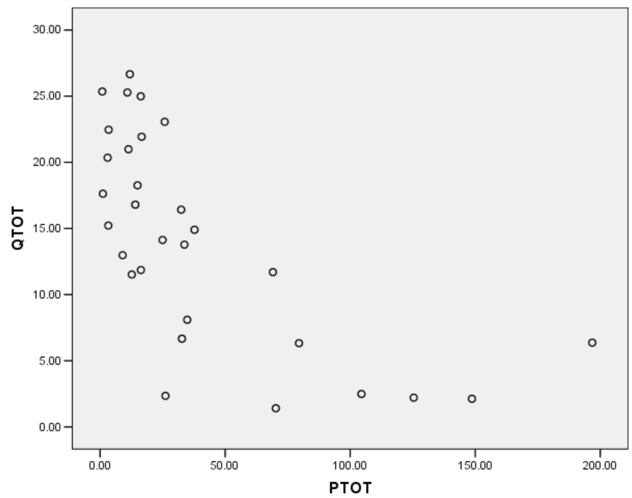
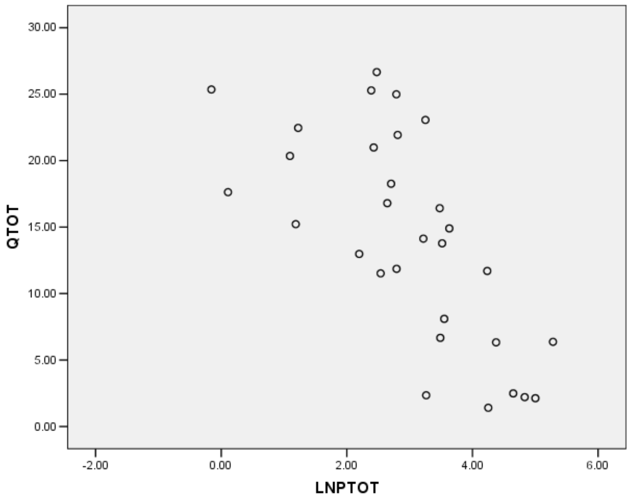
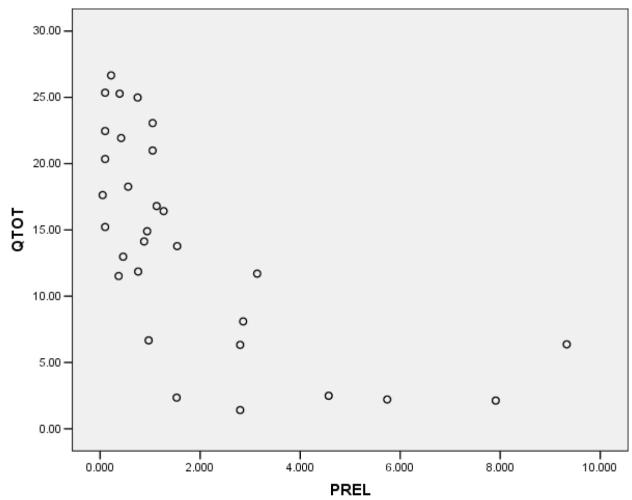
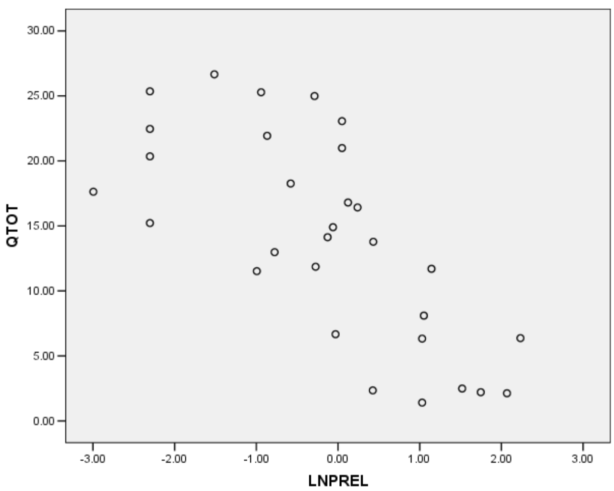
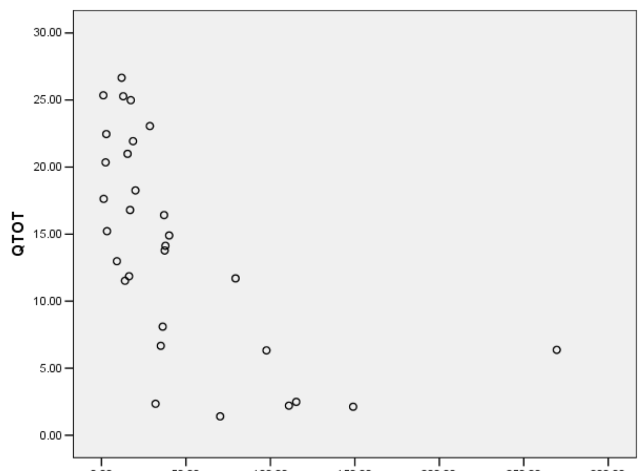
ANNEX 1A: BROADBAND PENETRATION AND PRICE (DECEMBER 2005)

