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Australian Broadband Regulation Reviewed

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Abstract

This article establishes the relationship between the condition of Australian broadband services and Australia's history of broadband regulation. It briefly surveys the history of the industry in terms of government action and firms responses. It reviews research on the effects of regulation and industry concentration internationally, which indicates that the effects of widely deployed policies are often small or undetectable. The article uses these findings to build models of national broadband prices, penetration and quality. The models are verified using recent statistics from developed economies, confirming that outcomes are little affected by access regulation, and also not by market concentration. Penetration and quality are strongly affected by technology factors. The models and the regulatory history are used to explain the condition of Australian broadband services, and to extract lessons applicable to future policy development.

Introduction

Australian regulation of fixed broadband networks was broadly consistent with other developed economies until 2009, when NBN Co was established as a government-owned monopoly. Australian consumers are currently less satisfied with Internet services than with mobile phone or fixed line telephone services, and are particularly dissatisfied with Internet data speeds, service costs and the speed of fault repairs (ACMA_2017 [5], pp. 60-61). Successive government policies are regularly criticised as contributing to poor Australian outcomes, but how much impact does policy actually have, compared to the impact of other economic and demographic factors

This article explores this question through an international comparison. It reviews Australian policy across the era of broadband Internet, and then reviews research about the impact of such regulation internationally. Models of broadband pricing, penetration and quality are formed by applying this research to recent data from developed economies. These models are used to explore Australian broadband outcomes, and to trace the effects of regulatory policies and decisions. Implications for future broadband policy are also discussed.

History of Australian Broadband Regulation

Ownership separation, competition and intermediate compromises have been features of Australia's telecommunications regulatory policy for decades. Ownership separation refers to detaching the ownership of monopoly infrastructure from the ownership of firms using that infrastructure to deliver services (Baldwin, Cave & Lodge, 2011 [6], p. 467). Ownership separation, referred to as structural separation, is the solution currently adopted in Australia (Telecommunications Act, 1997 [7]). It was adopted after long experimentation with other remedies for market failure, including competition and functional separation.

In the late twentieth century, competition, initially in long distance and international calls, was preferred to monopoly regulation of Australian telecommunications. Such competition would encourage the expansion of Australia's telecommunications infrastructure and industry (Brown, 1990 [8]). Enabling this competition initially required regulated access to Telecom Australia's (later Telstra's) local network, and AUSTEL was established as an industry regulator (Telecommunications Act, 1991 [9]). Beginning in 1997, the need for public oversight increased as Telstra was privatised in three stages (Telstra (Dilution of Public Ownership) Act, 1996 [10]). Over time, competition in telephony expanded to include infrastructure, when Optus and Telstra constructed rival hybrid fibre coaxial (HFC) networks, carrying pay TV alongside telephone calls. And as networks were expanding, new applications were emerging, notably the Internet (Richardson, 1997 [11]).

Internet access, especially email and the World Wide Web, emerged as a significant third use for telecommunications networks in the 1990s. Dialup Internet protocol (IP) services could be delivered to households over the existing (copper or HFC) networks, with new equipment required only on the customers' and the Internet service providers' (ISP) premises. Dialup Internet services had limited bandwidth and could not be used concurrently with telephone calls. HFC networks offered superior Internet access and enabled the "triple play" of telephone, pay TV and Internet services to utilize and repay the investment in HFC infrastructure. But accessibility and low cost meant dialup remained the most common mode of Australian household Internet access until 2006 (Figure 1). For households without HFC access, the alternative to dialup was a digital subscriber line (DSL) service delivered over existing copper telephone lines. DSL had at least 17 times the bandwidth of dialup services, up to 1500 kbps, and bandwidth increased further as technology improved. Increasing bandwidth over the copper network enabled Internet services such as video streaming, multiplayer computer games and file sharing, without significant new network construction.

Without overbuilding, entrepreneurial ISPs could only resell services delivered over Telstra's monopoly copper network. They could not easily compete with Telstra's and Optus's vertically integrated products, and captured little DSL market share. Figure 1 shows the initially high but rapidly falling retail market share (as percentage of total subscriptions) of dialup access from 2005. Telstra and Optus combined had 90% of retail broadband (DSL and HFC) subscribers in 2007. (In accordance with the Australian Bureau of Statistics, broadband here is defined as an 'always on' internet connection with an access speed of 256kbps or higher (ABS 2017) [12].) iiNet was the most successful start-up with only 6% of subscribers. Competition was not thriving.

