Factors Affecting Household Broadband Adoption in Australia

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Broadband networking technology has grown in prominence, driven by increasing interest from researchers, organisations, the popular media and the public alike. Using a data set of more than 20,000 households, this study examines residential broadband adoption and growth over time. The study uses classification tree analysis, which allows for simple interpretive descriptions of the relationship between explanatory variables and adoption propensity without the need for strong distributional assumptions, a priori variable transformation or interaction specification. The study finds that broadband adopters typically live in a metropolitan centre and were also cable TV subscribers. Online banking, research and share trading were also significant drivers for uptake.

(Broadband; Internet; Household; Adoption)

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1. INTRODUCTION

Broadband networking has become an important technological development, granting businesses more powerful communications and supply networks (Autor 2001), and giving individuals faster access to rich internet services including gaming, streaming video and music sharing (Hausman et al. 2001, Savage and Waldman 2005, Ha et al. 2007). However, a number of barriers exist with respect to broadband rollout. There are still policy and connectivity issues (Yoo et al. 2005) and, in some countries, significant implications for infrastructural development (Flamm and Chaudhuri 2007). Because it is costly to offer broadband services to just one household (Höffler 2007), telecommunications providers require a critical mass of willing adopters before it becomes financially viable to roll out broadband networking support (Ng et al. 2004). Unpredictable demand for these services makes such capital investment and planning difficult for provider firms (Antunes et al. 1998). Countries around the world are now grappling with how best to develop, implement and manage a broadband network infrastructure (Youtie et al. 2007). Governments and telecommunications firms would benefit from knowing more of the types of users likely to adopt broadband.

This paper documents a study into the factors that affect uptake of broadband services in the home environment. The project is aimed at determining how broadband is used so that policy may be formulated in order to support effective use of technology. Prior research work into residential broadband uptake has either classified use according to demographics (e.g. Choudrie and Dwivedi 2005) or explored behavioural effects (e.g. Oh et al. 2003, Ha et al. 2007). This study incorporates both dimensions in its analysis. This paper uses tree analysis, an innovative statistical method, to explore the factors likely to promote broadband adoption in the home. Tree analysis allows the researcher to collect a large number of variables down into a small set of key predictor variables. Pruning the resulting tree increases the tolerance threshold for variables. This allows us to gauge the sensitivity of our analysis, allowing for fine-grained analysis of predictor variables and better pinpointing of particular adopter types. In this way, the approach is sensitive to emerging or nascent phenomena.

This paper contributes to knowledge in three ways. First, the study allows for the detailed evaluation of the relative contribution and effect of factors affecting broadband adoption. As a result, some assessment can also be made of the relative effects of strategies which are designed to instrumentally spur this adoption (for example, the popular promotion of the technology or the provision of dedicated content). The knowledge gained can inform government policy on strategic investment, regulatory regimes and in key sectors such as education, health and community services. Second, the study examines broadband adoption at the national level, in the tradition of Hitt and Tambe (2007) and Venkatesh and Brown's (2001) analysis of computer uptake. The paper contributes by exploring large scale technology adoption, hence developing theory relevant to many users and managers. Next, prior work has also largely focused on nations with geographical circumstances sympathetic to broadband infrastructure, such as significant population density (such as Korea and Japan). There has been almost no work covering areas where the geography is hostile to large-scale networking ventures. This study focuses on

Australia, a continent where more than 80% of the population lives on the east coast, while the remaining 20% is spread across a significant land mass comprising deserts and rainforest regions.

The rest of this paper is structured as follows. First, it uses a literature search method to develop a list of critical factors which affect broadband adoption in commercial and domicile environments. This is followed by a discussion of the Tree analysis method in the context of theory building, using the list of broadband adoption factors. The paper then presents the research method and data sources, followed by analyses of the data set according to demographic and attitudinal perspectives. Finally, conclusions and implications for theory are presented.

2. FACTORS AFFECTING DEMAND FOR BROADBAND

The underlying theoretical base for the study lies in theory relating to the diffusion and adoption of innovations, in particular to the adoption of networked technologies. While there does not appear to be a single source for broadband adoption factors in the literature (Choudrie and Dwivedi 2005, Flamm and Chaudhuri 2007), the separate grouping of these factors is echoed in other studies. For instance, research into telecommunications services (such as POTS telephone access) suggests that demographic and socio-economic variables are likely to explain latent demand for broadband services (Bodnar et al. 1988, Taylor and Kridel 1990, Stanton 2004).

Consistent with research on prior networking technology (Stoneman 1983), economic and financial factors appear to have an effect on broadband uptake (Youtie 2007). Prior work has identified income as showing a relationship with the adoption of broadband services (Kim et al. 2003, Choudrie and Dwivedi 2005, Hitt and Tambe 2007, Robertson et al. 2007). The effect of income and education on uptake could contribute, in part, to a broadband digital divide whereby low income earners and the less educated forego broadband access (Lookabaugh et al. 2003, Dutton et al. 2004, Robertson et al. 2007). Demand drivers such as price, availability, content and applications have been proposed as the drivers of demand for broadband connections (Middleton 2003, Flamm and Chaudhuri 2007). Prior experience with similar networking technology may also affect demand (Oh et al. 2003). Madden and Simpson (1997) found that demand for broadband services in OECD countries has been affected by demographic factors such as age, education and location (consistent with Kim et al. 2003, Savage and Waldman 2005 and Wood 2008).