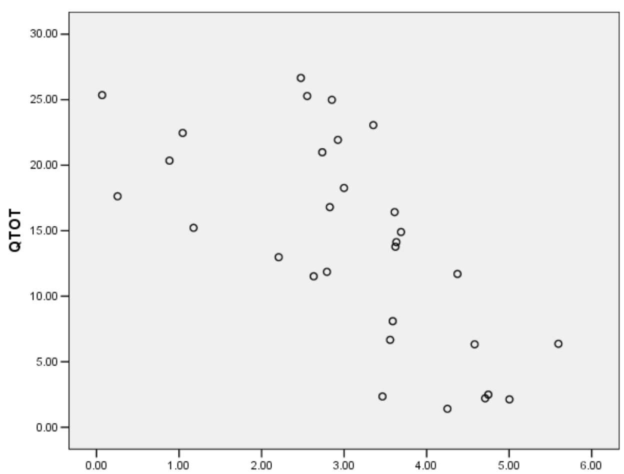




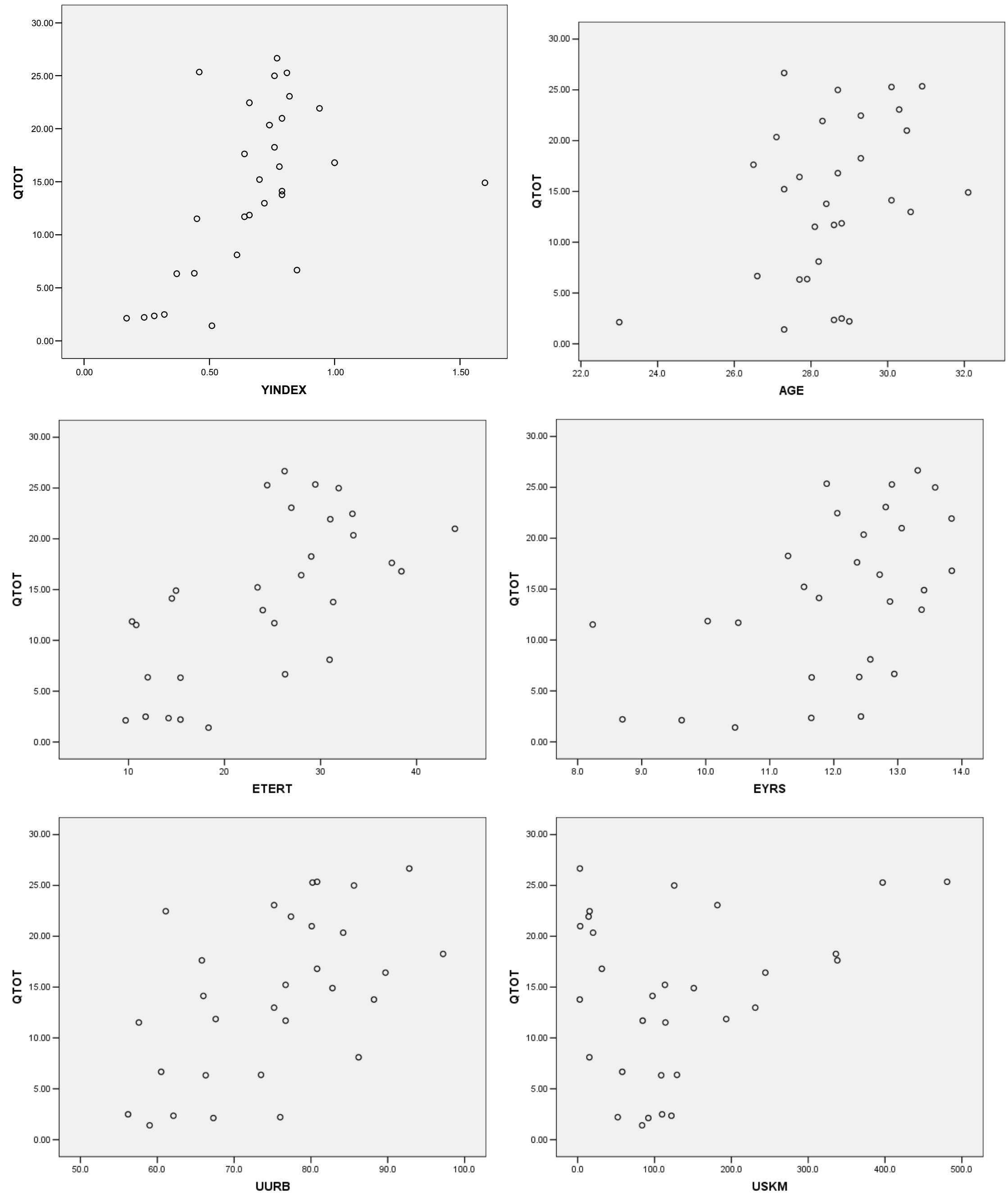




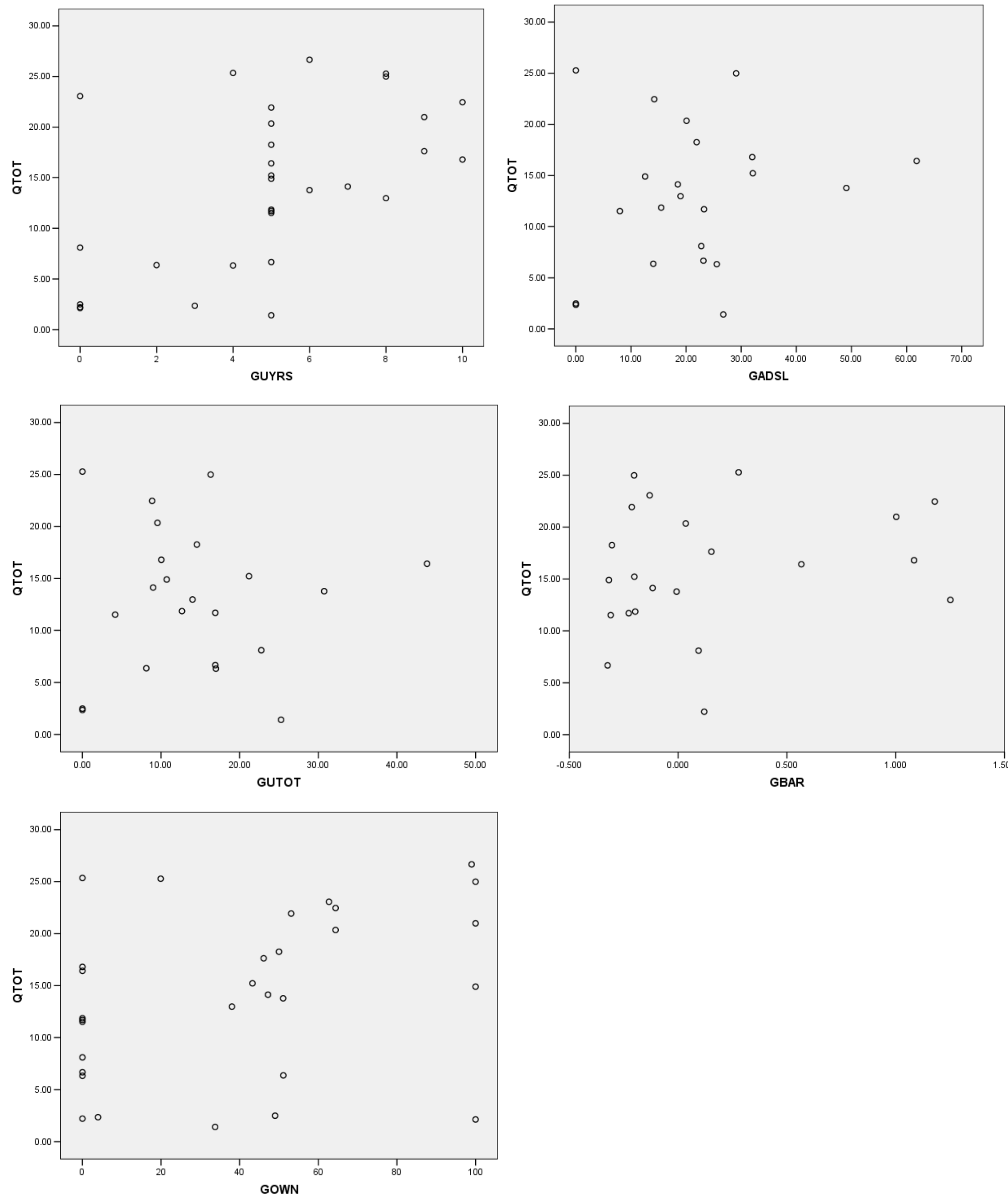