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Figure 1 Subscriber concentration in the Australian residential Internet market. Company and Other broadband shares are given for broadband subscriptions according to the ABS definition, dialup subscriptions are consolidated. (Source: Author's calculation from ABS data and companies public reports and investor presentation)

Australian law gives the Australian Competition and Consumer Commission (ACCC) authority to declare certain telecommunications services, that is, to establish regulated access to declared services (Telecommunications Act, 1997 [7], Clause 350A). Telstra's local line monopoly concerned the ACCC, and various Telstra operations were declared in 1997, which allowed other firms to access Telstra services on a wholesale basis at set prices (ACCC, 1997 [14]). Sharing of the copper lines to premises (local loop unbundling or LLU) was initially declared in 2002 (ACCC, 2002 [15]), but the regulated prices proved unattractive to competitors, and direct sale and resale of Telstra services remained the dominant mode. The basis for LLU pricing was altered in 2007 (ACCC, 2007a [16]), allowing rival ISPs to connect their own DSL equipment to Telstra's local copper lines for $14.30 instead of $30 per month (ACCC, 2008b [17]). The residential market responded by increasing the market share of Optus and fringe ISPs at Telstra's expense. Between 2007 and 2010 Telstra's number of broadband customers fell by 6% while the total number of Australian fixed broadband subscriptions grew by 70% (Figure 1). The regulator's determinations were often vigorously contested by Telstra, and a plan to upgrade much of the local copper to a higher bandwidth fibre to the node (FTTN) network was halted in 2006 as the ACCC and Telstra failed to reach agreement on competitive access pricing (Burgess, 2006 [18]).

Declaring and regulating Telstra's infrastructure increased retail competition and allowed customers meaningful choice within the infrastructure duopoly. However, access to, and the quality of, Telstra-owned exchanges and copper remained problematic for rivals, and there was no apparent path to an upgrade of the fixed telecommunications network (iiNet Pty Ltd, et al., 2007 [19]). Furthermore, regulatory requirements discouraged Telstra investment. Telstra instead directed investment to more profitable and less heavily regulated operations associated with mobile telephone and data services (Telstra, 2010 [20]). In 2007, the G9 consortium of telecommunication firms (excluding Telstra) proposed building a FTTN network, structurally separated from the investing firms and from Telstra, but also failed to reach agreement with the ACCC on access pricing (ACCC, [21]2007 [21]b).

Network quality became a significant political issue in the 2007 Australian federal election, when the challenging Labor party promised to invest up to 4.7 billion dollars upgrading most of the copper network to FTTN (Farnsworth, 2007 [22]). But Telstra, whose cooperation was required to install and connect the new fibre to the existing network, refused to participate without guarantees regarding future regulation (McGauchie, 2008 [23]). The government was unwilling to offer such guarantees; Telstra was particularly concerned about forced separation, but was also concerned about future regulatory consistency.

In response, the Australian Government revised its policy in 2009 and established a government-owned company to build a primarily fibre to the premises (FTTP) network, at an estimated cost of 43 billion dollars. The policy initially envisaged the company (NBN Co) being financed with majority government equity plus some private funding, but private investors could not be found and the new company began operations as entirely government-owned. The intention to eventually privatise the company, to recoup the public investment, remained (Wong & Conroy, 2010 [24], p. 12), requiring NBN Co to operate as a long-run profit-making firm.

The new FTTP network would replace Telstra's local copper lines with optic fibre, although it would rent access to Telstra's ducts and other passive physical infrastructure on a wholesale basis. The NBN would only sell wholesale access to retail ISPs, thus achieving structural separation at the local network level. Points of Interconnection (POI) between the NBN and the existing backhaul network were located only where competing backhaul services were already present, to preserve backhaul competition. Telstra agreed to work with NBN Co on access and transition arrangements, and other ISPs broadly welcomed the policy.

Difficulties emerged with the building of the FTTP network, and project delays and concerns about the eventual total cost were issues in the 2013 federal election. A change in government brought a focus on costs and speed of deployment, and in accordance with the recommendations of a cost-benefit study (Australian Government Department of Communications and the Arts Panel of Experts, 2014 [25]) the design of the network was modified to include a mix of technologies including FTTP, FTTN and the existing HFC lines. NBN Co accordingly purchased the HFC networks of Telstra and Optus, thus eliminating the fixed infrastructure competition to the FTTN/FTTP network. NBN Co agreed to progressively assume ownership of passive Telstra infrastructure as the NBN replaced Telstra's copper network and DSL broadband services.