Following from this previous work, a number of potential influences on the uptake of Internet technologies, including broadband services, can be identified. The resultant conceptual background gives an established framework for analysis, though it is recognized that broadband adoption may not be as straightforward as other technology products such as the telephone or personal computer. Table 1 shows the factors that will be investigated as influences on broadband adoption.

[Table 1 Here]

Some of the explanatory factors in Table 5 are included because they have been found to influence adoption of comparable technologies in prior studies (Premkumar and Ramamurthy 1995, Chwelos et al. 2001). The exploratory statistical techniques used will allow other significant influences, if any, to be identified.

The focus on Australia presents a different case to the focus of prior research. For example, Australia has a less dense population than Korea (Frieden 2005) and Japan (Ida and Kuroda 2006). There are differences between the North American networking market and the Australian market. Notably, the provision of subsidies for rural network connectivity in Australian communities (as in Madden et al. 2000) is not echoed as clearly in North America. Similarly, access provision in Australia is still largely the purview of Telstra and Optus, two large telecommunications infrastructure providers (Fan 2005). In the US, this access is spread over a larger number of providers. Despite these critical differences, much of the adoption theory is still relevant and useful.

3. CLASSIFICATION TREES

Classification trees are a modern non-parametric alternative to classical statistical discrimination techniques, such as logistic regression. Their advantages include the lack of a required a priori choice of model structure for the predictor scales and interactions, the ease of incorporating observations with missing covariate values and the interpretive simplicity of the resulting prediction formulae (Stern et al. 2004).

A classification tree determines a “sequential binary decision rule” for relating a qualitative outcome variable to various predictors. This is done by recursively partitioning the predictor space into rectilinear regions of increased homogeneity as measured by the deviance function:

$$D(T) = -2\sum_{t \in T}\left\{n_{t1}\ln\left(\hat{p}_{t1}\right) + n_{t2}\ln\left(1-\hat{p}_{t1}\right)\right\},$$

where T represents a tree model (i.e., a rectilinear partition of the predictor space), n_{tk} is the number of observations in the t^{th} element of T that fall into the k^{th} response category (k = 1 or 2) and $\hat{p}_{t1} = n_{t1}/\left(n_{t1}+n_{t2}\right)$ is the observed proportion of the observations in the t^{th} element of the tree partition that fall into the first response category.

The determination of the best tree model for a given set of observations is done sequentially, via a recursive partitioning algorithm, whereby the predictor space is repeatedly split using boundaries chosen parallel to the predictor axes chosen so as to minimize the deviance at each step until the resultant elements of the partition are either homogeneous or contain too few observations to allow reliable further partitioning

(Brieman et al. 1984). Since the partitioning scheme is recursive, each successive split of the predictor space is conditional on all those previous, so that interactive or non-linear structures in the relationship between the predictors and the response can be captured automatically. In addition, since the splits are simple bifurcations along predictor axes, the process is invariant to monotonic re-scalings of the predictors (so that whether a predictor or, say, its logarithm is used has no effect on the resultant analysis). The structure of a decision tree is easily interpretable, leading to insights into the data that are not as easily gleaned from classical parametric analyses without a more detailed mathematical understanding of their model structure.

Classification tree analyses do have some drawbacks. Notably, they have a tendency to over-fit the observed data. As such, it is important to effectively "prune" the originally constructed tree, in order to reduce its size and increase its applicability outside the set of observed data on which it was based. Such pruning also acts as a de facto variable selection phase of the tree modelling process, as some predictors may not appear in the determination of the partition once the tree is suitably pruned. Pruning is generally accomplished by trading-off the degree of homogeneity within each individual element of the tree partition against the complexity of the final tree model. Specifically, for all possible sub-trees of the original tree, a cost-complexity measure:

$$D_\alpha(T) = D(T) + \alpha|T|$$

is calculated, where $|T|$ is the number leaves of the tree, *T*. The sub-tree that minimizes $D_\alpha(T)$ is then selected as the final pruned tree. The complexity parameter, α, is chosen so that the resultant tree has a pre-specified size, and its selection is best carried out via cross-validation.

Cross-validation proceeds by fitting trees of various sizes using, say, 90% of the observed data, referred to as a training set, and then testing their accuracy using the remaining 10%

of the data, the validation set. As the size of the fitted trees increases, the problems of over-fitting the training data will become more severe, and this will be reflected by poorer predictive performance in the validation data, as measured by the predictive deviance:

$$D(T) = -2\sum_{t \in T}\left\{ m_{t1} \ln\left(\hat{p}_{k1}\right) + m_{t2} \ln\left(1 - \hat{p}_{k1}\right)\right\},$$

