NEW ZEALAND INSTITUTE FOR THE STUDY OF COMPETITION AND REGULATION INC.

Broadband Diffusion:

Lags from Vintage Capital, Learning by Doing, Information Barriers and Network Effects

By

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Executive Summary

Broadband access to the Internet is high-speed access relative to the existing modem technologies that most Internet users employ to access their Internet Service Provider (ISP), and through the ISO, the Internet. It has been widely predicted by the telecommunications industry and the general media that broadband Internet will quickly penetrate the residential and small/medium business (SME) markets, providing a platform for online video, entertainment and other services. However, in practice broadband uptake has been sluggish compared to predictions.

This paper examines the factors that affect the uptake of broadband in the residential and SME markets. We searched the economics literature on diffusion theory and identified five different models that potentially provide insights into the broadband phenomenon. These models were applied to the New Zealand market, using detailed product and market data from an index ISP and the major telecommunications network provider, which we consider representative of the market as a whole.

We find evidence to suggest that the adoption of ADSL, the dominant broadband technology in New Zealand, is driven differently in the residential and SME markets. SMEs pay a fixed fee for each telephone circuit plus a toll tariff for all calls including local calls. An SME with multiple computers accessing the Internet, requiring multiple telephone lines, or with a reasonable level of traffic, generating toll charges, can cost-justify prematurely retiring modem capital and introducing ADSL as there are immediate cost benefits. However, an SME with little traffic and only one telephone line may still find that dial-up modems provide adequate service at a lower price.

The residential market does not pay toll tariffs or connection charges for local calls. The New Zealand ISP's all offer toll-free access for modems dialing up Internet connection. In addition, the dominant ISP account type is unlimited Internet access time for a fixed monthly fee. As a result, there is no additional charge for residential users to access the Internet by modem, and hence, no cost-saving incentive to adopt ADSL.

Mild evidence is found of learning effects in the residential market and weaker effects in the SME market where users are learning a wider range of Internet applications and how to use these applications more extensively for productivity and personal utility advantage. We conclude that this learning increases an individual user's data transfer requirements until modems become a constraint on what can be achieved in available time, at which point the user adopts a faster technology to enable transfer of the data within the time that the user has available. We hypothesise that all Internet users are undergoing this learning effect at varying rates, with the rate being determined by the bandwidth requirements of the Internet applications utilised.

There is also some evidence of information barrier effects, where adoption of ADSL has been slowed by the time taken before Internet customers recognise the benefits from ADSL. These effects appear in both the residential and SME markets, with greater barrier effects evident in the residential market segment. The different barriers can be explained to some extent by the amount of product information communicated by ADSL service suppliers within each market segment.

Our examination of broadband has been simplified by the fact that, unlike almost all other countries, the New Zealand broadband market is not complicated by the presence of multiple broadband technologies. The dominant technology is ADSL provided by the dominant telecommunications company, while cable modems are available as an option to less than ten

per cent of households and satellite and transmission towers provide access to only around ten per cent of broadband users. This simple market structure provides us with confidence in these findings, which we believe can be applied to other markets, including those with multiple offerings.

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Introduction

High-capacity broadband Internet networks are much vaunted as the technologies of the future for information-based economies. As Internet user numbers increase, the volume of data exchanged via this channel has grown, and as the number of applications requiring the transfer of large volumes of data grow, the importance of the ability of users to access high-speed networks has increased (OECD, 2001).

Substantial policy analysis has been devoted to exploring ways of making high-capacity bandwidth networks available ubiquitously, leading to the adoption of policies such as local loop unbundling and compulsory wholesaling in many countries (OECD, 2001a). This strong emphasis on supply-side considerations has been predicated largely upon the assumption that use of broadband networks will grow as a response to the availability of network infrastructures. Underlying this assumption is the premise that the barrier to uptake of more data transfer-intensive applications has been a shortage of capacity to enable these transfers to occur. Considerable regulatory and investment faith has been placed in the policy of "build it and users (and uses) will come" (Howell, 2002).

While historically there has been some justification for the faith placed in such policies (for example, demand for telephone services has grown much in line with this presumption – OECD, 2001), there is a mounting body of demand-side evidence beginning to emerge that this faith may be somewhat misplaced in relation to growth of demand for broadband Internet services (e.g. Quah, 2002; Lamberton, 2001). Despite broadband networks becoming readily available, uptake of these services has been significantly slower than originally predicted, with the result that some broadband providers are coming under considerable financial pressure as a result of owning large quantities of under-utilised capacity (e.g. Global Crossing filed for bankruptcy on January 28, 2002, one of many US broadband providers to have failed - Anonymous, 2002). In New Zealand, for example, ADSL services are available to around 80% of residential addresses, but fewer than 3% subscribe (OECD, 2001a). Likewise, in the United States, cable services passed 95% of households (Hazlett and Bittlingmeyer, 2001), but total broadband penetration (ADSL and cable combined) was only 3.24 per 100 inhabitants at June 2001 (OECD, 2001a). Asian users are the largest uptakers of broadband services, but even in the highest-using nation, Korea, only 13.91% of the population subscribe (June, 2001 – OECD, 2001a).

Low levels of broadband uptake are surprising given the rapid growth of uptake of Internet services. Growth in the number of connections to the Internet since its commercial origins in the mid-1990s has been rapid. In New Zealand, in particular, this growth has been significant, with more than 50% of households and 95% of businesses connected by 2001 (Howell and Marriott, 2001). New Zealand users also rank amongst the most intensive users of the Internet, in terms of number of hours of use per month (OECD, 2001). Yet, uptake of broadband services has been slow. Furthermore, New Zealand's story is not unique. Australian use of the Internet is not very far behind that of New Zealand's on a per-capita basis, yet despite cable modem and ADSL services being available to 50% of the population, only 0.05% have subscribed to DSL services and 0.54% to other broadband technologies (OECD, 2001a). Regulatory and supply-side considerations seem unable to answer the question of why uptake has been so slow, especially in Australia, where there have been competing telephony and cable service providers since 1992, overt policies for local loop unbundling, and price-designated compulsory wholesaling provisions.

To paraphrase Solow (1987), the 'broadband paradox' – where you see broadband networks everywhere (in the media, policy debate, legislative and regulatory action and even dug-up roads as cables are laid), except in the uptake statistics - threatens to become equally as vexing as the 'productivity paradox'.

While many supply-side reasons have been offered for the ‘broadband paradox’, such as overly-high broadband pricing and punitive two-part tariffs relative to flat-rate dial-up (OECD, 2001), infrastructure investment uncertainty generated by threat of regulatory action (Crandall, 2001) and absence of competitive pricing due to bottlenecks created by price designation of incumbent services forcing all providers to have identical cost structures leading to potential for collusive pricing (Crandall, 2002), less emphasis has been given to analysis of demand-side explanations for this slow uptake pattern. Demand-side analysis has been confined largely to a demographic analysis of how many people are subscribing, what their broad defining characteristics are, and the form of broadband to which they subscribe (OECD, 2001). Much less attention has been given to studying the applications these users employ, the volumes of information they transfer, with whom they exchange information, the purposes to which they deploy the information they exchange, and how these dynamics interrelate with considerations of capital (both tangible and intangible) investment and productivity, to determine both the type of Internet connectivity the user chooses and the timing of investment. Yet these two factors, capital investment and productivity, feature prominently in the literature of technology diffusion, and are critical in determining the match between supply and demand side factors that will result in efficient outcomes.

The purpose of this paper is to explore the drivers of technology diffusion in relation to broadband technologies, in order to gain some demand-side insights and understandings of why we are witnessing the ‘broadband paradox’. By better understanding the demand-side factors that underpin user uptake of the technologies, supply-side decisions regarding the amount of infrastructure required, timing of its deployment and the requirements of a policy regime to encourage efficient deployment of scarce resources in this endeavour can be better-informed.

Methodology

Research Question.

The key question our research seeks to address is:

> *What factors drive the diffusion of broadband technologies used for Internet access?*

Research Process

In order to answer this question, we first undertook a comprehensive literature survey of the economics of technology diffusion, and developed five hypotheses grounded in the existing growth theory literature to examine potential causes of the diffusion lags in the broadband market. We then documented the patterns of diffusion of the Internet in New Zealand, within the scope possible using a combination of data from publicly-available sources and provided by our two index companies (Telecom New Zealand Limited, a telecommunications service provider and its Internet Service Provider (ISP) subsidiary, Xtra).

We then applied the New Zealand data against the hypotheses to determine whether they provide reasonable explanations for the patterns observed in the data. Further, we discuss three indicative points, raised in unstructured interviews with representatives of our index companies, that provide further understandings of how this technology may be diffusing as a result of demand-side factors. We then draw some conclusions for both practical purposes and further research.

A Note About the Data

New Zealand data has been chosen for this study for a number of reasons.

Firstly, we have had access to the data provided by our index companies, which would not otherwise have been available for research purposes.

Secondly, due to the absence of overt regulations in telephony and broadband markets, New Zealand provides an unique environment in which to study demand-side uptake factors relatively undistorted by supply-side intervention. Further, the absence of a widespread cable broadband product means that New Zealand broadband uptake figures are confined almost entirely to one technology – ADSL. Hence, factors that influence uptake patterns in jurisdictions where cable modems offer an alternative, but not perfect, substitute product (e.g. cable television content) do not have to be corrected for. New Zealand Internet uptake figures thus represent, as clearly as we can determine, demand for Internet connectivity services based purely upon information product and service demand, undistorted by bundling of other products or regulatory intervention. ADSL uptake stands as a close proxy for broadband uptake. This enables us to eliminate some levels of uncertainty that would colour conclusions made using data from other jurisdictions and adds a level of clarity to the conclusions.

Thirdly, New Zealand's high level of uptake of Internet applications by international benchmarks indicates that this is a relatively mature market (within the context of the short life of the Internet). Combined with the relative maturity of other information-related applications (for example, New Zealand has high levels of computer ownership, has one of the world's first computerised and centralised (nation-wide) clearing processes for banking transactions, and is amongst the world's leaders for retail use of ATM and EFTPOS technologies (Boles de Boer, Evans and Howell, 2000)), these indicators imply a level of user sophistication in the use of information technologies that gives added credibility to the conclusions that we draw.

Thus, while the results gained, and the conclusions drawn, directly reflect the New Zealand environment, we are confident that they are readily applicable to other markets.

SOHO/residential and Business Market Distinction

The available ADSL data enables us to examine two distinct markets for broadband: the business market, and the combined Small Office/Home Office (SOHO) and residential market. We use the term SOHO/residential, as there is blurring in the market between business functions conducted in the home and true residential usage with some business activities taking advantage of lower charges for residential-only products.

It is acknowledged that the data, as illustrated later in Figure 5, do not distinguish between the two segments from January 2001, when the residential-only JetStart product was released by Telecom, until June 2001. It is known that some residential users had adopted the JetStream business-focused product and switched to the cheaper JetStart product when it became available. Further anecdotal evidence from Telecom suggests that few residential users remained using JetStream after JetStart became available.