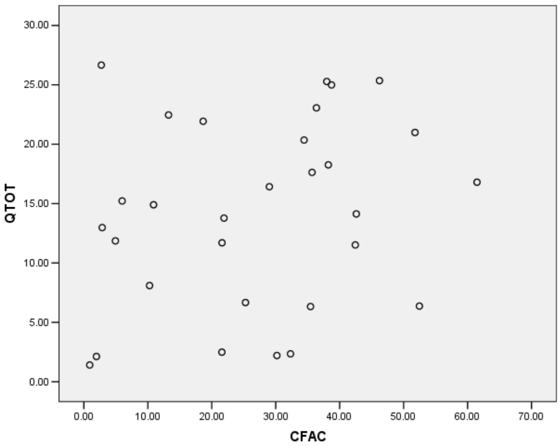
ANNEX 1B: BROADBAND PENETRATION AND DEMOGRAPHIC VARIABLES (DEC. 2005)

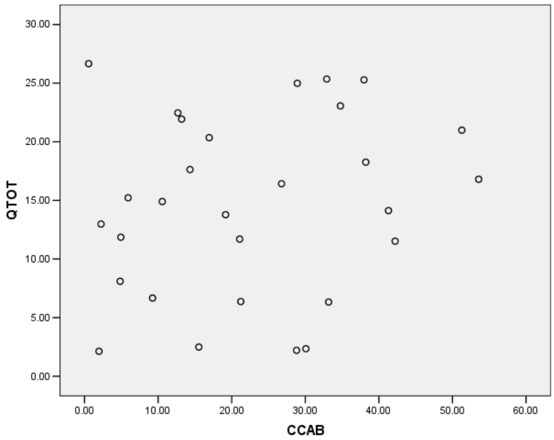


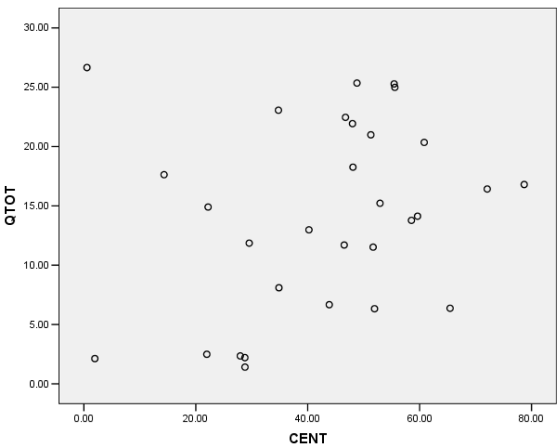
ANNEX 1C: BROADBAND PENETRATION AND POLICY VARIABLES (DEC. 2005)