where $\hat{p}_{t1}$ is the fitted proportions in each element of the tree model constructed based on the training set, while m_{tk} is the number of validation set observations in category *k* which fall into partition *t* of the fitted tree. As the size of the tree models increases, this predictive deviance will initially decrease, but eventually begin to increase, and this turning point represents a good estimate of the optimal choice of tree size. The most common implementation of cross-validation is termed random 10-fold cross-validation. It proceeds by splitting the full set of observations into ten randomly allocated equal-sized groups and then using each of the 10 different collections of 9 groups (i.e., the 10 different datasets arrived at by dropping one group in turn) separately as training sets with the appropriate remaining group used as the validation set. Predictive deviances are then totalled across the ten different analyses. Such an approach mitigates the effects of unfortunate choices for the training and validation sets, whereby artefactual aspects of the data appear only in either the training or validation set. Another advantage of this implementation of cross-validation is that it gives a useful measure of external assessment of the tree model. Each of the ten trees of the size eventually chosen as optimal can be used to predict for their appropriate validation sets to arrive at measures of accuracy that are independent of the fitting process. As such, measures such as the sensitivity and specificity, or area underneath an ROC curve, can be assessed on “new” data, which generally gives a better idea of the true predictive accuracy of the model. Moreover, as there are 10 such external assessments, we can use the mean assessment as the estimated predictive measure, and the precision of this measure can then be estimated by the standard deviation of the individual predictive measures on the 10 validation sets.

Finally, another major advantage of classification tree models is their ability to readily handle missing data. This can be accomplished in various ways (Venables and Ripley 2002). The method of choice for this analysis is the use of surrogate splits, a secondary decision rule to be used if an observation has a missing value for the primary covariate that determines the split associated with any particular node (Ripley 1996). Surrogate splits are chosen to match the outcome of the primary decision rule as closely as possible among those observations for which the primary covariate value is not missing. The measure of closeness is based on the concordance between the decision rules, $C(j,k) = \max\{C_L(j,k), C_R(j,k)\}$, where X_i is the primary predictor associated with the node and c its associated cut-off, X_j is any other predictor and k any cut-off. In other words, the concordance measures the proportion of observations for which the surrogate and primary splits co-segregate.

4. METHOD

The analysis of broadband adoption in Australia was based on a Roy Morgan Telecommunications Monitor dataset. The dataset contained a vast array of communication and media-oriented responses from nearly 100,000 participants, interviewed over a four-year period. However, information directly concerning broadband adoption was collected only in the final two years. As such, the analysis presented here is based on the 20,937 respondents with valid replies to these home internet connection questions. The total number of these respondents who indicated that they had a home connection with a speed of greater than 64k was 932, giving a raw overall take-up rate across the two year period of 4.45%.

Table 2 details the covariates chosen for inclusion. The covariates were selected to represent geographic and domestic demographics, as well as basic usage patterns for both the internet specifically and media-related technology in general.

[Table 2 Here]

In order to better explore the importance of existing technology in the household, a "Technology Usage Index" was developed. This index was designed to provide an ordered indication of the degree of technology use in the respondent's home. The index was defined as follows:

+1 for: Digital TV or set top box
+1 for: DVD Player
+1 for: MP3 Player/Mini-disk player
+1 for: Digital video camera
+1 for: Digital camera valued over $150
+1 for: Fax
+1 for: Any Games Console

5. ANALYSIS

Analysis was conducted in four stages. The first stage examined broadband adoption using all the attitudinal and demographic variables in the data set. The second analysis explored adoption according to internet usage factors. The third analysis was conducted according to attitudinal, usage and interest variables. Finally, analysis was conducted according to uptake by geographic region. In all cases, overall trees are appropriately pruned using cross-validation techniques to ensure that the resultant trees are not overfit, so that the outcome is externally reliable and is not overly sensitive to small, atypical subsets of observations.

The data was collected and analysed across sixteen quarters (from January-March 2001 to October-December 2002) and a wide range of geographic and demographic areas. The dataset provided was weighted according to geographic region (11 categories: Sydney, Other New South Wales including the Australian Capital Territory, Melbourne, Other Victoria, Brisbane, Other Queensland, Adelaide, Other South Australia including the Northern Territory, Perth, Other Western Australia, and Tasmania) and overall household size (3 categories: 1-2 Persons, 3-4 Persons, and 5 or more Persons). Using this weighting scheme, the adjusted overall broadband adoption across all quarters was 4.18%. Table 3 gives the specific percentages as well as their weighted standard errors.

[Table 3 Here]

Two features are apparent. First, a steady increase in adoption was observed from 2.17% at the start of 2001 to 5.72% by the end of the study. In addition, there is a marked drop in overall adoption between the final quarter of 2001 and the first quarter of 2002. This drop is consistently present in every state and almost every region (see Section 5.4). There is no data management issue which seems likely to account for this. For example, there is no concomitant spike in response rates at this time, merely a steady decline over the period of study from about 60% in the first quarter to about 40% in the final quarter. One plausible explanation for this phenomenon is an effect of expiry of initial contract periods.

5.1. Adoption Analysis of Basic Demographic Variables

A classification tree analysis was undertaken in order to examine the relationship between broadband take-up and basic demographic covariates. In addition, demographic data was included, such as the type of dwelling, the number of people in the household, the number of children in household and the number of children over fourteen years of age. Figure 1 shows the best 12-node tree based on binomial deviance pruning, where the overall size was chosen based on minimising cross-validation deviance.