However, the data does show that business ADSL uptake has occurred both earlier and in greater numbers than SOHO/residential uptake but the SOHO/residential uptake is now growing more rapidly. This evidence demonstrates that there are two separate markets, with different diffusion patterns driven by different effects.

Regional Data

The Department of Statistics provides data on business and population demographics on a regional basis. The region boundaries reflect the political boundaries of local government. The regional data from the telecommunications company is based on telephone exchange areas. There is an imperfect matching of boundaries between the two sets of data, and so we expect some distortions of the magnitude of our results using regional data. We have focussed upon looking at trends from this data rather than the magnitudes involved, and hence, we do not believe that the limited matching affects the robustness of our conclusions.

Literature Survey

General Purpose Technologies

For the purposes of this analysis, we presume the Internet to be a General Purpose Technology (GPT)

Helpman and Trajtenberg (1996) define a GPT to be one with universal and far-reaching applications throughout the economy, and which may spawn a flood of innovations in complementary technologies. The key features that separate GPTs from individual innovations are:

1. wide scope for improvement and elaboration;
2. applicability across a wide range of uses;
3. potential for use in a wide variety of products and processes; and
4. strong complementarities with existing and potential new technologies.

GPTs have a diffusion pattern characterised by two distinct stages:

- an initial stage, with intermittent growth, as early adopters make the required investments, while laggards keep producing with the old GPT; and
- a later stage, when a critical mass of potential users have already adopted the technology, that both pioneers and laggards are induced to make further complementary investments that pay off immediately.

Thus, GPT diffusion typically follows an ‘S’-shaped curve pattern. It is widely accepted (Helpman and Trajtenberg, 1996; Gordon, 2000; Gordon, 2000a; David, 1990) that computers (sometimes termed as electronics) comprise a GPT that has had wide-reaching effects upon the economy since at least the 1970s (Greenwood and Yorukoglu, 1997; Gordon, 2000). We contend, along with other sources (including Quah, 2002; Bosworth and Triplett, 2000) that the Internet is not merely a technology that has been spawned by computerisation but is itself a GPT that is at the beginning of driving transformations in the economy – as per the pattern in Figure 1. Our interpretation of the Internet as a GPT is supported by its meeting Helpman and Trajtenberg’s four-point definition.

When testing ADSL against their four features, it fails to meet the tests of ‘scope for improvement and elaboration’, and ‘applicability over a wide range of uses’ (Table 1). Thus, although its diffusion pattern fits the classic ‘S’ curve shape, we cannot support the argument that it is a GPT. Instead, we find it to be a technology derived from the computer GPT.

Table 1 Technologies as GPTs

	General Purpose Technology Feature			
Technology	**1**	**2**	**3**	**4**
Computers	√	√	√	√
Internet	√	√	√	√
ADSL	X	X	√	√

ADSL technology is derived from the computer GPT, as it is an electronic device that could operate regardless of whether or not the Internet exists. However, the emergence of the Internet has provided ADSL and other broadband technologies with impetus to diffuse through the economy.

ADSL as only one of a set of technologies, including dial-up modems, that enable people and computers to connect and exchange information over the Internet, represents a subset of those devices that enable the Internet to function as a GPT. Both dial-up modems and ADSL are individual innovations that complement the Internet. It is the growth of the Internet itself (proxied by the total number of ISP accounts, both dial-up and broadband together) as an information exchange mechanism that follows the GPT diffusion pattern. ADSL diffusion, as an enabler of increased data movement growth between the Internet *per se* and individuals, contributes to the overall pattern. ADSL is the current frontier technology, and based on bandwidth availability for the ISP network, it represents a frontier gap of 275% over modem access.

Diffusion Models

Diffusion patterns of new technologies through economies occur from lags between the time of invention of the technology and the various times at which users adopt that technology. Four predominant theories are offered to explain the origins of these lags:

1. Growth theory, where exogenous technology improvement drives increased productivity (developed by Abramovitz, Atkeson, Bosworth, Bresnahan, Brynjolfsson, David, Hall, Helpman, Hitt, Gordon, Greenwood, Jorgenson, Jovanovic, Kehoe, Romer, Sichel, Solow, Stiroh, Trajtenberg, Triplett and Yorukoglu, among others);
2. Learning models, where productivity improvement models are enhanced by learning acquired in the use and/or adoption of technologies (developed by Atkeson, Brynjolfsson, Greenwood, Jovanovic, Kehoe, Rousseau, Yang and Yorukoglu, among others);
3. Barrier models, where barriers exist that slow the discovery or application of new technology (developed by Jovanovic, McDonald and Rob); and
4. Risk theory, where time lags created from the other three areas can be exacerbated by the injection of uncertainty in the returns to technology investment (e.g. Dixit and Pindyck, 1994).

These theories have led to the development of five different models explaining the diffusion of technologies through economies:

- *Vintage Specific Physical Capital Diffusion*: where new capital gradually replaces old capital as it gets worn out or too expensive to operate (Triplett, 1998; Greenwood and Jovanovic, 1998).
- *Learning Effects, comprised of*
    - *Technology Diffusion*: a firm must learn to use its new technology to obtain the potential from the technology ((Atkeson and Kehoe, 1997 and 2001; Greenwood and Yorukoglu, 1997). .
    - *Organisational Capital*: Firms embody learning as a separate capital, which improves their productivity (Brynjolfsson and Yang, 1999; Jovanovic and Rousseau, 2001; Atkeson and Kehoe, 2002).
- *Asynchronous Technology*: Firms with more than one complementary input upgrade the inputs separately to provide the opportunity for learning to use a new technology before upgrading complementary inputs (Jovanovic and Stolyarov, 1997 and 2000).
- *Network Effects*: where productivity improvements and hence diffusion rates are accelerated by externalities (Saloner and Shepard, 1992; Economides, 1996; Liebowitz and Margolis, 1994; Shapiro and Varian, 1999; Goolsbee and Klenow, 1999); and

- *Information Barriers:* diffusion rates are affected by the ease with which firms can find out about new technologies and how to use them (Jovanovic and Rob, 1989; Jovanovic and McDonald, 1993).

These models, while offering explanations for diffusion lags between invention, investment and gaining returns, can also be influenced by other factors, including:

- worker-machine matching (Jovanovic, 1998:2) , where greater productivity gains are achieved by matching new capital with the most skilled workers
- skill premia, where the value of time taken to accrue skills is a factor in assessing the time taken to accrue benefits of switching, hence influencing investment timing and diffusion, including:
  - skill in use (Arrow, 1962; Jovanovic, 1998; Jovanovic and Rousseau, 2002), where older capital is associated with less skilled workers; and
  - skill in adoption (Greenwood and Jovanovic, 1998; Cummins and Violante, 2002), where skills acquired from the adoption of new technologies reduce the impact of productivity losses when new technologies are adopted;
- risk and uncertainty (Dixit and Pindyck, 1994), where uncertainty can lead to delays in investing in new technologies, even though a net present value calculation indicates the investment is worthwhile. The greater the level of uncertainty, the longer the lag may be. Hence, diffusion of new technologies with high degrees of uncertainty attached may be slower than ones with lower uncertainty.

Hypothesis Development

These models lead us to propose five hypotheses to explain the diffusion of ADSL technologies against which we can test the New Zealand data:

Hypothesis 1:
That ADSL technologies, as the current frontier technology, replace modems, as the existing *IT* capital reaches the end of its economic life and is retired, in accordance with the vintage capital model.

Hypothesis 2:
That learning effects govern the substitution of ADSL for modems in each of the business and SOHO/residential markets.

Hypothesis 3:
That ADSL is adopted asynchronously with initial Internet investment.

Hypothesis 4:
That the rate of ADSL diffusion is regulated by an information barrier.

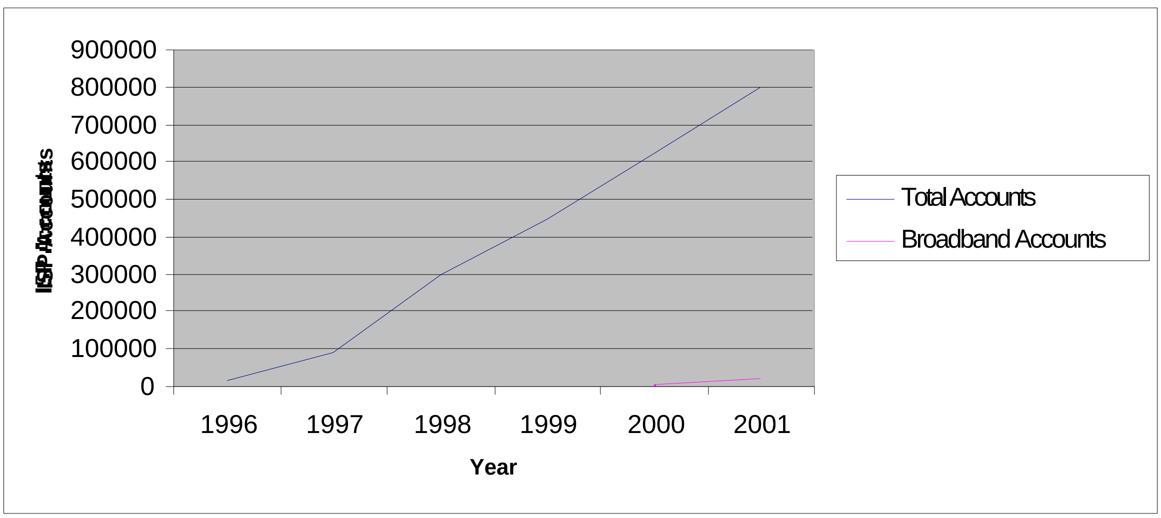
Hypothesis 5:
That the rate of ADSL diffusion is influenced by network effects.

The Internet and ADSL in New Zealand[1]

Since 1997, Internet access in New Zealand has been provided in three ways: dial-up access using either modems connecting to ISPs via the local loop or high-speed digital ISDN telephone connections, high capacity leased line connections direct to businesses, and broadband services. Satellite services were introduced in October 1998, but the cost has restricted large-scale adoption. High-speed ADSL services, first offered commercially in July 1999, provided an alternative to dial-up methods of connecting to the Internet. By utilising technology upgrades in telephone exchanges, the twisted copper pair of the standard fixed telephone line becomes capable of transmitting digital data at speeds up to 8 Mbps compared to a maximum throughput of 53 kbps by analogue modem over a standard telephone line, though the maximum commercially offered downstream speed during the period of this study was 2 Mbps. Furthermore, while use of a dial-up modem is sporadic, necessitating a new telephone call for each information exchange session, and precludes use of the telephone line for voice calls when the modem is connected to the ISP, ADSL connections are 'always on', effectively providing real-time connectivity. In addition, ADSL transfers data at high frequency and allows the telephone line to be used simultaneously for voice calls.

Our estimate of the New Zealand market for Internet accounts during 1996 to 2001 is contained in Figure 1.