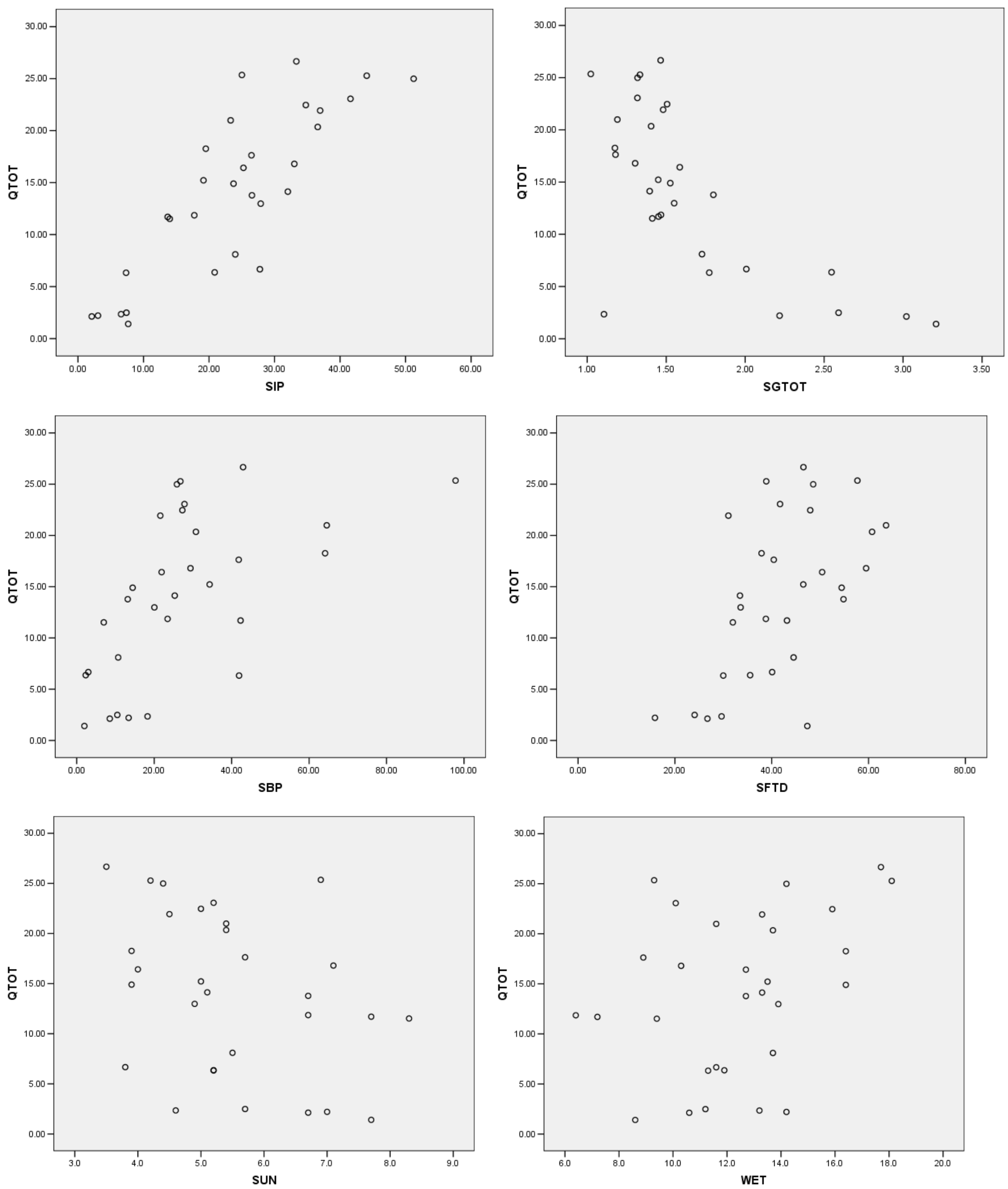
ANNEX 1D: BROADBAND PENETRATION AND COMPETITION VARIABLES (DEC. 2005)







ANNEX 1E: BROADBAND PENETRATION AND MARKET VARIABLES (DEC. 2005)