[Figure 1 Here]

The most relevant predictors, as chosen by the cross-validation criterion for tree size determination, were frequency of internet usage, geographic region, household income, income of main earner, length of internet use, Pay TV subscription, and time of day for main internet usage. One useful way to interpret the output of a tree is to construct groups of nodes where predicted usage is high, to investigate defining characteristics of likely users versus non-users. In the current tree, if we group together all terminal nodes with an observed usage larger than the overall prevalence (4.18%), the group of "adopters" is characterised as:

1) Those who use the internet more than once per day and either:
   a) live in the ACT, Sydney, Melbourne, Brisbane or Perth; or,
   b) have a household income of at least $120,000 per annum.
2) Those who use the internet no more than once per day and either:
   a) live in the ACT, Sydney, Melbourne, or Brisbane and:
      i) have a household income of at least AU$120,000 per annum; or,
      ii) currently subscribe to a Pay TV service.
   b) live outside the ACT, Sydney, Melbourne, or Brisbane, but have a main earner with an income of at least AU$100,000 per annum.

This grouping has an estimated take-up percentage of 9.59%, 5.5 times as high as the 1.74% take-up among the remaining households. In general, we see that broadband take-up appears to be most prominent among those in the major population centres who either use the internet very frequently or have large incomes. Notably, there seems to be a relationship between broadband take-up and pay television subscription. This phenomenon may reflect a bundling of services by media providers or a general propensity for consumption of all media services.

Finally, if we increase our threshold for inclusion into the group classified as adopters to, say 10%, this removes all households outside of the major capital cities and incorporates length of usage and time of main usage. In particular, the group of adopters has been using the internet for at least 3 years or tends to use the internet in the evening (the most common time of usage) as well as some other time of day (indicating, again, a high frequency of usage throughout the day). Also, the overall take-up percentage among this latter group of adopters increases from 9.59% to 20.30%, as opposed to a take-up rate of 3.24% among those classified as non-adopters.

In interpreting these results, it is important to remember that the location variable may well be a partial surrogate for availability, not only of potential for household connections but of basic infrastructure as well. Moreover, as many of the explanatory variables are likely to be inter-related, the absence of a predictor from the final tree does not necessarily mean it is unrelated to broadband take-up, but could simply be subsumed in the relationship between broadband adoption and other variables. For instance, there appears to be no connection between broadband take-up and mobile phone ownership or type of dwelling. However, these variables may have an effect which is already captured by the variables included in the tree model.

5.2. Adoption Analysis of Main Usage Variables

A classification tree analysis was undertaken in order to examine the relationship between broadband adoption and stated areas of main internet usage. The covariates were provided in six categories, each with a variety of sub-categories. There were 332 respondents whose values were missing for all the relevant covariates, and were thus excluded from the current analysis. For ease of interpretation, these sub-categories were further grouped into the cognate areas outlined in Table 4.

[Table 4 Here]

The tree analysis based on these breakdowns was equivocal, given that respondents' listings of main uses were highly variable. In general, the analysis pointed to those who used on-line banking and/or share trading, browsed the internet for things other than classified ads and were either web-publishers/promoters or else academic researchers as the main adopters. Indeed, among this group the broadband take-up rate was 22.69%, as compared to a take-up rate of 4.15% among those outside this group. In other words, individuals who make a living from internet use and content (such as web-publishers and academic researchers) and who do not tend to use the internet for everyday activities (such as grocery shopping and classified ads) are 5.5 times as likely to adopt broadband at home as other individuals.

The complexity of the usage patterns in the dataset means that the results stated above are best interpreted with caution. To this end, a simplified analysis was performed examining only the main usage categories (and ignoring the breakdown into specific usage areas). Broadband take-up rates were examined for each main category. In particular, we examined the take-up rates among those who stated that email was their sole main use of the internet and compared it to the take-up rate for those who stated a main use other than email. For this comparison, the take-up rate in the "email-only" group was 2.67% (standard error 0.27%) as compared to a take-up rate of 5.03% (standard error 0.19%) among those who used the internet for purposes other than just email. This result supports the view that broadband is a tool for those who want more than just simple communication capabilities.

More generally, the take-up rates among those who stated that they used the internet for various purposes are presented in Table 5. In general, the results indicate that broadband adoption is highest among those whose use of the internet is multi-faceted; that is, if a main use category is stated, then adoption rates are higher than if that use is not stated. Specifically, the use of the internet for publishing and/or product sales and promotion attracts a take-up rate of 13.42% compared with only 4.25% among those not involved in these activities. This is consistent with the results of the initial tree model summarised previously.

[Table 5 Here]

The adoption percentages given in Table 5 are aggregate across the two years of observations. An analysis of take-up rates by quarter showed that the temporal pattern was very similar to the overall adoption rate pattern depicted in Figure 1.

Finally, another tree model was fit based on the main usage categories alone. The results from this tree are broadly consistent with the results given above. Generally, individuals who do some form of research on the internet or do web-publishing and/or product promotion and sales are the major adopters. Moreover, the results suggest that the more diverse the range of activities, the higher the adoption rate. Specifically, the tree model shows that those who list some form of general browsing, some form of on-line financial transactions and web-publishing/promotion all as main internet activities have a take-up rate of 22.07%, as opposed to a take-up rate of 4.33% among the remaining population.