Role of Regulation and Industry Concentration

The quantity of broadband units purchased is an important measure of the industry's economic contribution. In the early twenty-first century, many governments supported increased quantity by promoting affordable home broadband. For instance, a key objective of the eEurope initiative was to bring every home into the digital age and online (Liikanen, 2000 [26]). Many studies of these policies investigate how government and industry actions affected broadband penetration (the typical measure of quantity). A common finding is that broadband adoption is driven by competition between different technological platforms (inter-platform) and not, or less, by competition on a single platform (intra-platform) (Bouckaert, van Dijk, & Verboven, 2010 [27]; Cincera, Estache, & Dewulf, 2012 [28]; Distaso, Lupi, & Manenti, 2006 [29]). Cincera et al. (2012 [28]) also found that larger incumbent market shares are associated with slower broadband diffusion. There is some evidence of regulated local loop unbundling (LLU) having slightly positive effects, and other forms of access regulation having small, insignificant or negative effects. Cave (2014 [30]), whose work informed much regulatory practice, reviewed results from the period of DSL's technological dominance.

As fixed broadband penetration approached saturation in developed economies (see Figure 2) interest shifted from broadband to superfast next generation network penetration. Briglauer (2014 [31]) found strong regulation of DSL networks hinders adoption of next generation networks. He has argued that competitive firms invest to escape competition, and so refrain from investing if their competitors will share the rewards. Australia apparently witnessed this effect when neither Telstra nor the G9 consortium were able to agree with regulators on conditions to privately build a FTTN network. Australian regulators must have recognised the benefits of upgrading the network, but were concerned about the effect on consumer prices.

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Figure 2. Fixed broadband penetration in OECD nations. (Source: Author's calculation from collated OECD data)

Costs of supply and consumer demand together drive broadband prices. But institutional factors, such as price controls, or market imperfections allowing firms to exploit their market power, may also affect prices. The effect of imperfect competition on price has been detected in particular markets. Correa and Crocioni (2012 [33]) used a range of broadband prices in Ireland and the Netherlands to detect which firms in those markets have market power, mitigated by three levels of access regulation. Fageda, Rubio-Campillo, and Termes-Rif (2014 [34]) studied prices in Spain, and found intra-platform competition affects price, while inter-platform competition does not reversing the common finding for broadband penetration. They also found service-level competition (bitstream access) is significant, results replicated across Europe by Calzada and Martnez-Santos (2014 [35]). Studying prices is typically complicated by problems of selecting which broadband price to study from the often large number of offers in the market, and by the need to take account of varying quality.

For the purposes of this article, I consider quality to include all aspects of a product that consumers are willing to pay a higher price for, except quantity. Here quantity is measured as the number of broadband subscriptions, so a contract with a higher download cap, for example, is considered higher quality, not greater quantity. Some aspects of broadband quality are difficult for consumers and analysts to assess (Nirmalathas & Lodders, 2016 [36]). Service reliability, data transmission speeds, fault resolution and bundled services all influence consumers product choice, but they are difficult to compare within a market, and even more difficult between markets. Cross-national data on customer satisfaction or complaints regarding home Internet services is not available, so is not considered here. This article accounts for download caps (which are also a direct proxy for advertised download speeds in the data set) in national prices, and for differences in broadband network quality internationally.

Empirical Data and Analysis

In this article I analyse data from the OECD Digital Economy Outlooks (OECD, 2015 [37], 2017 [38]) supplemented by a range of other sources covering the OECD economies (Central Intelligence Agency, 2016 [39]; OECD, 2013 [40], 2016 [41]; Transparency International, 2016 [42]; World Bank, 2016 [43]). Price data is from a single survey in 2014, so the analysis does not attempt to detect trends over time. It does use some 2016 data, without prices, to check model robustness. The particular value of this data is the inclusion of cross-national broadband prices for comparable bundles (bundles here being combinations of advertised speed and data download caps it excludes bundles of Internet services with telephone, pay TV or other services). The data is also relatively recent, coming from generally mature broadband markets serviced by DSL, fibre and HFC technology.

Using the survey's price data does introduce limitations. Broadband consumers typically do not simply select from a range of connection speeds or download caps at single prices. Rather, firms market broadband subscriptions bundled with complementary products, and at differing service levels. Australian firms commonly maintain multiple brands which support price discrimination, as in Telstra's Bigpond and Belong, and TPG's ongoing use of the iiNet and Internode brands from merged firms. Haucap, Heimeshoff, and Lange (2016 [44]) address this by testing price diversity as a factor influencing broadband penetration (finding diversity positively affects penetration) but this method is not transferable to the consideration of price as the dependent variable. This article does not attempt to explain price differences within markets, but does consider underlying price differences between markets.