Figure 1. ISP Accounts 1996-2001



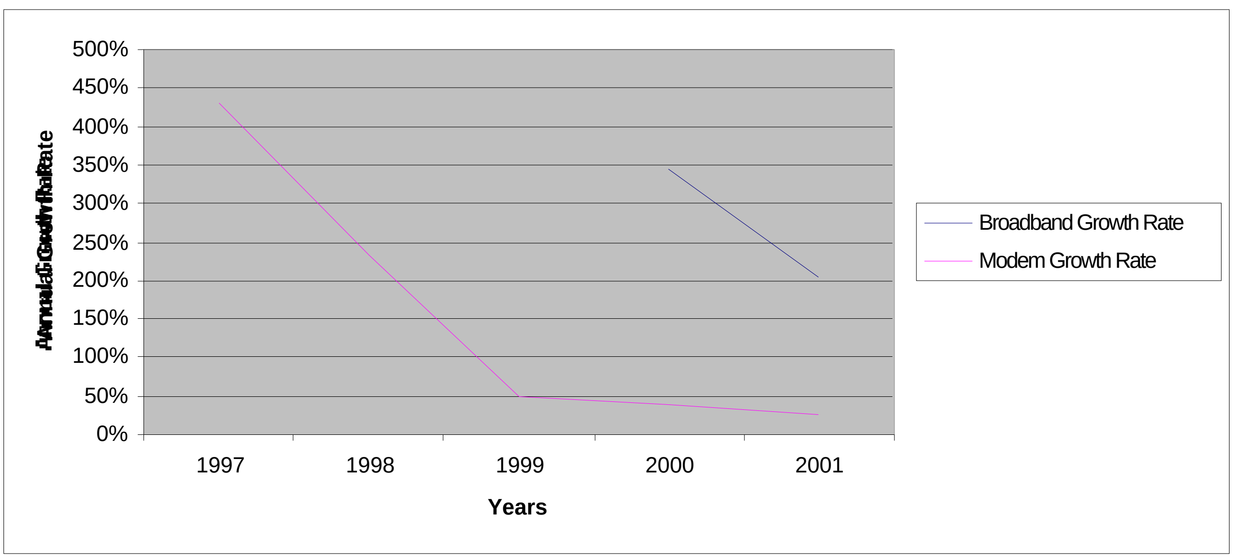
[1] The data displayed in this section are compiled from a range of sources. Uptake data pre-1999 come from Enright (2000), the most comprehensive history of the New Zealand Internet from pre-1996 to July 1999. Monthly data from 1999 to the present are based upon figures provided by our Index ISP, corrected to reflect the ISP's market share and our index telecommunications company, plus the official New Zealand statistics for annual IT investment, regional and national business and domestic population demographics. Implicit in this analysis are the assumptions that our index ISP provides a fair representation of the entire New Zealand market, and that the market shares applied on a month-by-month basis, as supplied by the ISP, are accurate. Given the size and market share of this ISP, and that the estimates of market size yielded by this method very closely approximate the 6-monthly data provided by the OECD (OECD, 2000; OECD, 2001; OECD, 2001a) suggests that these assumptions

Rate of Internet Growth

Growth of Internet connections over the entire period from pre-1996 to the present has been rapid and strong. The Internet diffusion pattern follows the classic pattern of slow initial uptake, dominated by the early adopters. Early adopters, although small in number, undertake early experimentation with the technology, learning how best to apply it to generate productivity improvements. The majority of potential users, the laggards, refrain from adopting the new technology until the early adopters have identified its productivity improvements. Once benefits are ascertained (generally when around 5% of potential users have adopted), a critical point in the diffusion pattern has been reached and the laggards begin to take up the technology in increasing numbers. This creates the upswing in the classic ‘S curve’ diffusion pattern. When the majority of laggards have adopted the technology (around 50% of potential users) the uptake rate begins to tail off, completing the tail of the ‘S curve’.

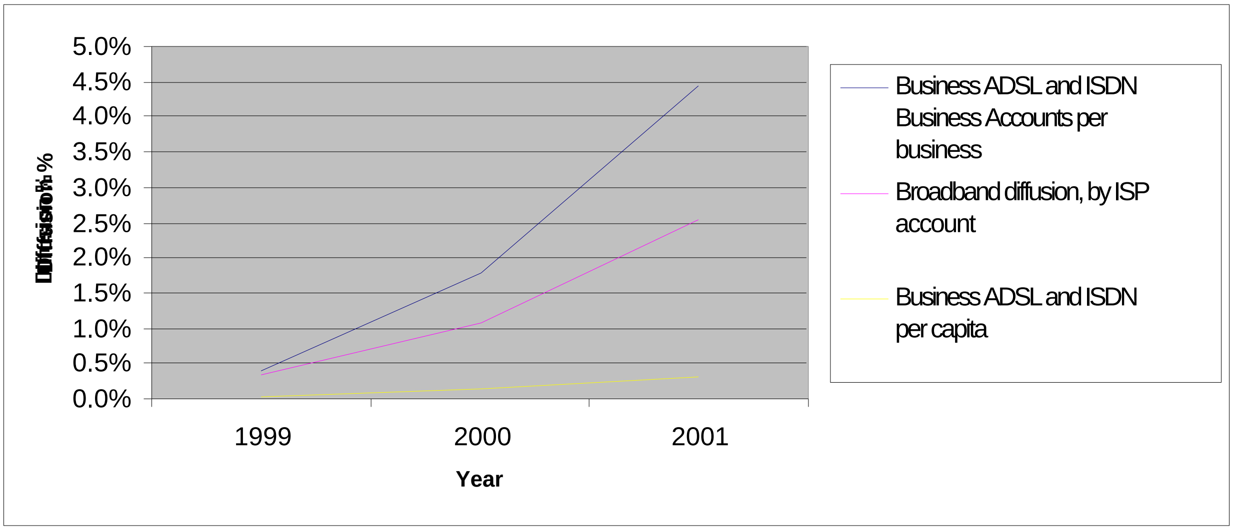
Figures 1 and 2 show Internet diffusion to be about half-way through this process, with a clear tail at the lower end, where early adopters predominate, followed by a large upswing due to laggards adopting. The 5% threshold of Internet connections on a population basis was reached in 1998 and is currently over 20%. Based upon households, this point was reached in 1997 and exceeded 50% during 2001.

Figure 2 Annual Rate of Growth of ISP Accounts 1997-2001



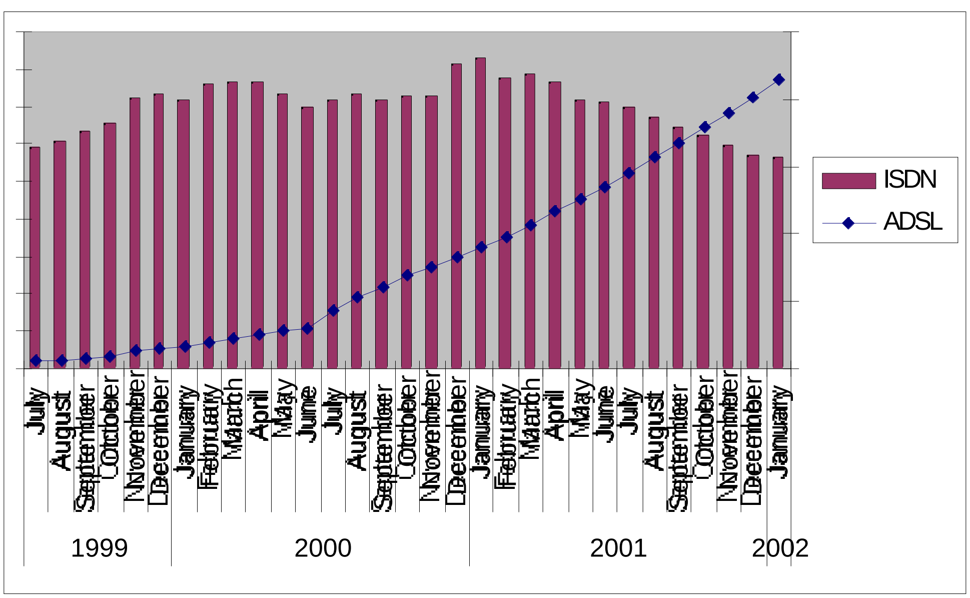
ADSL diffusion, beginning in 1999 with a handful of early adopters, also appears to be following the classic ‘S’ curve, although is much earlier in the process (Figures 2 and 5). The ratio of broadband business users to business population is approaching the 5% threshold during 2002 (Figure 3), and on a per capita basis, uptake exceeded 0.3% in 2001. (We note, however, that on a regional split, some regions demonstrate a diffusion rate approaching 7% of businesses – Figure 11). This implies that current users are almost exclusively early adopters – any significant uptake by laggards, either business or home users, is still to occur.

Figure 3 Business Broadband Diffusion



Our data also enable a limited comparison of broadband users based upon technology type and market segment. As our index ISP, Xtra, was the only significant provider of ISDN dial-up services, we can isolate this technology as a subset of broadband services. While ADSL technology has grown significantly over our study period, the use of ISDN has fallen away (Figure 4). As ISDN was supplied only to business users, with billing rates linked to business line rates, this enables us to explore aspects of user segments that influence demand for broadband products.

Figure 4   ISDN and ADSL Markets[2]



Products and Pricing

Residential telephone subscribers in New Zealand face a zero marginal cost per call for use of the service. When connecting to the Internet, using flat-rate ISP services, which have been the predominant form of dial-up pricing since 1998, there is a zero marginal cost of accessing the Internet. Flat-rate telephony charging has been cited as one of the key drivers of New Zealand's Internet uptake and use (OECD, 2000).

Business users, however, face a two-part tariff comprised of a fixed fee for access to the network, and a per-minute charge for each minute connected via a dial-up modem. This is in addition to the flat-rate ISP fee. Hence, dial-up business Internet users face a cost for information exchange proportional to both each call they make to their ISP and the amount of time they are connected to the Internet – the more calls made, and the higher the number of minutes connected to the Internet, the higher the fee, irrespective of the amount of data exchanged.

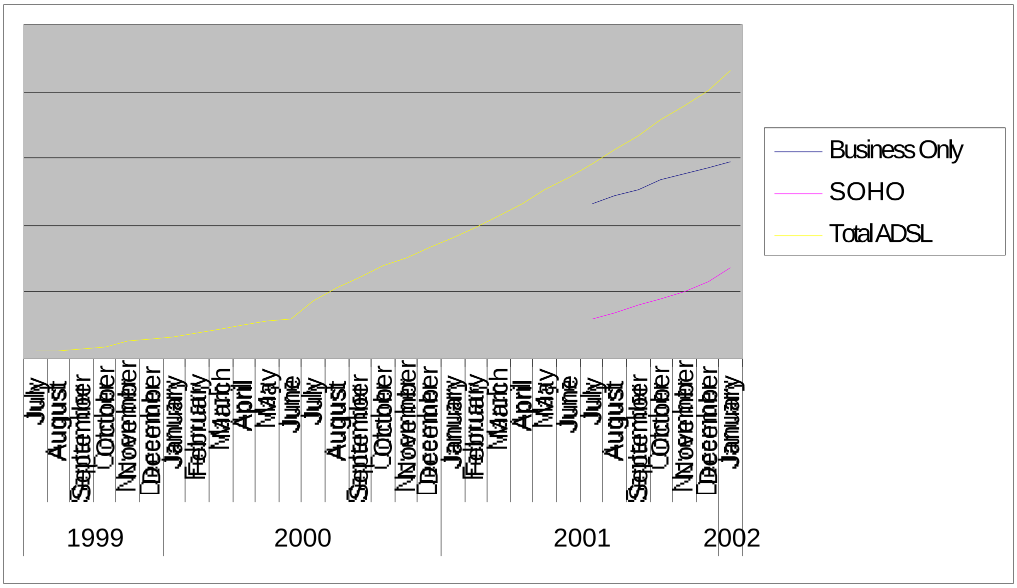
When first introduced in New Zealand in July 1999, all ADSL packages were priced as a fixed fee covering a specified number of megabytes of data downloaded, and a per-megabyte charge for each megabyte exceeding the limit. These packages were branded Jetstream, with an identifier denoting the data limit in terms of megabytes. Some ISPs charged different rates for international and national traffic. Both business and residential customers faced the same prices.