5.3. Adoption Analysis of Attitudinal and Interest Variables

A classification tree analysis was undertaken to examine the relationship between broadband adoption and stated attitudes and interests regarding the internet. The covariates consisted of agreement / disagreement responses to 12 statements regarding the internet, and responses detailing the level of interest in using five general areas of internet applications. Three respondents had missing values for all the relevant covariates, and were excluded from the analysis. The 12 statements were:

S1 - "None of this stuff about the information super-highway makes any sense to me"
S2 - "I go out of my way to learn everything I can about new technology"
S3 - "I'm worried about invasion of my privacy through new technology"
S4 - "I find technology is changing so fast, it's difficult to keep up with"
S5 - "Computers and technology give me more control over my life"
S6 - "Would like to use the internet but am intimidated by the complexity of it all"
S7 - "To me the Net is far more an information tool than an entertainment tool"
S8 - "It's important for me to control appropriate internet content for my family"
S9 - "I really enjoy going on-line to chat"
S10 - "I really enjoy going on-line to receive and send emails to friends"
S11 - "I feel comfortable giving my credit card details over the Net"
S12 - "I'd consider doing some of my grocery shopping on the internet in the next 12 months"

The five areas of potential interest, which were rated on a 5 point Likert scale were accessing the "information super-highway", viewing streaming videos on-line, online shopping, online gambling and communicating with others worldwide.

Again, due to the complexity and highly varied nature of the responses, the results of the tree analysis are equivocal, and should be interpreted with some caution. In general, the variables that were chosen as most relevant to broadband adoption were the responses to S11 (credit card use) and S12 (on-line grocery shopping), other variables that were relevant were S1 (sense of super-highway), interest in on-line games, S2 (learning about new technology), S8 (content control) and interest in viewing on-line videos. The tree model highlighted that the main group of adopters were those individuals who either:

1) were comfortable with giving out their credit card details over the internet and would consider on-line grocery shopping in the next year (i.e., they agreed with S11 and S12); or,
2) were not comfortable with giving out their credit card details over the internet, but did feel that the "information super-highway stuff" made sense and would consider on-line grocery shopping in the next year (i.e., they disagreed with S11 and S1, agreed with S12) and:
    a) were interested in on-line gaming; or,
    b) did not feel the need to control content for the family and went out of their way to learn about new technology (i.e. didn't agree with S8 but did agree with S2).

Overall, this collection of individuals had 11.33% broadband take-up, compared to a take-up rate of 3.50% among the remaining population. However, interpretation of this group is difficult at best. A more highly pruned tree indicates that only the first sub-group above remains a distinct node, meaning that perhaps the other sub-group is an artefact. If so, this would indicate that the main attitudes associated with broadband take-up involve the willingness to engage in some form of electronic commerce.

5.4. Broadband Adoption by Geographic Region

Available household weights were constructed based on 11 geographic regions and household size. An analysis of percentage take-up within these regions was conducted. Table 6 presents percentage take-up and weighted standard errors:

[Table 6 Here]

There is a marked difference in take-up between the major capital cities and other areas, echoing Venkatesh and Brown's (2001) findings for household PC adoption. Indeed, in the final quarter of the analysis Sydney, Brisbane, Melbourne and Canberra (ACT) show over 8% take-up while Perth shows a 6.65% take-up. By contrast, all other regions have less than a 5% take-up rate, with most well below 3%. Interestingly, in the final quarter take-up in Adelaide is actually lower than in "Other South Australia and The Northern Territory", though this difference is not statistically significant. As noted previously, there is a distinct decrease in take-up rate between the final quarter of 2001 and the first quarter of 2002 in almost all regions, most markedly in Sydney, Brisbane and Perth.

Where sufficient data was available to make useful inferences, it was seen that in Northern Sydney take-up was very high throughout the two years (14.1% in the first quarter of 2001 and as high as 17.8% in the third quarter of 2002) while take-up in other areas of Sydney was slower and generally did not reach the levels of those in Northern Sydney (though Southern Sydney did have a take-up rate of over 16% in the final quarter of 2002 and Central Sydney had a take-up rate of nearly 16% in the final quarter of 2001, before the aforementioned across-the-board drop in take-up). In Melbourne, take-up percentages were rather even across geographic region, while in Brisbane take-up was rather light in the Inner City (perhaps due to relatively low residential density) and was quite variable in the other regions.

6. CONCLUSIONS

This study examined decisions regarding the residential uptake of broadband networking. The analysis highlighted several important aspects of household broadband take-up. Consistent with studies of other geographical areas, take-up rates have generally increased over time, though there was a distinct drop in take-up between the end of 2001 and the start of 2002. Take-up is related to geographic region (though this is likely to be in some sense a surrogate for service availability), consistent with Flamm and Chaudhuri (2007). In contrast to evidence from more densely populated areas such as South Korea (Rhee and Kim 2004), adoption is most prevalent among those who use the internet frequently, have been using the internet for a long time or have sufficient household income. There is also an apparent association between broadband take-up and subscription to a pay television service (consistent with Yu et al. 2005).