Prices are supplied for 18 standardised bundles per nation, characterised as combinations of advertised speed and data download cap. Not every bundle is available in every nation, and the survey sometimes includes bundles with lower speed or download caps at the same price as bundles offering more. These lower offerings have been excluded from the data, so retained prices represent the most generous bundle offered at that price in that market. The OECD collected advertised price data from the incumbent telecommunications firm, and the largest cable firm, and one alternate firm (all subject to availability), for offers available in the nation's largest city. The survey reports only one price per bundle per nation. In theory, we expect negligible price differences between firms if we assume broadband bundles are interchangeable commodities but, as discussed above, prices in fact show significant variation. In this article, I assume the OECD's data collection method accurately reports incumbent pricing, and that international differences in incumbent pricing (corrected for the incumbents market share) reflect underlying price differences across markets.

I imputed data to fill occasional gaps in demographic data using methods recommended by Hair (2014 [45]), but did not impute missing market share data. Instead, where market share data was unavailable, I excluded the affected nations from parts of the analysis addressing market concentration. Dependent variable distributions from this subset are not substantially different to the whole sample.

I use Ordinary Least Squares (OLS) regression to estimate a control equation for broadband price, initially excluding regulatory and market share information. Regulatory and, separately, market share measures are then added to the specification to see if they make a statistically significant improvement to the control equations accuracy, i.e. its ability to estimate price. Given sufficient variation of these measures with the sample, finding significant effects would confirm a general capacity for broadband service retailers in more concentrated markets to maintain higher prices through coordinated conduct, and a capacity for access regulation to curtail the effects of coordinated conduct. Coordinated conduct involves firms implicitly or explicitly coordinating their pricing, output or related commercial decisions (ACCC, 2008a, [46] p. 30) and may be more sustainable when the number of competitors is fewer. Conversely, the absence of effects would suggest that coordinated conduct is not prevalent, or has effects too small to detect. The analysis is repeated for broadband penetration, which is expected to decrease in situations of oligopoly pricing, and the same factors are checked for any contribution to network quality.

I test market share and concentration using several measures, including those used by regulators (ACCC, 2008a [46]). I calculate the broadly used Herfindal-Hirschman Index (HHI) for retailers number of subscriptions, independent of connection type, and for connection types, independent of retailers. Other concentration indicators tested included the combined market share of the one, two, three and four largest firms, and Anbarci and Katzmans (2015 [47]) industry concentration index, classifying one, two and three firms as dominant. Results using other concentration indices are not substantially different to those using HHI and the incumbents market share, and are therefore not reported.

More importantly, the only drivers and indicators of market power considered are market share and concentration measures, regulatory settings, and the potential substitutability of wireless broadband for fixed. Barriers to entry other than network access, consumers countervailing power, the availability of information, and more broadly defined substitutes may all be relevant to market power within particular markets, but due to the difficulty of classifying and comparing these they are beyond the scope of this cross-national analysis.

Principles of parsimony and the modest sample size require including all available useful data while excluding variables which do not add significant explanatory power to the regression equations. I consolidate related factors to single indicators for national population concentration, public investment in telecommunications, national broadband speed, the technological quality of the network, the technological diversity of the network, and the market power of the five largest firms. Table 1 lists the raw factors and Table 2 the consolidated factors tested in the analysis. All factors are naturally numerical, except those representing regulatory options, which I code as dummies indicating presence (1) or absence (0). Three nonexclusive options corresponding to successive rungs on the ladder of investment (see OECD (2013 [40]) page 10 for a nontechnical description) are included, for low level bitstream access, mid-level unbundled local loop (LLU) access and high level direct (naked) access to the local loop. Mutual interaction terms are also generated for these dummies.

I generate OLS regression equations including all remaining independent variables and factors. I progressively eliminate the least significant variable, and repeat the regression estimation, until the returned Sum of Squares due to Error (SSE) stops decreasing with subsequent eliminations. This stepwise elimination of covariates can produce misleading predictions under some circumstances, so the selection of variables for the control equations was verified using Lasso estimation (Tibshirani, 1996 [48]). The confirmation of selected variables by Lasso estimation suggests the retained variables do indeed have consistent effects compared to those eliminated. I note one exception in the discussion of results.