In January 2001, a new ADSL product, Jetstart, was introduced based upon a lower synchronous speed (128kbps). Volume limits were initially set to zero by the first ISP to market, Xtra, but other ISPs who later introduced similar products placed volume limits and additional charges for data transferred above those limits. In April 2002, Xtra followed the trend and unmetered ADSL has now disappeared.

Residential users in this context are defined as the same class of users who quality for flat-rate residential telephony charging. As defined in the Data section, in recognition of the fact that this market does comprise of a number of home office and small business users, we use the term SOHO/residential to define this group of customers. Introduction of this SOHO/residential product has been instrumental in a definite acceleration in the growth of ADSL connection among this user category (Figure 5).

For the first few months of ADSL availability, a supply constraint on the number of exchanges in which ADSL was available slowed the uptake in some locations. Figures 10 and 11 show the patterns of regional ADSL availability. Since 2000, we find little evidence of supply side constraints as Telecom, the dominant telecommunications company, has commissioned surplus ADSL capacity throughout most of the New Zealand market, and has embarked upon extensive marketing campaigns to inform current and potential Internet users of the availability and benefits offered by the ADSL products. In addition, Telecom trained a substantial number of ADSL installers to provide new ADSL subscribers with rapid and simple installation of the new equipment, without any requirement for end-user training. This service included installation of Ethernet cards in PC workstations at the users' premises to enable connection to an external ADSL modem.

Figure 5[3] ADSL market split by Jetstream/Jetstart



Given the small average size of business in New Zealand, we believe that there has been no significant substitution of leased lines by ADSL. Instead, it is our view that some ADSL customers will migrate to leased lines once the transmission costs of their data requirements exceed the lease costs for digital data services. As this market is insignificant in number compared to total ISP account numbers, we have excluded testing for the effect of leased lines from this analysis.

GPT Diffusion

Taking the combined dial-up and ADSL diffusion curves as the diffusion pattern for the Internet GPT, it would appear that the first stage of growth of the GPT, where early adopters invest in the new technology and laggards wait to learn from others' experiences, has been passed in New Zealand. The Internet was introduced commercially in New Zealand in 1992, exceeded 5% of households in 1998, and 50% in 2001 (Table 2) – a *diffusion lag* of three years. The 5% threshold in household computers connected to the Internet was reached in 1995, 50% in 1998, likewise a three year diffusion lag.

The Internet's diffusion pattern is unusual in that it follows the same pattern as that pioneered by computers (Triplett, 1998). The new technology – the Internet – offers benefits so compelling that it is adopted despite any remaining productive capacity in installed capital embodied in earlier technologies, as the productive benefits of adopting far outweigh the benefits of retaining the old capital base.

Broadband, dominated by ADSL, had reached 2.5% diffusion of all New Zealand ISP accounts by 2001, and 4.4% in the Business Internet account market (Table 2 and Figure 6).

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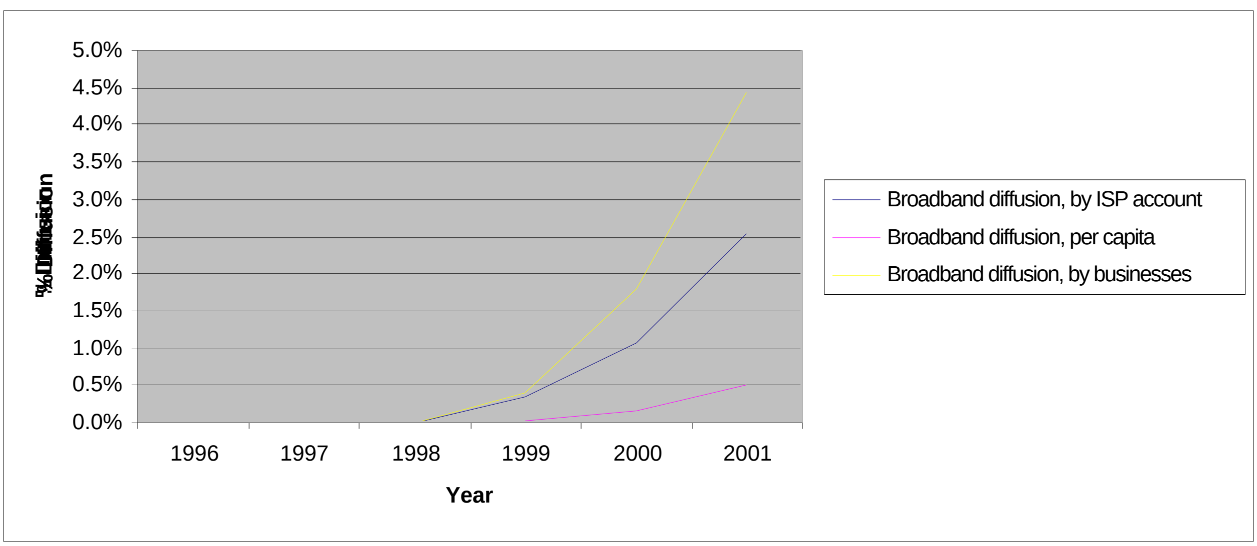
[3] We have not shown the Y scale detailing the number of accounts to protect commercial confidentiality. In addition, limitations with our data means that we cannot split the SOHO/residential Jetstart product from Jetstream

Table 2. Internet and ADSL Diffusion Rates

	1996	1997	1998	1999	2000	2001
Internet Diffusion in Business Computer	N/A	N/A	N/A	38.9%	46.9%	56.6%
Internet Diffusion in Home Computer	19.9%	30.0%	52.4%	61.5%	71.8%	84.4%
ISP Accounts per household with telephone	1.5%	7.8%	25.9%	38.5%	53.7%	69.0%
ISP Accounts per household	1.3%	7.1%	23.7%	35.2%	49.1%	63.0%
ISP Accounts per capita	0.5%	2.4%	7.9%	11.7%	16.3%	20.8%
Business ADSL and ISDN Business Accounts per business	N/A	N/A	N/A	0.4%	1.8%	4.4%
Business ADSL and ISDN per capita	N/A	N/A	N/A	0.0%	0.1%	0.3%
Broadband Diffusion per capita	0.0%	0.0%	0.0%	0.0%	0.2%	0.5%
Broadband diffusion in ISP accounts	0.0%	0.0%	0.0%	0.3%	1.1%	2.5%

Figure 6 Broadband Diffusion by ISP, Capita and Businesses



Hypothesis Testing

For each of the hypotheses proposed above, we apply a combination of data provided by our primary and secondary sources to either support or refute the claims. While none of this data is sufficient to conclusively prove a firm hypothesis, there are strong indications that a relationship can be deduced, and that further quantitative research is indicated to determine more conclusively the nature of the relationship. The supporting discussions rely predominantly upon a combination of observation by the researchers and qualitative interviews with practitioners from the organisations providing the primary data.

Hypothesis 1.

That ADSL technologies substitute for modems as modems reach the end of their economic life, in accordance with the vintage capital model.

This hypothesis presumes that when a user invests in a technology, the investment will be made at the prevailing frontier, or best, level of technology. When the capital investment wears out and is replaced, then this replacement will be at the new frontier technology available at that time. The vintage capital diffusion model also predicts that when the returns on the 'new' capital exceed the returns on maintaining the 'old' capital, 'old' capital will be retired, thus providing a technique for predicting the life of capital.

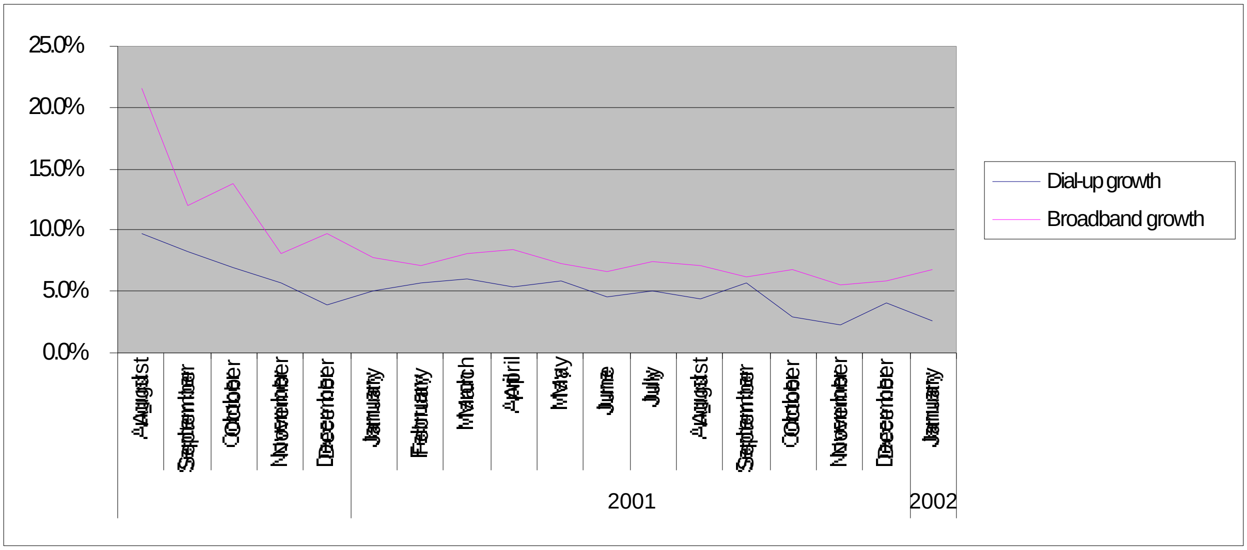
Modem Replacement

ADSL and dial-up modems both provide access to the Internet, with modems representing the first generation of technology offering this capability and ADSL the second generation. If a vintage capital model explains the diffusion of ADSL, then we would expect to find evidence that new entrants into the market will purchase the prevailing level of Internet connection technology (i.e. second generation ADSL), with the previous generation technology (i.e. first generation modems) gradually being phased out as early entrants come to replace their first generation technology purchases at the end of their economic life. Furthermore, if ADSL is superior to the extent that it provides greater returns than the returns to be gained from maintaining existing modems, then we would expect to see accelerated ADSL uptake and rapid disappearance of modems within the computer capital stock.