The relationships between uptake and attitudinal and usage factors were more equivocal. In general, adopters tended to be those individuals who have more diverse usage patterns. In particular, they tend to either be web-publishers/promoters or academic researchers, and are not overly concerned about giving out credit card details and are interested in on-line e-commerce activity in general.

The study raises a number of implications for theory and practice. First, the study showed empirical evidence of the difference in demand for broadband across states. Broadband uptake in countries with distributed populations is likely to be uneven. Yet demand may exist outside densely populated areas as salary rates and requirements vary. The main adopters are likely to be frequent users with significant disposable income, and hence most fertile potential market, in distributed population areas. This may also hence have implications for appropriate regulatory regimes. Provision of broadband services in these built-up areas is also likely to be more competitive (Grubesic 2006).

This study has presented some of the first empirical evidence of a relationship between the availability of and demand for cable television and broadband services. While both of these technologies are different in terms of their degree of interactivity and ongoing costs, both may provide avenues for shopping, entertainment and current events. This finding may be evidence of media substitution (Lin 2001, Rhee and Kim 2004) among these adopters. In this context, partnerships with cable TV provider companies could provide an effective way of overcoming or bridging the broadband digital divide.

Third, the study provided tentative evidence of the importance of trust in the initial adoption process. Users who were comfortable distributing their credit card details online were also more likely to adopt broadband services. The desire to purchase products online was closely related to this finding, adding support for prior studies such as Chau et al. (2000), Smith and Sivakumar (2004) and Lin (2008). In cases where adopters were less comfortable revealing their credit card details, they were nevertheless interested in the opportunities provided by high speed networking, such as gaming and content publication. The popularity of online gaming may support the sense of escapism associated with higher internet usage (Armstrong et al. 2000).

Online gambling was not found to be significant in the tree analysis, despite evidence from Conway and Koehler (2000) to the contrary. This finding could highlight a problem of social desirability bias when exploring self-reported online behaviour. Users may be reluctant to report behaviour that could be subject to social censure, resulting in divergence between observed and reported usage. Such online activities may be under-reported and also under-researched in the literature.

The study may be open to a number of limitations. The dataset on which this analysis was based was designed for a enquiry into a range of technology products, and not just broadband. As such, it does not have direct information on a number of important factors such as broadband pricing and availability/infrastructure.

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Figure 1. Tree Model for Overall Broadband Adoption