A further robustness check uses the penetration equation generated from 2014 data to estimate penetration in 2016, and compares it to actual penetration. (An updated price survey is unavailable.) The 2014 equation predicts 2016 outcomes quite consistently, with the coefficient of determination (R-squared) only falling from 0.665 in 2014 to 0.577 in 2016.

Table 1 Test variables used in the OLS regressions

Name	**Definition**
MSn (MS1-MS5)	Cumulative market share of nth largest operator/s, n = 1 to 5
CAP	Fixed Broadband download cap for the associated PRICE bundle
BBP100	Broadband subscriptions per 100 people
NUMDSL	DSL subscriptions per nation
NUMCABLE	Cable subscriptions per nation
NUMFTTX	FTTx subscriptions per nation
NUMOTHERSUB	Other subscriptions per nation
POPTOTAL	Total population per nation (2014)
GDPPC	GDP per capita 2014
POPURBAN	% urban population (OECD classification)
POPINTER	% intermediate urban/rural population (OECD classification)
LANDURBAN	% land urban (OECD classification)
LANDINTER	% land intermediate (OECD classification)
LLU	LLU access regulated, 0=unavailable 1=available
BITS	Bitstream access regulated, 0=unavailable, 1=available
NAKED	Wholesale line access regulated, 0=unavailable, 1=available
PINV	Public investment in telecommunications as a % of telecommunications industry revenue in year #
PINVPC	Public investment in telecommunications per capita, mean for years 2011-2013
WIRELESS	Wireless broadband subscriptions per 100 people, mean for years 2012-2013
AKAMAI	Measure of average actual fixed broadband network speeds (Akamai reported by OECD), high number is fast
OOKLA	Measure of average actual fixed broadband network speeds (Ookla reported by OECD), high number is fast
MLAB	Measure of average actual fixed broadband network speeds (Mlab reported by OECD), high number is fast
EASE	Ease of doing business score 2014, from World Bank, high number is high difficulty
TAX	Top corporate tax rate 2014, from World Bank

Table 2 Composite factors tested in OLS regressions

Factor	Calculation
POPCON	(POPURBAN*LANDURBAN + 0.5*(POPINTER*LANDINTER))/100
PINVC	sqrt(PINV*PINVPC)
SPEED	(AKAMAI/AKAMAI.mean + MLAB/MLAB.mean + OOKLA/OOKLA.mean)*10
TECH	(100*NUMFTTX + 50*NUMCABLE + 20*NUMDSL)/(POPTOTAL*300)
HHIINFRA	MSDSL*MSDSL+MSCABLE*MSCABLE+MSFTTX*MSFTTX+MSOTHER*MSOTHER
HHI5	MS1*MS1+MS2*MS2+MS3*MS3+MS4*MS4+MS5*MS5

Broadband Outcome Models

Table 3 describes an equation to estimate price. The strongest contribution is wealth, measured as GDP per capita. Household budgets are larger in wealthy economies, so broadband costs and willingness to pay are also higher.

Table 3 OLS regression coefficients for broadband price with regulation and infrastructure concentration variables. Standard errors are in parentheses; n=110.

Factor	Original	With Regulation	With Infrastructure Concentration
Intercept	-17.56 (5.869)	-17.47 (6.881)	-21.01 (6.484)
GDP per capita	0.8430*** (0.111)	0.7932*** (0.0087)	0.7312*** (0.0926)
Corporate tax rate	0.6628*** (0.2079)	0.7651*** (0.2262)	0.6011*** (0.2155)
Download cap	0.0734*** (0.009)	0.07482*** (0.0000)	0.07103*** (0.0086)
Population concentration	-0.3320*** (0.0807)	-0.3538*** (0.0836)	-0.2973*** (0.0791)
Public telco investment	0.1815** (0.0789)	0.2187*** (0.0820)	0.2032** (0.0790)
Wireless penetration	-0.1070* (0.0611)	-0.0781 (0.0639)	
Bitstream access regulation		2.118 (4.4670)	
LLU access regulation		-4.641 (5.4355)	
Naked access regulation		-3.258 (2.9854)	
Infrastructure concentration			3.835 (7.7042)
Adjusted R^2	0.685	0.686	0.676

*** Indicates significance at the 99% confidence level.

** Indicates significance at the 95% confidence level.

* Indicates significance at the 90% confidence level.