This hypothesis presumes that ADSL provides a perfect substitute for dial-up modem technology. While this assumption holds for the majority of users, the substitution is not a perfect one, as ADSL connections are physical location-specific, but dial-up modems only need access to any telephone line. While ADSL may provide a perfect substitute for fixed base applications (e.g. physical office, home installation), the substitution is not perfect for mobile users. Hence, we could expect that there would be a low level of first generation technology repurchase to cover this functionality.

The number of ADSL and dial-up modems in use at any one point in time will represent the capital stock of each technology. The number of ADSL accounts and dial-up accounts managed by ISPs provides a robust proxy for the number of each type of connection device in use. Hence the number of dial-up and ADSL accounts in Figure 1 represents analogue, for dial-up, and ADSL modem stock, while the growth of analogue modem and ADSL modems can be deduced from the growth of the two account types as shown in Figure 7. If the vintage capital diffusion model accounts for ADSL diffusion, we would see no new investment in modems once ADSL became available, as all new Internet users would purchase ADSL modems, and all dial-up users would replace old capital stock (modems) with ADSL modems when the dial-up modems reached the end of their economic life. Hence, we would expect negative growth in dial-up and positive growth in broadband.

Figure 7 – Dial-up and ADSL Growth



The data do not support this hypothesis. Figure 7 shows that, although ADSL represents the frontier technology for Internet, and investment (determined by the number of units) is growing strongly, investment in dial-up modems (the number of units) still occurs. Indeed, in January 2002 new modems accounts outpaced ADSL accounts by a factor of around eleven to one. New entrants are continuing to enter with the first generation technology, despite the second-generation technology being available.

Multiple Modem Replacement

In the Small-Medium Enterprise (SME) market, many businesses access the Internet using multiple computers. If these computers all use modems to access the Internet, then each computer requires a telephone circuit, shared, via an exchange, or direct. In addition, more computers implies higher traffic exchanged with the Internet. Furthermore, SMEs are likely to have their computers connected onto a Local Area Network (LAN), which simplifies the introduction of shared broadband network resources such as ADSL.

We found that almost 90% of business computers have access to the Internet in January 2002. Anecdotal evidence suggests that businesses have rapidly adopted ADSL based upon the cost savings they have made by the replacement of the multiple telephone lines and metered access costs with a single networked ADSL circuit.

Therefore we conclude that ADSL is being introduced in those areas where it is cheaper to replace existing modem capital with new ADSL capital than to continue using existing modem stock and to continue incurring resultant communication charges. This finding is in line with the diffusion rate first identified with computers and reported by Triplett (1998).

ISDN Replacement

While we cannot support the hypothesis that ADSL is diffusing as a result of vintage capital substitution for dial-up modems, there is a stronger case supporting the vintage capital argument for the substitution of ISDN technology by ADSL, thereby influencing ADSL diffusion. Base rate ISDN technology was introduced in New Zealand in 1992 and provides high-capacity digital bandwidth to dial-up telephony customers, with 64k data access to ISPs from 1996. As such, it represents an early broadband access technology, to which ADSL acts as a successor technology.

While functionally ADSL is a very close substitute for ISDN, the substitution is not perfect. ADSL connections are typically impractical for data transmission beyond a 7km radius of a telephone exchange or a distributed exchange interface point. ISDN, on the other hand, is not as severely constrained by a distance limitation. ISDN-based transmission, while expensive with respect to capital cost, is charged for on a per-call basis. Hence, ISDN connections offer a portability and distance facility not possible with ADSL. ISDN offers a practical alternative for high-speed Internet connection for episodic and transitory high volume data transmission at locations further than 5km from a telephone exchange, for example at race meetings and fairs, such as Agricultural and Pastoral shows. Hence, while there may be a strong element of substitution, it would be expected that there would be a residual number of ISDN users who would not replace with ADSL technology.

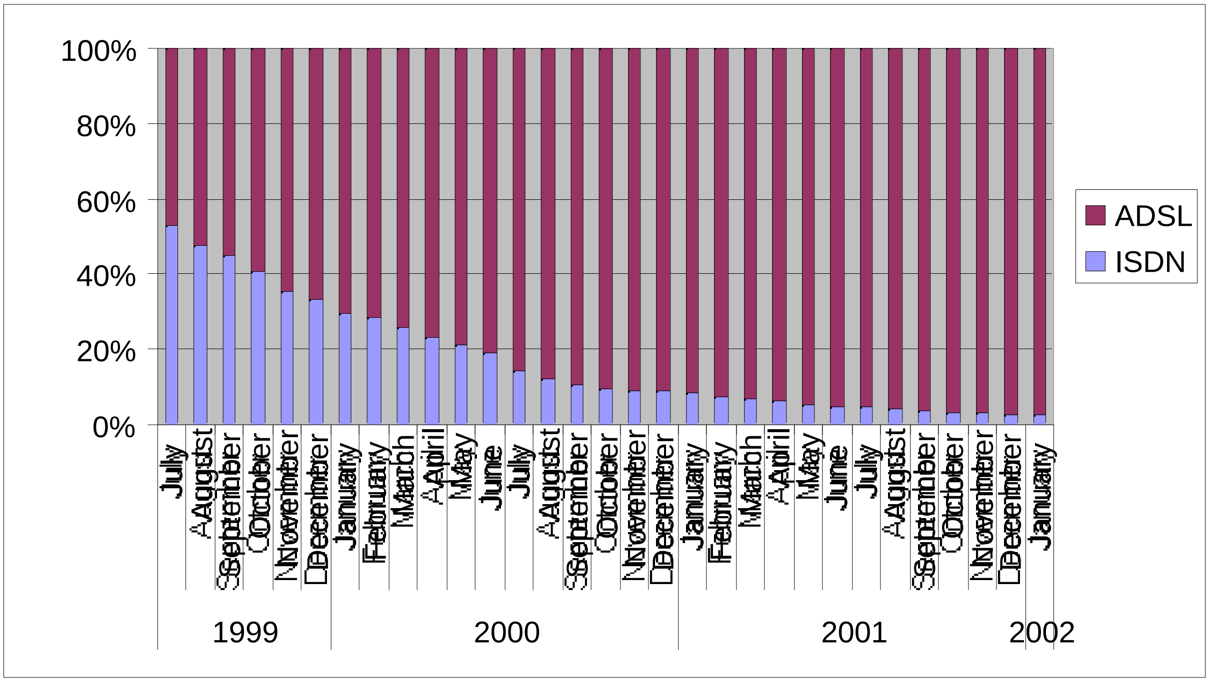
Using the same methodology as above, and analysing the number of ISDN and ADSL ISP accounts, we get the uptake patterns shown in Figure 4. There is clear evidence of a decline in the number of ISDN connections from February 2001, at the same time as the number of ADSL accounts is climbing steeply, implying substitution of ISDN data connections by ADSL. That the decline in ISDN accounts did not occur immediately once ADSL became available indicates that ADSL, while in itself a superior technology, is not sufficient on an operating cost basis to justify retiring ISDN technology immediately. The lagged and gentle decline in ISDN for data transmission accounts suggests that this (expensive) technology is being replaced by ADSL technology on retirement of ISDN capital, in accordance with the classic vintage capital model. The lag of approximately 18 months between the introduction of ADSL and the obvious decline in ISDN investment is consistent with an average capital stock life of 3 years for computer and communications equipment, and reinforces the argument that the cost-benefit trade-off is insufficient to prematurely retire ISDN in favour of ADSL. This pattern is clearly shown in Figure 8.

Results

Thus, while there is no evidence to suggest that the diffusion of ADSL is being driven by vintage capital effects with respect to single dial-up modems, there is strong evidence to support the hypothesis that vintage capital effects are driving diffusion of ADSL amongst the population of users who entered the broadband market using ISDN technology. However, this market is very small (at its maximum, only 831 customers subscribed to this technology) so any impact of this effect within the entire ADSL stock is minimal.

Conversely, the SME market, with multiple modems, shows some evidence of vintage capital effects with the diffusion of ADSL in that market.

Figure 8 ISDN as a proportion of Broadband



Hypothesis 2.

That learning effects govern the substitution of ADSL for modems in each of the business and SOHO/residential markets.

Learning effects are utilised by Atkeson and Kehoe (2001) to explain the pattern of diffusion represented by a small initial slow uptake of new technologies when substituting for existing technologies. This theory presumes that users of existing technology have built up a stock of knowledge required to operate that technology, and that moving to new technologies requires a decision about the value of maintaining the old knowledge together with the old capital relative to investing in new technology with no learning. Learning effects may thus be associated with a drop in productivity when a technology switch is first made, as it takes time for the operators to learn how to utilise new technology to extract maximum productivity. New technology is only purchased when the productivity advantage of the new technology with no learning exceeds the productivity of the old capital with the learning already captured by that capital's user.

Capital Learning

Learning effects offer a plausible explanation for the continued purchase of dial-up modems after ADSL became available, as evidenced in Figures 1 and 7. This would imply that there is specific knowledge required to efficiently operate an ADSL modem that takes time to capture, while the dial-up modem user has existing learning in the old technology. Existing users will delay the purchase of ADSL modems until such time that they can switch to the new technology with no productivity loss.

The data contain little to support this argument that users undergo learning when introducing ADSL modems. Both ADSL and dial-up modems operate as 'plug-in' devices, with the most complicated action required of operators being installation of software drivers on the computer to which the modem is attached, which is often undertaken by installation technicians rather than the end user. The time utilisation for a dial-up user is a learning effect, it is not a significantly valuable skill to acquire, and is rendered completely unnecessary by the faster response of ADSL. Thus it is unlikely that learning effects associated with the use of the equipment itself are influential in ADSL diffusion. In addition, new users with no experience are still purchasing dial-up modems, whereas the learning effects model predicts that new users would purchase ADSL immediately as they have no embedded learning which would bias them against purchasing ADSL.

Application Learning

Introduction of ADSL may, however, be associated with learning effects related to the computer-based Internet-accessible applications employed by the user. The key functional differences offered by ADSL are the faster data exchange speed and the consequent greater data exchange capacity within a particular time period.

Application Effects

Changes in the speed of data access may result in learning effects that influence both the types of applications used – that is, the portfolio of applications will evolve through encompassing both increased functionality and through progressive development of software products - and the ways in which existing applications are managed. Given that the applications employed by users vary with the purpose for which they are used, these effects may be different in different markets.

Application Usage

Learning effects associated with applications are unlikely to be a barrier to ADSL diffusion of themselves, as the substitution of the technology for dial-up modems has no impact upon the functionality of applications on the computers concerned. However, anecdotal evidence supports the suggestion that there may be some learning effects in relation to the use of web browsers for productivity advantage, which accrue irrespective of the market definition of the user. Whereas a dial-up user, used to slower response times, may 'stack' up requests for a number of web pages, and switch between them when extracting information in order to maximise the use of time as the scarce resource, an ADSL user, more accustomed to faster response times, may consecutively request a page, examine and extract information, then request another page. This learning effect, while affecting the productivity of existing dial-up users, is small and unlikely to be influential in the diffusion of ADSL. Hence, it is unlikely that the resources put into building this skill are large enough to be a significant factor in delaying the purchase of the new technology or necessitate reinvestment in the old technology.