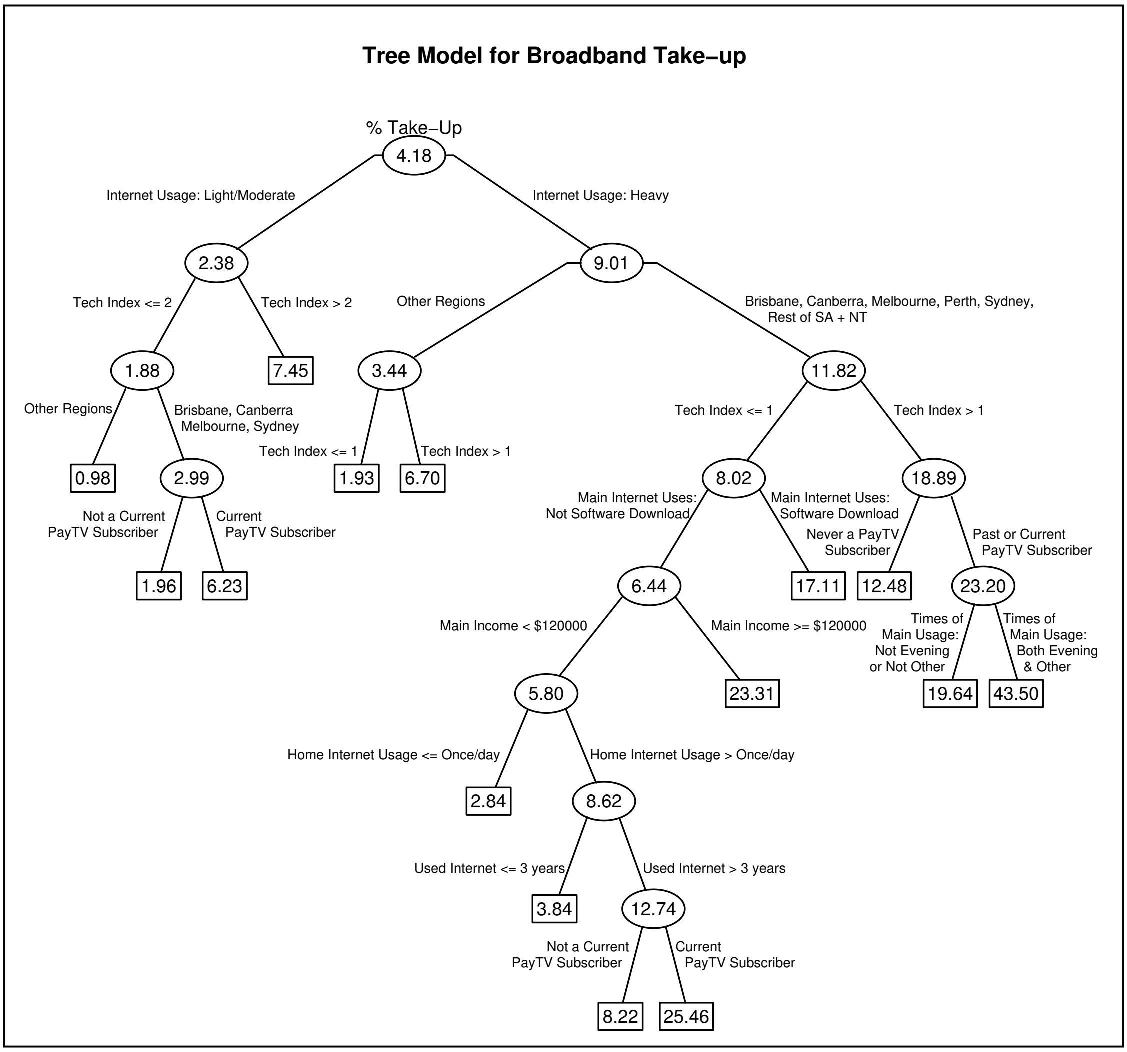

Table 1. Factors Affecting Household Broadband Adoption

Technology In Household	More technology (such as a personal computer) in the user's home environment raises the latent level of technical knowledge and provides a ready platform for broadband adoption.	Lookabaugh et al. (2002), Stanton (2004), Priger and Wu (2008)
Number Of Phone Lines In Household	The presence of sufficient or additional phone lines allows for multiple simultaneous lines of communication (such as voice, dialup and ADSL broadband).	Lookabaugh et al. (2002), Papacharissi and Zaks (2006)
Amount Of Hours Spent Online	More hours spent using the network will result in greater technical knowledge and greater propensity to pursue "always on" broadband.	Lookabaugh et al. (2002), Savage and Waldman (2005), Hitt and Tambe (2007)
Remoteness of location	People located far away from a population centre will pay more for broadband.	Bittlingmayer and Hazlett (2002), Strover (2003), Tookey et al. (2006), Ramírez (2007)
Occupation and Education Level	Users whose occupation requires or predisposes them to technology will have a higher propensity to adopt. Higher levels of education results in greater skill sets and technical knowledge.	Madden and Simpson (1997), Madden et al. (2000), Lookabaugh et al. (2002), Lee et al. (2003), Choudrie and Lee (2004), Choudrie and Dwivedi (2006), Dwivedi and Lal (2007)
Income Level	Users with larger income levels are more likely to adopt largely out of greater disposable income.	Madden et al. (2000), Hitt and Tambe (2007), Robertson et al. (2007)
Prior Exposure	Perceived changes arising or anticipated from prior use or exposure to networking.	Horrigan and Rainie (2002), Sawyer et al. (2003), Stanton (2004),
Intention	Users who intend to use or have an interest in broadband-related services, such as games or streaming video, will have higher levels of broadband adoption.	Madden and Simpson (1996), Chau et al. (2000), Oh et al. (2003), Dwivedi et al. (2006), Khoumbati et al. (2007), Ha et al. (2007), Daly et al. (2008)
Use	Users who derive utility or perceive usefulness from using networked applications will have higher levels of broadband adoption.	Hausman et al. (2001), Oh et al. (2003), Savage and Waldman (2005)

Table 2. Covariates Selected for Inclusion in the Classification Analysis

Technology In Household	Technology Usage Index (described below) Type of home PC (Mac, Windows, Linux, Other) Ownership of a mobile phone Whether interested in WAP technology Length of time owned a mobile phone Whether current mobile phone supports WAP Type of mobile phone (Digital, CDMA, Other) Pay TV subscription status (current, previous, never)
Number Of Phone Lines In Household	Number of private telephone lines in household Number of business telephone lines in household Whether switched telephone provider (any service)
Amount Of Hours Spent Online	Length of internet use Frequency of internet use at home Degree of internet usage at home Whether use WAP capabilities of mobile phone Time of day for main internet usage (day, evening, other)
Remoteness of location	Geographic region (12 regions)
Occupation and Education Level	Number in household looking for work Work from home (paid/unpaid, self-employed/employed) Quintiles of Socio-Economic Status
Income Level	Annual income of main income earner Total household annual income Number of incomes in the household Age of main income earner Home ownership details (Own, Mortgage, Rent)
Prior Exposure	Whether ever bought anything over the internet. Any change in newspaper reading since using internet Any change in magazine reading since using internet Any change in TV viewing since using internet Any change in radio listening since using internet Any change in local calls since using internet Any change in long distance calls since using internet Any change in international calls since using internet Any change in sports activities since using internet Any change in seeing friends since using internet Any change in shopping since using internet
Intention	Interest in accessing information on information super-highway (very, quite, somewhat, not very, not at all) Interest in accessing streaming videos Interest in shopping on-line Interest in on-line gambling Interest in communicating with others world-wide
Use	Whether Email is a main internet use Research is a main internet use(academic/business+banking&insurance/both) Main type of internet sites visited info&entertain[tv,mag,newspaper,radio]/classifieds[ads&job hunting]/buying&selling[auctions,property]/ software download) Main type of internet transactions (banking&bills/share trading/shopping) Main type of social/entertainment sites (search for info/make contact[chat,social,calls]/games/entertainment[gambling/adult/sports]) Main use of internet is publishing/selling