The company tax rate also significantly increases consumer prices. Using tax incidence theory, this implies, in accordance with previous research (Galperin & Ruzzier, 2013 [49]), that demand for broadband services in OECD countries is relatively price inelastic. Where price demand is inelastic, firms charged high taxes pass the cost on to consumers, knowing that few consumers will drop their subscription in response to a higher price. This implication only extends to the developed economies studied here, and is expected, given the low household-budget share of fixed broadband subscription (less than 2% averaged across the included markets) and the stronger network benefits of Internet access in markets with high penetration.

Higher download caps (which are indistinguishable from higher advertised download speed in the data) generate higher prices, probably both as a reflection of higher costs in backhaul transmission and as effective price discrimination by Internet service providers.

Higher population concentration (the composite factor defined in Table 2) significantly reduces price, likely an effect of network building costs. The effect contributes about 10% to the total price.

Wireless broadband availability has a negative effect on fixed broadband price, although only significant at the 90% level, and less under other model specifications. The low consistency of the effect may reflect a change underway in only some of the economies studied. Technologically improved wireless broadband, previously considered a complement to fixed broadband, is emerging as a substitute in markets such as Finland (OECD, 2017 [38]). The possibility of substitution must be considered in Australia, where some measures find wireless network speeds are higher than fixed (speedtest.net, 2017 [50]), and is further discussed below.

Public investment raised broadband prices, against expecting public funds to function as a subsidy for customers. Causation is not clear. High prices and public investment could be independent but positively correlated where infrastructure construction is expensive, sharing costs between governments and users. Or public investment could actually support higher prices, by establishing monopolies that crowd out competitive pricing, or if levies on broadband services fund the investment, as considered in Australia (Minister for Communications and the Arts, 2017 [51]). The lower significance of this result (from 95% to 99%) suggests variation in the relationship between public investment and prices between markets.

Belying Australias long political, legal and commercial debates, there is little evidence of competition or market power affecting consumer prices. The interaction of wholesale and local loop access regulation is statistically significant at the 90% level, with a large effect size, but this result is isolated and only tentative without further confirmation. Effects of regulatory settings may be hard to detect because most OECD nations have similar regulatory regimes in place, especially for LLU, and effective regulation across all jurisdictions could be uniformly forestalling monopoly pricing. Or access regulation of ADSL networks may mostly affect the distribution of profits between network owners and access seekers with little flow-through to consumer prices. All OECD broadband markets had five or fewer significant broadband retailers at the time of the price survey, so oligopoly pricing and quantity setting may have persisted generally despite regulation.

Infrastructure diversity did not affect broadband prices.

Table 4 OLS regression coefficients for broadband penetration. Standard errors are in parentheses.

Factor	Original	With Infrastructure Concentration	With Regulation	With Market Concentration
Intercept	14.48 (3.94)	6.56 (4.89)	6.37 (6.22)	6.99 (10.34)
GDP per capita	0.2792** (0.0664)	0.2580*** (0.0621)	0.2559*** (0.0682)	0.2159** (0.0783)
Technology	0.1695*** (0.0567)	0.2163*** (0.0559)	0.2179** (0.0593)	0.2712*** (0.0922)
Ease of doing business	-0.1197* (0.0652)	-0.1330** (0.0607)	-0.1293* (0.0690)	-0.1077 (0.0951)
Infrastructure concentration		13.62** (5.5700)	13.34** (5.9114)	14.40 (8.7414)
Bitstream access regulation			-0.9641 (3.2886)	
Local loop access regulation			0.8540 (4.2976)	
Wholesale access regulation			0.5184 (2.0505)	
				-0.0029

Largest firm market				(0.2963)
share Market concentration				-0.0003 (0.0027)
Adjusted R^2	0.674	0.674	0.638	0.525
n	34	34	34	26
*** Indicates significance at the 99% confidence level. ** Indicates significance at the 95% confidence level. * Indicates significance at the 90% confidence level.				

Table 4 summarises the OLS coefficient estimation for quantity, measured as broadband penetration per 100 residents. Per capita GDP is again the driving economic factor wealthier nations predictably have greater access. Wide use of better technology and consumers concentrating on one form of technology both have positive effects, possibly related, if high technology infrastructure attracts consumers to that technology particularly and to fixed broadband generally. But TECH and HHIINFRA are not strongly correlated (Pearsons correlation coefficient=-0.38) and HHIINFRA does not appear in the Lasso estimate. (Public investment, with a positive sign, is the next coefficient to appear in a Lasso estimate.) The positive influence of better technology is understandable, but the strong positive effect of more homogeneous technology choice is not. As the finding reverses other research discussed above, this anomalous result can be tentatively disregarded. The World Banks Ease of doing business measure is weakly significant, with the negative sign expected as high numerical scores represent high barriers to business. No regulatory factors are significant in the penetration estimate, and neither are measures of concentration.