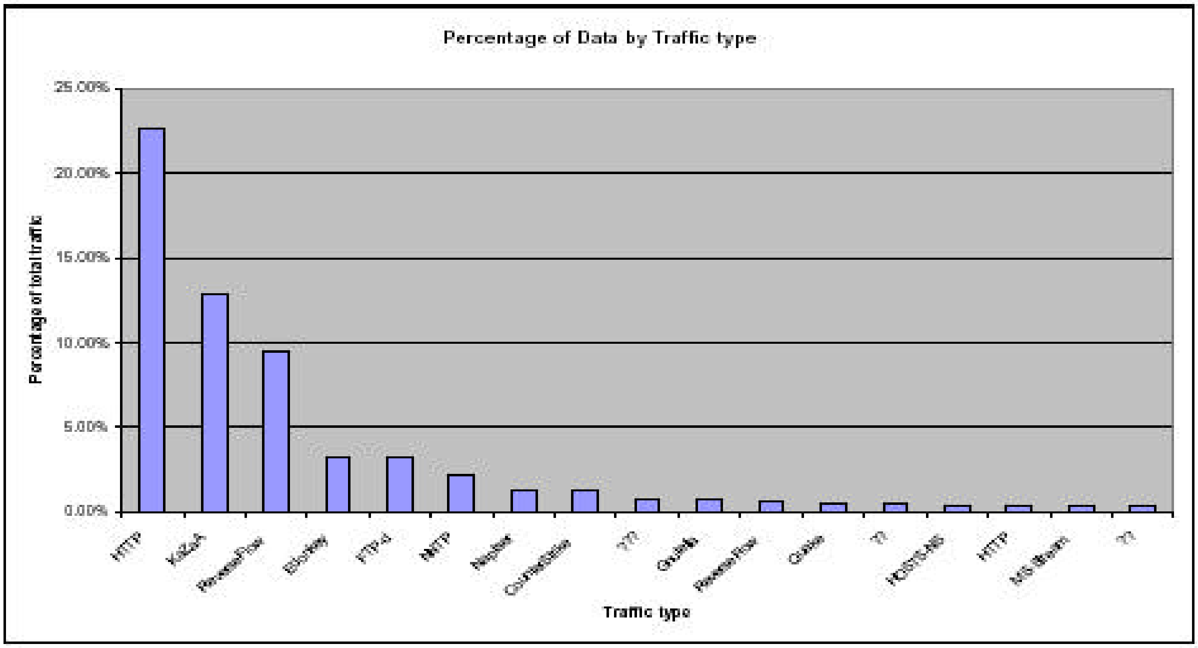
Application Range

While no application capable of running with a dial-up modem is precluded from running with an ADSL modem, and hence there are no learning effects associated with these applications that are lost, it is noted that the faster speed of ADSL makes a number of new bandwidth-intensive applications, such as video streaming, video conferencing and voice over IP in a multi-computer environment, more useful when using ADSL than dial-up modems. Achieving maximum productivity gains from these applications will take time and be subject to a learning effect, so it is feasible that reluctance of users to invest in this learning may dampen ADSL uptake. Data about the patterns of applications used by SOHO/residential ADSL users suggest a strong preference for bandwidth-intensive applications such as peer-to-peer networking. We also find that residential ADSL users access the Internet for twice the duration of modem users, exchanging four times as much data. The average traffic transferred by these users in one sample application, web-browsing, exceeded the total traffic of the average modem. We take these results to indicate the average SOHO/residential ADSL user has experienced a greater degree of application learning, in terms of the *learn-by-doing* models, than the average user.

Results

Hypothesis 2 has been found to be not proven for the business market – there is evidence to suggest that no learning effects exist that delay the substitution of dial-up modems by ADSL modems. However, the hypothesis is proven for the SOHO/residential market by the extended use of the Internet by its users. Learning to use applications encourages increased usage, leading to increased bandwidth consumption, and hence, earlier need for the increased volume capacity of ADSL. By extension, an increased range of application will lead to more learning and likewise increased uptake of ADSL.

Figure 9 ADSL Application Usage



Hypothesis 3.

That ADSL is adopted asynchronously with initial Internet investment.

Jovanovich and Stolyarov (1997) assert that in normal practice, when two complementary technology investments are used to make a single product, the two technologies are purchased concurrently and economics normally treats these as a single input into a process to create an output. However, if either or both of the complementary technologies is influenced by learning effects, then productivity gains are maximised by investing in the technology requiring the greatest learning effects first and delaying investment in the second complementary product until after the first set of skills is learned. This investment pattern is asynchronous adoption.

We have found in hypothesis 2 that the SOHO/residential market has significant learning effects but there is no significant evidence of the effect in the business market. By considering Internet applications and Internet connection devices as separate technologies, and recognising that there are significant learning effects associated with Internet applications, but practically none with connection devices, the rational investment pattern would be to invest in application learning first, and connection technology second. In this instance, connection is necessary to develop learning in applications, so the rational investor, faced with two options (dial-up and ADSL) will invest in the cheaper and lower risk option first (dial-up), and migrate to the more expensive technology (ADSL) only once learning associated with the applications has been achieved. This hypothesis contends that the delayed uptake of ADSL by the majority of users and continued investment in dial-up modems, as shown in Figure 8 is a consequence of this asynchronous investment pattern. Furthermore, if the learning effects differ between user groups, then the lag between first investment and second investment for each group will be different.

The greater learning effects in the SOHO/residential market may be due to a larger range of applications requiring learning and a lower average opportunity cost of time for users in this market. As there is no specific additional learning required for dial-up users in moving to ADSL, once the learning in applications has been acquired, then we see asynchronous investment in ADSL.

Results

Thus, there would appear to be support for the hypothesis that asynchronous investment in ADSL supported by learning effects gained in the use of the Internet from dial-up modems is a key driver of diffusion of ADSL technology.

This raises the question, though, of whether new Internet users purchase dial-up technology with the intention of learning to use the Internet, or whether there are new users who move straight into Internet use with ADSL equipment, and do their learning on this technology platform. In the New Zealand environment, it is difficult to determine if this is the case, given the different pricing policies applying to business and SOHO/residential users. There is some anecdotal evidence that while new SOHO/residential users are more likely to begin their Internet experience with dial-up modems, businesses may be more likely to utilise ADSL. This may be due to businesses already having learning embodied in staff members, or having the ability to recruit staff with the appropriate skills, or may be due to the different cost-benefit trade-off facing commercial, as opposed to residential, customers in New Zealand.

Therefore, we have shown that there are learning effects with applications but negligible learning effects for user introduction of ADSL capital. Jovanovic and Stolyarov's (1997) model predicts that initial investment should be in application learning until a user becomes sufficiently competent to make good and efficient use of the ADSL capital, at which point the user would implement ADSL. We find modest anecdotal evidence to support the view that existing ADSL users have indeed undertaken application learning prior to introducing ADSL, especially in the SOHO/residential ADSL market described in hypothesis 2.

Hypothesis 4.

That the rate of ADSL diffusion is regulated by an information barrier.

Information barriers slow the diffusion of new technologies because users have to first discover that the technology is available, and then learn what it may offer them in terms of productivity improvements. These factors can be learnt directly, by information on the technology being furnished by providers, or indirectly, by learning from other users (that is, imitation). If acquisition of this information is costly or difficult, then diffusion will be slowed to a much greater extent than if information acquisition is low-cost and readily available (Jovanovic and MacDonald, 1993).

There is little evidence in the national figures to suggest that ADSL diffusion in New Zealand is being delayed by any specific information barriers.

However, examination of regional ADSL uptake reveals distinctly different uptake patterns between regions where ADSL was available earlier (e.g. soon after the product's release) and other regions, generally smaller towns, where ADSL rollout occurred later. Regions with early deployment exhibit slow initial uptake, followed by an accelerating growth rate, while the later-deploying regions show a more rapid initial uptake followed by a slower growth rate. We suggest that these different uptake patterns are representative of more knowledge about ADSL and the ways to use it being available to customers in the latter regions, providing evidence that ADSL uptake has indeed been slowed by barriers to customers acquiring information about the product. These barriers have been lower for customers in later-adopting regions, as they have benefited from the existence of an expanded base of providers of information about the product – satisfied consumers as well as supply-side marketers.

Figures 10 and 11 below show the regional diffusion of ADSL into the SOHO/Residential and Business markets, respectively. The diffusion rate shown in the two tables represents the number of connections as a percentage of population and significant business units, respectively. Comparing the shapes of figures 10 and 11, the business diffusion graph looks more mature as the growth rate is declining in the two most mature markets, Auckland and Wellington.

We conclude that there are information barriers in place and that they have a higher threshold in the SOHO/residential market than in the business market.

This information barrier exists despite knowledge of the Jetstream product's existence being widespread and in no way constrained by any component of commercial confidentiality. Telecom and Xtra both have a substantial multi-media advertising budget, including television, print, mailout, website and billboard media raising awareness of the product. Other ISPs would be expected to have similar budgets. This information has been spread widely, both to existing customers of ISP services, and customers of its parent and allied companies. The ISP also operates a free-phone marketing service to provide information and advice to both existing and prospective customers. Generic advertising by other service providers, including telecommunications companies, has also raised awareness of the existence of the ADSL product. Telecom offers a service on its website via which potential customers can check if ADSL is available via the telephone exchange servicing their telephone number and links customers to ISPs that retail the product. However, it is reasonable to assume that business customers do receive more attention from suppliers than residential customers, as each individual business represents greater revenue opportunity for the supplier and warrants greater focus by sales strategies.