Table 3. Overall Percentage Take-Up Australia Wide (Weighted by 11 Regions and Household Size)

	Jan-Mar, 2001	Apr-Jun, 2001	Jul-Sep, 2001	Oct-Dec, 2001	Jan-Mar, 2002	Apr-Jun, 2002	Jul-Sep, 2002	Oct-Dec, 2002
% Take-up	2.17	3.22	3.75	5.07	3.85	4.43	5.07	5.72
SE	0.33	0.34	0.40	0.50	0.37	0.40	0.42	0.46

Table 4. Main Internet Usage Categories

Main Usage Categories	Specific Usage Areas
Email	None
General Browsing	Information and current events Classified advertisements Details of products and services (including real estate) Software downloading
Financial Transactions	On-line banking and bill payment On-line share trading On-line shopping (grocery and other)
Research	Academic Business (including banking and insurance)
Entertainment & Social Contact	Information and current events Classified advertisements Information regarding products and services (including real estate) Software downloading
Publishing and Promotion	Web-publishing Web promotions and product sales

Table 5. Adoption Percentages By Main Internet Usage Categories (Standard Errors in parentheses)

Usage Categories	Specific Usage Sub-Categories	Adoption Rate Among Those Who: Use*	Don't Use**
Email	Sole Main Use	2.88 (0.30)	3.03 (0.24)
	Other Main Uses	5.70 (0.24)	--
General Browsing	Information and current events	4.30 (0.15)	9.11 (1.18)
	Classified advertisements	4.27 (0.16)	6.55 (0.57)
	Details of products and services (including real estate)	4.17 (0.16)	7.59 (0.62)
	Software downloading	4.13 (0.16)	8.21 (0.71)
Financial Transactions	On-line banking and bill payment	3.81 (0.16)	7.28 (0.45)
	On-line share trading	4.35 (0.16)	8.60 (1.21)
	On-line shopping	4.25 (0.15)	10.43 (1.24)
Research	Academic	4.34 (0.17)	5.18 (0.40)
	Business (including banking and insurance)	3.89 (0.16)	6.76 (0.43)
Entertainment & Social Contact	Information on Social Activities	4.17 (0.16)	7.60 (0.68)
	Communicating with Others	4.46 (0.16)	4.98 (0.62)
	On-line Games	4.30 (0.16)	9.23 (1.15)
	Entertainment	3.93 (0.16)	8.72 (0.62)
Publishing and Promotion	Web-publishing	4.45 (0.16)	12.89 (3.85)
	Web promotions and product sales	4.29 (0.15)	13.41 (1.76)

Table 6. Percentage Take-up by State and Regional Areas (Weighted by Household Size, Standard Errors given in Parentheses)

Region	Quarter							
	Q1'01	Q2'01	Q3'01	Q4'01	Q1'02	Q2'02	Q3'02	Q4'02
Sydney	4.49 (1.16)	5.61 (1.18)	5.75 (1.34)	10.42 (1.87)	7.71 (1.24)	5.96 (1.26)	8.83 (1.37)	8.87 (1.45)
Other NSW & ACT	0.58 (0.34)	1.65 (0.55)	1.16 (0.50)	2.02 (0.70)	2.79 (0.77)	4.12 (0.98)	2.46 (0.72)	2.33 (0.67)
Melbourne	2.52 (0.72)	5.68 (1.01)	5.70 (1.08)	6.39 (1.23)	6.03 (1.10)	7.38 (1.08)	7.53 (1.10)	8.86 (1.27)
Other Victoria	0.59 (0.59)	1.65 (0.87)	1.41 (0.83)	1.03 (0.59)	1.61 (0.83)	1.80 (0.81)	1.22 (0.72)	2.60 (1.03)
Brisbane	2.68 (1.11)	4.80 (1.30)	7.26 (1.66)	7.12 (1.65)	3.73 (1.30)	4.79 (1.30)	8.01 (1.94)	8.31 (1.70)
Other Queensland	0.82 (0.57)	1.87 (0.76)	2.97 (1.06)	2.78 (0.98)	1.18 (0.60)	4.12 (1.12)	1.79 (0.83)	2.03 (0.77)
Adelaide	2.67 (1.31)	1.49 (0.77)	1.16 (0.59)	2.45 (1.11)	0.87 (0.51)	1.41 (0.73)	1.93 (0.88)	2.72 (1.13)
Other SA & NT	0.00 (n/a)	0.00 (n/a)	3.12 (1.84)	2.53 (1.77)	0.00 (n/a)	2.23 (1.33)	5.67 (1.98)	4.82 (2.38)
Perth	2.84 (1.70)	0.55 (0.55)	2.54 (1.28)	3.87 (1.48)	2.55 (1.16)	2.05 (1.02)	4.28 (1.33)	6.61 (1.89)
Other WA	0.00 (n/a)	0.00 (n/a)	0.88 (0.88)	0.00 (n/a)	0.00 (n/a)	1.67 (1.67)	0.00 (n/a)	2.49 (1.74)
Tasmania	0.00 (n/a)	0.39 (0.39)	0.58 (0.58)	2.74 (1.37)	1.68 (1.02)	1.23 (0.70)	1.16 (0.66)	1.89 (0.95)