ANNEX 2: TABLE OF DECEMBER 2005 DATA

		QTOT	PTOT	PDSL	PREL	YINDEX	AGE	ETERT	SIP	SUN	UURB	GUYRS	CFAC
AUS	Australia	13.78	33.70	37.40	1.54	0.79	28.40	31.00	26.55	6.70	88.20	6.00	21.91
AUT	Austria	14.13	24.99	37.84	0.88	0.79	30.10	15.00	32.03	5.10	66.00	7.00	42.60
BEL	Belgium	18.26	14.95	20.06	0.56	0.76	29.30	29.00	19.51	3.90	97.20	5.00	38.22
CAN	Canada	20.99	11.33	15.42	1.05	0.79	30.50	44.00	23.30	5.40	80.10	9.00	51.78
CZE	Czech Rep.	6.37	196.81	269.53	9.33	0.44	27.90	12.00	20.86	5.20	73.50	2.00	52.46
DNK	Denmark	24.99	16.25	17.32	0.75	0.76	28.70	32.00	51.23	4.40	85.60	8.00	38.73
FIN	Finland	22.46	3.40	2.84	0.10	0.66	29.30	33.00	34.77	5.00	61.10	10.00	13.24
FRA	France	15.22	3.28	3.24	0.10	0.70	27.30	23.00	19.15	5.00	76.70	5.00	5.98
DEU	Germany	12.98	9.00	9.09	0.46	0.72	30.60	24.00	27.89	4.90	75.20	8.00	2.86
GRC	Greece	1.41	70.24	70.24	2.80	0.51	27.30	18.00	7.66	7.70	59.00	5.00	0.91
HUN	Hungary	6.33	79.53	97.66	2.80	0.37	27.70	15.00	7.34	5.20	66.30	4.00	35.44
ISL	Iceland	26.66	11.89	11.89	0.22	0.77	27.30	26.00	33.33	3.50	92.80	6.00	2.72
IRL	Ireland	6.67	32.73	35.08	0.97	0.85	26.60	26.00	27.76	3.80	60.50	5.00	25.27
ITA	Italy	11.86	16.31	16.31	0.76	0.66	28.80	10.00	17.75	6.70	67.60	5.00	4.93
JPN	Japan	17.63	1.11	1.29	0.05	0.64	26.50	37.00	26.48	5.70	65.80	9.00	35.68
KOR	Korea	25.35	0.85	1.07	0.10	0.46	30.90	29.00	25.02	6.90	80.80	4.00	46.22
LUX	Luxembourg	14.90	37.76	40.04	0.94	1.60	32.10	15.00	23.74	3.90	82.80	5.00	10.89
MEX	Mexico	2.21	125.41	110.93	5.74	0.24	29.00	15.00	3.05	7.00	76.00	0.00	30.18
NLD	Netherlands	25.28	10.89	12.84	0.39	0.81	30.10	24.00	44.07	4.20	80.20	8.00	37.98
NZL	New Zealand	8.10	34.83	36.21	2.86	0.61	28.20	31.00	24.01	5.50	86.20	0.00	10.27
NOR	Norway	21.93	16.60	18.63	0.42	0.94	28.30	31.00	36.96	4.50	77.40	5.00	18.65
POL	Poland	2.35	26.13	31.97	1.53	0.28	28.60	14.00	6.58	4.60	62.10	3.00	32.31
PRT	Portugal	11.52	12.66	13.89	0.37	0.45	28.10	11.00	14.00	8.30	57.60	5.00	42.44
SVK	Slovak Rep.	2.49	104.51	115.28	4.57	0.32	28.80	12.00	7.39	5.70	56.20	0.00	21.58
ESP	Spain	11.70	69.08	79.33	3.14	0.64	28.60	25.00	13.69	7.70	76.70	5.00	21.60
SWE	Sweden	20.35	2.99	2.42	0.10	0.74	27.10	33.00	36.59	5.40	84.20	5.00	34.43
CHE	Switzerland	23.06	25.82	28.61	1.05	0.82	30.30	27.00	41.59	5.20	75.20	0.00	36.36
TUR	Turkey	2.13	148.67	148.96	7.91	0.17	23.00	10.00	2.10	6.70	67.30	0.00	1.96
GBR	United Kingdom	16.42	32.42	37.03	1.27	0.78	27.70	28.00	25.25	4.00	89.70	5.00	29.00
USA	United States	16.80	14.06	16.89	1.13	1.00	28.70	38.00	33.02	7.10	80.80	10.00	61.47
	N	30	30	30	30	30	30	30	30	30	30	30	30
	Mean	14.14	39.61	44.64	1.79	0.67	28.53	24.07	23.76	5.50	74.96	4.97	26.94
	Std. Deviation	7.92	47.78	56.94	2.31	0.27	1.70	9.42	12.47	1.30	11.07	2.97	16.93

NOTES

1 Adoption of broadband has been explored with other data sets such as US States data (Aron and Burnstein, 2003; Denni and Gruber, 2005) and for the EU-15 (Distaso *et al.*, 2006).

2 Both competition and policy may be endogenous too but it is hard to find any direct influence from either on broadband penetration so having to explain them within the model would be too ambitious.

3 It is important for the measures of correlation and the ordinary least squares (OLS) estimates that there are straight-line relationships between the variables.