Figure 10 Regional SOHO/Residential ADSL Diffusion

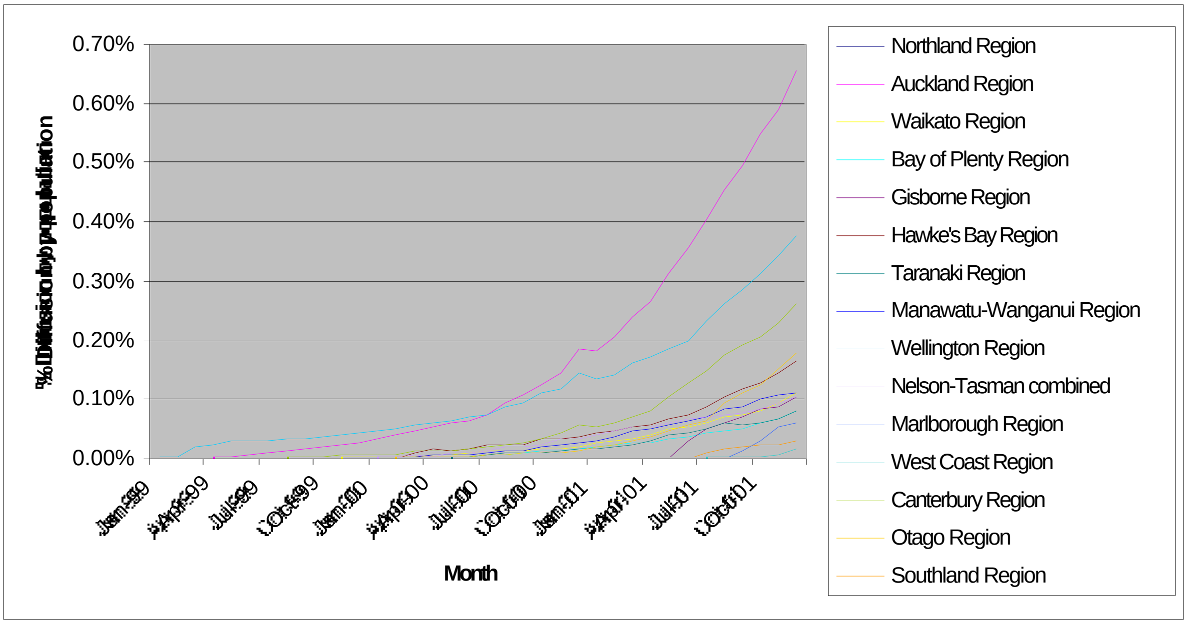
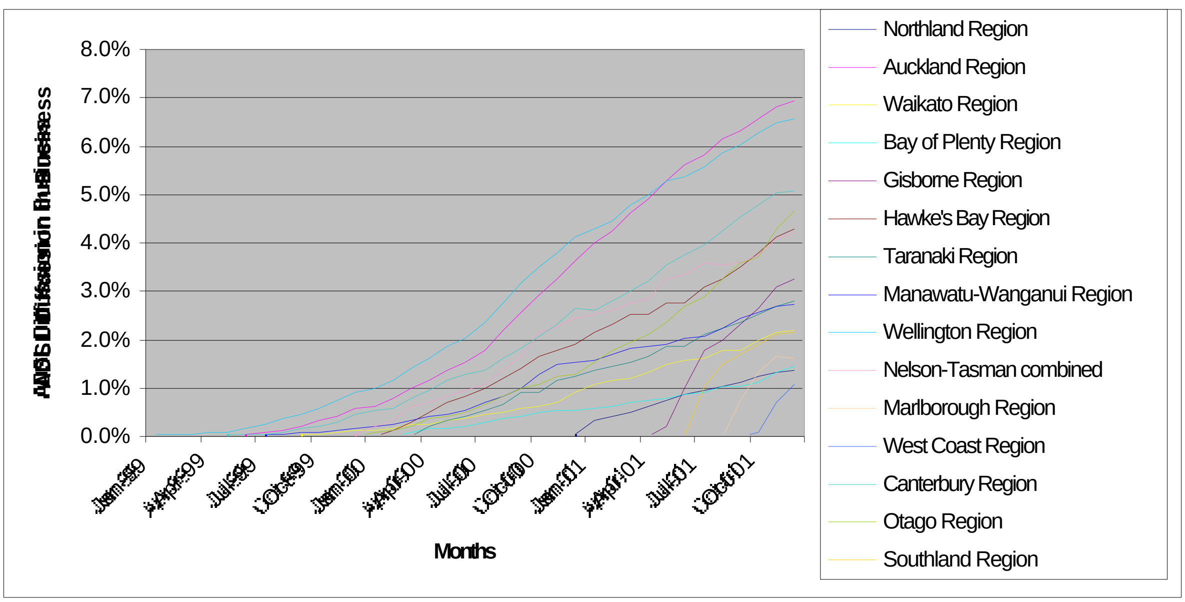


Figure 11 Regional Business ADSL Diffusion



Furthermore, the telecommunications company's full installation service negates any threshold that might exist for ADSL installation by the Internet user. There are negligible learning effects required for the Internet user to install and operate an ADSL modem (Hypothesis 2), there is also little evidence to suggest that it is costly to acquire the knowledge to operate it. Access to, and availability of, broadband connections has also been drawn into public and policy-making prominence by the Ministerial Inquiry into Telecommunications (Fletcher *et. al*., 2000), which reported to Parliament in 2000.

Therefore, the existence of the information barrier, despite attempts at communicating information to Internet customers, demonstrates the difficulty people have at recognising the value of ADSL from this information compared to imitating early adopters.

Results

Thus, we support the hypothesis that the rate of ADSL diffusion in New Zealand is regulated by a mild information barrier in the business market and a more powerful barrier in the SOHO/residential market.

Hypothesis 5.

That the rate of ADSL diffusion is influenced by network effects.

Network externality effects occur when benefits accrue to all users of a network from one more user entering (Shapiro and Varian, 1999). Examples of such networks include telephony networks and the Internet. The more users connected, the more beneficial the network becomes to all users.

While the Internet forms a network from which such externality effects accrue, it is debatable whether there are any individual network effects specifically attributable to ADSL. Such effects would accrue if collectives of firms and colleagues perceive there to be greater value for all of them (in excess of the costs) to be connected to the Internet via ADSL, and purchase simultaneously (or at least in very rapid succession) in order to accrue these greater benefits. However, there may be some network effects if users who habitually transmit large quantities of data between each other simultaneously invest in the technology.

The speed of communication between any two users of the Internet will be affected by the turn-around of responses by the two users. Communication between an ADSL user and a dial-up user will be impacted by the speed of the dial-up connection, as the modem user will require more time to access and retrieve information and to transmit responses. If the purpose for which the information is being exchanged requires interactive responses (e.g. chat room, file exchange via email or file-server applications), then total productivity of the two users together will be impacted (limited) by the speed of communication of the slower, dial-up modem. Hence, for users who regularly communicate via interactive applications, such as video conferencing and voice over IP, there will be productivity advantages if both convert simultaneously, if the application can make use of the bandwidth in excess of modem speed. These benefits may be substantial for business users, for whom co-ordination of activities may be very important, and for whom timeliness of response and ability to react is critical.

Interaction response time may also improve the quality of user experience for Internet game players, by providing a response advantage leading to a competitive advantage when playing an online game. The network effect driver in this case is the game network rather than the technology *per se*.

Whether these uses count as a network effect, or merely just an added advantage from standardisation, is debatable From a business perspective, similar advantages in reduced costs from servicing time saved accrue if all computer users within a firm standardise on a particular equipment brand and configuration. Software standardisation, on the other hand, offers network effects, as all users can communicate messages 'literally' as all share the same 'language'. These benefits do not apply directly to co-ordinated ADSL or co-ordinated modem users, as the 'translation' is done by end-user software applications rather than the transmission hardware.

Results

Thus, while there may be some advantages from standardisation among regularly communicating users, we can find no evidence to support the hypothesis that the existence of network effects is significantly accelerating the diffusion rate of ADSL, beyond the existence of some localised effects.

Conclusion

The hypotheses, as discussed, lead to the conclusion that the Internet represents a GPT, and ADSL is a specific application within that technology, which is enabling greater innovation and ongoing uses of the GPT in order to increase economic and social benefit. While the diffusion of ADSL within the business market exhibits some elements of a vintage capital driver, at least in respect of substituting for ISDN connections, it is learning effects that seem to predominate in the SOHO/residential market. These learning effects are dominated by the learning about how to use the technology of the Internet, leading to asynchronous investment in ADSL as a 'second stage' investment once individual usage patterns (e.g. demands, applications, information exchange volumes, individual cost-benefit trade-offs etc.) have been established.

Distinctly different ADSL uptake patterns are emerging depending upon the particular market. This implies the extent of the learning effects differ, dependent upon the applications used and the market definition. Specifically, learning effects appear to be accruing faster in the SOHO/residential sector, driving a more rapid growth rate. This implies the crucial functional element provided by ADSL – time – is valued differently in the two sectors. If time is more valuable to business users, then for the same application, we would expect to see, by the marginal benefit-marginal cost trade-off of the vintage capital model, earlier adoption of the technology that offers time advantages by the sector that places a higher value upon the time saved by ADSL.

However, both of these conclusions also presume that the price mixes faced by each market are identical. Unfortunately, extensive market segmentation throughout the life of the Internet has meant that this has rarely been the case. While the initial ADSL offering was identical, data from our index companies makes separation by business and SOHO/residential impossible before July 2001, due to data limitations.

We also believe that there have been some information barrier effects in the ADSL markets, with higher threshold in the SOHO/residential market. An information barrier would explain the slower than expected uptake of JetStart and the earlier stage of growth along an S-curve, as demonstrated by the regional diffusion data. Such a barrier would lead to growth by JetStart primarily by imitation.

While we can see evidence of all of these effects in our data, we are unable to separate out the individual impacts of each of these sufficiently to attribute a proportionate effect to each. Rather, we summarise this section by recognising that, while each of these elements is significant, the patterns we witness are a result of the interaction of all of these factors.

These findings give rise to a number of discussion points that we believe warrant further analysis in order to fully understand the drivers of ADSL diffusion. While we cannot support these discussions with empirical evidence, as we have the five theses above, each of these discussion points has been supported by anecdote in the unstructured interviews we conducted with staff of our index companies. While there is some evidence to support these points, each remains to be more rigorously tested.

Discussion Items

Discussion Item 1.

That price policies are the dominant effect in driving ADSL diffusion.

Our data show some evidence of impact of pricing policies. We conclude that among the 'laggards' in ADSL uptake, there are many users for whom continued dial-up usage is a result of reasoned defection based upon the relative costs and benefits faced. For residential users, this may be due to a very low valuation of time, or low value placed on the data obtained. For business users, it may be due to small data transfer volumes and lack of time-criticality in the data transferred being insufficient to justify the substitution, subject to being able to transfer the required data within the time available.

The vast majority of New Zealand users accessing the Internet via dial-up modems do so using flat-rate pricing plans, due to the relatively low prices and the very low financial risks faced by consumers (unlike two-part tariffs, there is no risk of having to pay more than the fixed amount, making budgeting simple)[4]. ADSL prices, however, have historically been metered by data exchange volume. For a typical business user, facing a per call charge for dial-up access, substitution by ADSL is immediately beneficial as the telephony bill is excluded. Higher marginal costs of data exchange automatically bias business users towards earlier adoption of ADSL than a SOHO/residential user with identical usage patterns. Indeed, this benefit has been the key element in our index ISP's marketing strategy to its existing and new business customers, and is thus likely to be an important factor in the greater proportion of business users switching to ADSL.

Yet despite this advantage, there is still evidence of intentional defection among business users. Anecdotal evidence indicates that many still use dial-up connections from choice, because their data exchange volumes may be small (perhaps just clearing emails two or three times a day) and do not justify the combined capital expense and additional operational costs of ADSL.

In either case, these price-based decisions could not have been made without learning about existing cost patterns from use of dial-up services. Thus, price points alone do not drive the choice of technology – information about usage that can only be gained from learning effects is also significant. Although we cannot empirically test the extent of sharing of this type of information across businesses to determine if there is also a barrier to learning depressing uptake, we are aware that benefits associated with information-based usage is increasingly being conveyed to prospective users by our index ISP's marketing staff. Indeed, our index ISP, in an effort to minimise risks, promote learning and increase ADSL usage, will allow businesses to revert to dial-up without cost penalty after an initial period if costs prove prohibitive.