I also generate regression equations for speed, as a measure of the quality of broadband service, moderating the price and penetration measures. The speed analysis excludes Korea, as its history of particularly intense infrastructure competition (Brown, 2015 [52]) has yielded a SPEED indicator which is a strong outlier. Results in Table 5 show the technological quality as the only factor to affect speed, with very strong significance. The importance of technology is entirely expected, but the lack of detectable effect from other factors, including public investment and population concentration, is notable. Regulation and competition again show no influence there is no hint in the data of monopoly networks having lower speed.

Table 5 OLS regression coefficients for SPEED. Standard errors are in parentheses.

Factor	**Original**	**With Regulation**	**With Market Concentration**
Intercept	10.60 (2.94)	8.69 (3.81)	14.44 (7.94)
Technology	0.5609*** (0.0770)	0.5636*** (0.0816)	0.5529*** (0.1020)
Bitstream access regulation		-0.4113 (3.9467)	
Local loop access regulation		4.0425 (4.9541)	
Wholesale access regulation		-2.388 (2.6823)	
Largest firm market share			-0.2612 (0.3703)
Market concentration			0.0026 (0.0034)
Adjusted R^2	0.627	0.554	0.554
n	29	29	23
*** Indicates significance at the 99% confidence level.			

Australias Position

These empirical models perform well as estimators of national broadband prices, penetration and speed, and all control equations strongly pass the F-test at 99.9% confidence. The equations also predict the associated Australian outcomes well, compared in Table 6. Predicted values are all close to the centres of the 95% confidence intervals. So we can plausibly use these models to explore the determinants of Australian broadband performance.

Table 6 Model estimations for Australia (2014). Low and High estimates are at 95% confidence.

	Actual	Fit	Low	High
Price, 400GB download cap	70	72	46	97
Price, 200GB download cap	51	57	32	83
Price, 100GB download cap	47	50	24	75
Broadband penetration per 100 people	27	31	20	42
SPEED	20	24	12	37

Actual Australian prices (in 2014) are slightly lower than the OECD means for the three download caps considered. According to the model, this is wholly due to the very high number of wireless broadband subscriptions per capita taken up by Australians - almost twice the OECD mean. In every other price factor, Australian factors tend to raise prices above the average. This implies that, within Australia, high take-up of mobile broadband constrains fixed broadband prices. Two related mechanisms may contribute to this. Firstly, as discussed in the preceding section, consumers in some markets may see mobile broadband as a substitute for fixed, so fixed prices must remain comparatively low to retain customers. Australia is a likely market for substitutability to emerge due to the comparatively high quality of its mobile data networks. Australian wireless spectrum policy has historically relied significantly on the functioning of free markets and been less prescriptive than fixed broadband policy. Political disputes, rent seeking or dependency on public spending have consequently not held up wireless technology deployment. Consistent policy has attracted infrastructure investment and competition. Mobile broadband technology deployment in Australia at least matches international peers and sufficient spectrum is available, so mean mobile broadband speeds can even exceed fixed broadband speeds (speedtest.net, 2017 [50]).

Secondly, in Australia one incumbent firm is dominant in both fixed and mobile broadband, and, if it is an effective price setter in both markets, it may keep the prices close to avoid cannibalising across its divisions. Figure 3 shows some evidence that Telstra maintains an approximately constant ratio between its fixed broadband and mobile prices. (The notable exception, where average revenue per user moves in opposite directions, is from 2017 and the report does not explain this.)

[53]

Figure 3. Annual changes in Telstras average revenue per user (ARPU), 2008-2017. Mobile ARPU is Telstræ blended result 2008-2011, otherwise the unweighted mean of prepaid and postpaid. 2015 and 2016 are omitted due to missing data. The line of equality (not a fitted trendline) is shown for reference. (Source: Telstra Annual Reports 2008-2017)