4 The data for DSL enabled loops is for either 2002 or 2003 and is taken from the OECD (2002, Table 5). The figure for Australia is 87% and represents potential supply compared with less than 7% of lines actually providing DSL service.

5 This coefficient lies between 0 and 1 where the latter means the relationship between the two variables lies on a straight line.

6 In a normal distribution, 95% of observations will fall between the mean plus or minus 1.96 standard deviations.

7 By definition, the possible range of values for Q_{TOT} is bounded by zero and 100%. This might suggest the use of a Tobit model, which would allow for the logistic shape of broadband penetration, rather than using least squares (OLS) regression. However, broadband penetration rates are concentrated between 1 and 25% (as shown in Figures 1 and 2), so OLS is a good approximation.

8 The OECD stopped reporting the dial-up costs of Internet access in 2002.

9 For December 2005, the correlation coefficient between Y_{INDEX} and E_{YRS} and E_{TERT} is 0.619 and 0.399 respectively.

10 The ITU reports higher subscriber numbers in 2002 than 2004 for Germany, Portugal, Turkey and the United States, which seems unlikely.

11 From http://www.bbc.co.uk/weather/world/country_guides/ which also has temperature data. Capital city data are not considered too limited when the greatest broadband penetration rates are found there too.

12 A detailed study on the impact of population density on the cost of service to-date was done by the Productivity Commission in Australia (Cribbett, 2000). This study normalised population density distributions to a consistent low level of aggregation. Then, average line costs for Australia, New Zealand, Finland and the US States of Alaska, California, Oregon and Washington were estimated using line density distributions and a common cost function. It found that low line density areas, defined as less than two services per square kilometre, accounted for 25% of the costs of providing local service in Australia compared with 5% in California.

13 Other population/urbanisation measures considered were:

- The population inside the most populated 10% of regions from Table 1.1 of the OECD's "Regions at a Glance". On this measure, Australia is counted as the most geographically concentrated country with 10% of regions accounting for 64% of the population; compared with about 34% on average for the OECD. This reflects the vast tracts of land that are sparsely populated in Australia.
- The index from Table 1.1 of the same OECD publication showing geographic concentration that "*offers a more accurate picture of the spatial distribution of the population, as it takes into account*

the area of each region". Again, Australia is counted as densely populated at 0.8 compared with an OECD average of 0.4.

- The variances in regional population densities from Table 1.3 of the same OECD publication; which are marked. The highest population density is in Paris with 20 356 people per sq km. The population density in Sydney and Melbourne is less than 500 per square kilometre compared with Korea's 17 000 plus in Seoul and over 2 500 in each of Pusan, Taegu, Incheon and Kwangju.
- The urban population density from Table 1.4 in the OECD publication which finds that only 55% of Australia's population is urban compared with 88% on the United Nations definition of urbanisation. But the OECD average in Table 1.4 is not much different from Australia's at 53% so this definition of population density is no improvement over U_{URB}.

14 ECTA's *Broadband Scorecards* are at http://www.ectaportal.com/en/basic276.html with the earliest at September 2004. Its ADSL numbers are used for G_{ADSL} rather than the OECD's if they differ slightly.

15 The FCC reports the number of lines provided with and without switching. Assuming the latter (UNE-L) is used to support broadband, there were 4.3m ULL lines or 10% of all broadband services at June 2005.

16 For example, in 13 countries, cable accounted for less than two percentage points of total broadband penetration.

17 It is interesting to note that Denmark leapt to the top of the broadband penetration ranking in June 2006.

18 Also, Howell (2006) points out that relatively cheap dial-up prices are a factor in New Zealand. Only the Czech Republic, Mexico, the Slovak Republic, Spain and Turkey have higher values of LNPREL than New Zealand. On the results presented in this paper, reducing LNPREL to the OECD mean would have increased New Zealand's penetration rate 2.0 to 4.4% above its 8.1% level.

19 Some other studies have also used fixed effects transformations (Gross 2006, Wallsten 2006).

20 Cava-Fuerruruela and Alabau-Munoz (2006) found this variable to be "the most relevant variable for both the estimation of both DSL and cable coverage" (p453). But for our dependant variable, per capita broadband penetration, it does not appear in either their estimated model (p457) or correlation matrix (p458). Bauer *et al.* (2003) obtained a negative coefficient on income, which is contrary to expectations.

21 As at December 2005, only Denmark, Japan, Korea and Sweden had higher than 2% penetration in technologies other than DSL and cable.