Australian fixed broadband penetration is very slightly below the OECD average. Australia's low TECH score alone pulls it down; all other factors promoting broadband penetration are above average. The model predicts raising Australia's TECH score merely to the OECD average (i.e. similar to Hungary and Portugal) would increase fixed broadband penetration by 10% (3 additional subscriptions per 100 capita). Early regulatory decisions discouraging commercial investment and the ad hoc establishment of the NBN have both contributed to the technology lag. Fortunately, the problems in fixed broadband are not representative of the whole economy, and Australias generally business-friendly environment has provided some compensatory support for broadband penetration. With fibre-rich NBN construction well under way, can Australians now expect to enjoy the results of better technology

Possibly not. Australias poor absolute network speeds, in these 2014 measurements, are below estimates based only on the then network technology. (In 2014 the NBN served only 3% of Australian subscriptions (NBN, 2014 [54]).) This indicates other barriers to quality. Australias TECH score is 0.71 standard deviations below the OECD mean, while the SPEED score is 0.88 standard deviations below. More recent statistics (speedtest.net, 2017 [50]) reveal average network speeds still lag international peers, despite substantial public investment in the NBN. Critics, such as Varghese (2017 [55]), argue this is not primarily due to the technology but to the monopoly pricing structure applied to NBN access. The high Connectivity Virtual Circuit charge simulates bandwidth bottlenecks where capacity is not a technical problem. To consumers, the effect is indistinguishable from a technological deficiency, and so we expect that, uncorrected, it will continue to prevent the technological improvements from the NBN from fully contributing to improved broadband penetration and quality measures.

Conclusions

Despite achieving structural separation, results of the twenty-year project to introduce competition into the Australian telecommunications industry are mixed. Retail competition is well established, but with effectively four large firms (ACCC, 2017 [56]) it remains below the ACCC's indicative threshold for effective competition, which is equivalent to five equally sized firms (Herfindal-Hirschman Index=2000) (ACCC, 2008a [46], p. 35). NBN Co.s purchase of the Telstra and Optus HFC networks, the automatic retirement of DSL following NBN expansion, and legislation mandating the declaration and thence regulation of any new competing networks, mean infrastructure competition is and will remain mostly absent from the local fixed network. If privatisation of NBN Co proceeds, NBN regulation will likely be as complex as regulation of Telstra was. As a profit maximising firm, NBN Co will have incentives to exploit its monopoly by setting high prices and underinvesting in quality, which will have to be constrained.

Australian fixed broadband regulation has been preoccupied with issues structural separation, retail competition and shared access that show scant evidence of affecting outcomes. Meanwhile, Australian politics have been concerned with the quantum of public spending without considering whether broad public investment may cost Australians more than they would be willing to pay for the outcomes. The NBN cost-benefit assessment concluded that halting the NBN rollout, or allowing it to proceed unsubsidised, had greater benefits than continuing the rollout at Government expense (Australian Government Department of Communications and the Arts Panel of Experts, 2014 [25] Section 6). But this conclusion was immediately dismissed (Turnbull, 2014 [57]).

Due to the limitations of the data discussed above, this article's analytical findings regarding price strictly apply only to incumbent ISPs. I have assumed regulation particularly affects the largest firms, and that pricing decisions by incumbents affect price in the whole market. This concern with the incumbent is also apparent in Australian policy, where Telstra and NBN Co are specifically subject to sections of telecommunications and competition law. I have not considered the possible use of regulation to protect or otherwise benefit an incumbent in other markets, but reviewing regulatory history alongside market outcomes, as has been done here for Australia, could reveal this.

In the international context, the regulatory history of the Australian broadband industry is not exceptional. Most of the policies applied in Australia were also applied elsewhere, with similar results. The outstanding event was the nationalisation of local fixed networks, creating the NBN to resolve the tension between investment and competition, and hence address the outstanding technology deficit. Other jurisdictions have deployed various policies. For example, Canada supplements private investment and access regulation with public subsidy to improve quality only in poorly served areas (Canadian Radio-television and Telecommunications Commission, 2016 [58]), similar to Australian Government policy in early 2007 (AFP, 2007 [59]). Singapore has established a privately owned, structurally separated fibre to the premises network (Jones, 2015 [60]), with a similar role to an eventually privatised NBN. New Zealand has established local (not national) fibre network monopolies, but maintains infrastructure competition with other technologies (Beltrn, 2013 [61]).

Establishing the NBN marked a strong shift in Australian regulatory policy, from relying on competing forms to satisfy demand for fixed broadband services, to establishing a protected monopoly to secure investment. The NBN's mixed technology improves the quality of Australian broadband services but, if protecting its monopoly forestalls future technology upgrades (such as extending fibre to the premises where commercially viable), Australian fixed broadband access and quality may continue to lag other developed economies.

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