For residential users, however, we believe that flat-rate ISP pricing and zero marginal cost of telephony have posed significant barriers to switching to ADSL. On a marginal price basis of telephony alone, no rational residential dial-up user would be motivated to switch to metered ADSL. Thus, residential customers switching to ADSL must be doing so because they place a premium on either their time, or the timeliness of the data. The value placed upon these must have been determined by learning effects.

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[4] It is noted, however, that while residential users face a zero marginal cost for telephone connection to the ISP, business users are required to pay their standard metered rate for telephony connection to the ISP.

If the trade-off between flat-rate dial-up and metered ADSL has been a factor in delaying entry by residential users (the point at which a residential user will substitute will be, by the marginal cost-marginal benefit argument, at a lower valuation of time than an equivalent business user), then learning and pricing together may explain the lag of SOHO/residential uptake vis-à-vis business. That is, learning and pricing together substantiate reasoned defection.

The introduction of a flat-rate pricing scheme in 2001 has been significant in increasing the percentage of SOHO/residential users purchasing ADSL. This segment represents the fastest-growing Internet sector in our study, with 18.4% growth in January 2001. This rate is seven times the dial-up growth rate and 2.5 times the total ADSL growth rate, reinforcing the pattern witnessed with dial-up growth that unmetered pricing policies are significant drivers of firstly Internet uptake (OECD, 2000), and ADSL uptake.

Flat rate pricing schemes reduce financial risks to consumers vis-à-vis metered charges, and will therefore accelerate the rate of diffusion (Dixit and Pindyck, 1994). However, they will also increase information transfer consumption, leading to significant amounts of capacity being used by a small number of users (Varayia *et. al*., 1999), as heavy users do not face a price signal of their consumption. Our index ISP reports that, in one month surveyed, 50% of the available bandwidth for SOHO/residential ADSL services was consumed by fewer than 10% of these customers. When faced with comparing flat rate dial-up and ADSL services, the user needs only to assess an individual valuation of time. Valuations of data volume or benefit are unnecessary, resulting in usage patterns that transfer the consequences of inefficient use of resources by consumers onto the service provider. This places a considerable burden on the service provider to accurately estimate the 'average consumer valuation of time' in order to price the flat-rate product in such a way that covers both the cost of services provided and the additional inefficiency costs incurred through decision-makers facing prices that bear very little relation to marginal cost. Risks of financial burden from high use are shifted from the user onto the ISP by flat-rate pricing.

Persistence with flat-rate pricing in both dial-up and ADSL SOHO/residential markets mean ISPs must gamble with setting a price and hoping that it will not induce overly large inefficient usage. By extension, the price difference between dial-up and ADSL will always have to be higher than the 'average' user's difference in valuation in order to cover the costs of increased cross-subsidisation. Thus, users for whom the substitution of ADSL is efficient at marginal cost will not purchase at the higher flat rate, delaying uptake. In any event, flat-rate pricing skews the type of users who will substitute towards those who under-value the volume of information exchanges and over-value their time, compared to those users facing marginal costs. This form of adverse selection results in even greater risks being borne by the ISP. Such risk effects have led to the introduction of volume caps for SOHO/residential ADSL by all New Zealand ISPs, with the last ISP introducing its cap in 2002.

Discussion Item 2.

That the applications most commonly used by Internet customers will also influence the point at which ADSL will substitute for modem access.

Anecdotal and survey evidence (e.g. Clark, 2001) suggests that different categories of Internet users will employ different applications, with varying volumes of information transfer need. These variations will result in variations in the point at which it becomes economically feasible for a user to substitute ADSL for dial-up access.

Some applications, such as the majority of email and web-browsing, where sites are accessed for data exchange, followed by several minutes of human information processing, require only very small amounts of data to be transferred, and the transfer of much of this data is not especially time-critical. Applications such as peer-to-peer applications and file exchange, while transfer-intensive, are not especially time-critical. Others, such as video-conferencing, video streaming of movies and interactive gaming are both data transfer-intensive and time-critical, or merely time-critical (for example, registering bids and offers in online auctions). The extent to which these applications are both used, and add value for which the user is prepared to pay a premium (that is, meet pre-defined cost-benefit trade-offs) will be important in deciding when to invest, and hence influence the ADSL diffusion pattern.

Customer demographics may offer some level of discrimination regarding the type of applications likely to be used. For example, video conferencing is almost certain to be more highly utilised by business users than residential, and interactive gaming and peer-to-peer applications for exchanging video and MP3 files (e.g. Napster, KaZaA, Edonkey and Morpheus) are unlikely to feature highly within business priorities. But there is considerable overlap in use of generic applications such as email and web browsing, making decisions about the likely application profile and usage intensity difficult to predict from demographics alone.

Nonetheless, some broad categorisation may be possible. Business users opting for ADSL services will be (most likely) those with high needs for timeliness of information and moderate data volumes communicated to a variety of destinations (high data volumes exchanged with a small number of partners would be much more likely to be carried via leased data lines). Business users with high valuations of time would also be likely to be utilising ADSL, in order to maximise labour productivity. Residential ADSL users, on the other hand, are much more likely to be engaged in gaming and peer-to-peer exchange. A limited number with a high valuation of time, high volume and valuation of the information sourced or a propensity for accessing websites with complicated (data-intensive) graphics will be prepared to pay a premium for faster exchange and higher volumes.

In a ‘snapshot’ of residential ADSL subscribers’ usage from our index ISP (Figure 9), this usage pattern is reflected. Web surfing and peer-to-peer exchange account for almost all user traffic by megabytes; email megabytes are negligible.

Thus, user uptake of ADSL is driven by a trade-off of valuation of information exchanged (by both quantity and application value), valuation of individual time, valuation of information timeliness, and the prices charged for the capital equipment and operational costs of services.

Availability of applications plays a key role in determining the volume of information exchanged, and hence the cost-benefit trade-off for users in determining whether individual information usage patterns of this application justify ADSL purchase. As new applications become available, each user must reassess this trade-off, in respect of the information-based utility of the new application. Application availability, hence, plays a key role in determining not only who will purchase ADSL, but also when the cost-benefit analysis will dictate purchase occurs. Thus, the relationship between available applications, user information usage intensity, valuation profiles and ADSL diffusion is crucial to ADSL diffusion rate.

The learning effect of Hypothesis 2 will also influence the point at which a user may choose to substitute. As a user becomes more familiar with the applications, each application will be used (potentially) more extensively, requiring larger quantities of information to be transferred per user. Flat rate pricing in particular encourages this form of learning effect, as there is no financial impediment to increasing the volume of information transferred. When application learning effects are combined with an increasing array of available applications utilising larger quantities of bandwidth (possibly even 'discovered' as a result of the larger amounts of information available as a result of greater proficiency in information search acquired through learning-in-use), then the quantity of information required to be transferred increases dramatically. Capacity limitations of dial-up infrastructures may be challenged, leading to the need to substitute higher-capacity ADSL connections.

The relative maturity of the user market and the type of applications in which learning has led to greater facility will also have an influence in the ADSL diffusion rate. Table 3 provides an assessment of a number of applications and the relative level of maturity that users have reached[5]. It reveals that high bandwidth-intense applications, such as software and file downloading and web browsing, account for a significant proportion of information transfers. This is consistent with the ADSL data snapshot in Figure 9, where peer-to-peer file exchanges, file transfer and web browsing account for almost all of the bandwidth activity. Greater facility in these bandwidth-intensive activities leads to a demand for greater volumes of information exchange, which leads to increased demand for technologies with greater exchange capacity, such as ADSL. That Figure 9 shows the predominant applications used by SOHO/residential ADSL consumers are almost exclusively these bandwidth-intensive applications reinforces the impact of the combination of learning effects with application availability to influence the ADSL diffusion pattern.

While learning effects and application availability influence ADSL diffusion by this argument, it does not explain the slow diffusion rate of ADSL identified in the 'broadband paradox'. Rather, in the absence of any other influence, this slow rate may be accounted for not in the supply-side availability of infrastructure, but in demand-side characteristics associated with applications. Users, when first encountering the Internet, take time to learn both the range of applications available, and to increase the use of these applications as proficiency grows, leading to increased information transfer, and ultimately, bandwidth demand or timeliness requirements that dictate substituting ADSL for dial-up modems, given that the marginal benefits of the substitution exceed the marginal costs (Mantell, 2000). User learning will be constrained if there are insufficient applications for which the user can find cost-justified reasons to learn of, and how to use them, or there are information barriers to locating such applications. ADSL uptake will be constrained if there is a shortage of such applications, or if the applications in which the user prioritises the development of learning have low bandwidth requirements.

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[5] The maturity indicator is defined as the number of people who have used the application in the last 12 months, divided by the growth in the number of people using that application over 12 months ago. Bandwidth intensity is an arbitrarily assigned number indicating the relative amount of bandwidth required for an 'average' usage of each

Table 3. Application Maturity and Bandwidth Intensity, Dec 2001

Application	Used in last 12 months	Growth Rate compared to 12 months ago	Maturity: Use/Growth	B/width Intensity, 1=low, 2=moderate, 3= high
Email	48%	30%	1.60	1
Browsing	37%	37%	1.00	2
Search Info on Products	33%	37%	0.89	1
Download Software/files	35%	40%	0.88	3
Reading Electronic Magazines	19%	26%	0.73	2
Access Education Services	23%	35%	0.66	2
Interactive Discussions	27%	42%	0.64	1
Search Info on Companies	21%	40%	0.53	1
Play Games	21%	50%	0.42	3
Check Account Balance	14%	40%	0.35	1
Internet Banking	15%	50%	0.30	1
Access News/Current Affairs	21%	75%	0.28	2
Access Classified Ads	14%	55%	0.25	2
Purchase Goods/Services	19%	90%	0.21	1
Transfer Funds btw Accounts	13%	116%	0.11	1

While we have seen rapid uptake of business ADSL connections as higher volumes of data are exchanged, the rate of growth in new connections is slowing, indicating some level of equilibrium is being reached for demand in this market at least, given current levels of applications and pricing. Stable growth indicates that in the business market at least, the strongest driver is learning effects with the current base of applications.

While we have no firm evidence, we find some indications that suggest there may be a shortage of bandwidth-intensive applications in the business market at least. In this market, where the number of Internet applications used is more likely to be a small and targeted subset of all available applications specifically for meeting business purposes, the growth rate in ADSL uptake is flattening out (Figure 11). This indicates that the extent of any learning effect in relation to current applications is diminishing, and that there are insufficient new net-benefit applications to maintain the ADSL growth rate at previous levels. This is in direct contrast with the residential/SOHO market (Figure 10), where there is a much larger range of applications not utilised in the business market (for example, entertainment products such as peer-to-peer video and music file exchange such as Napster, KaZaA, Edonkey and Morpheus, as shown in Figure 3), and where learning effects still appear to be strong, as indicated by an increasing growth rate.

However, while we are currently observing significant substitution of bandwidth-intensive information exchange for lower bandwidth and non-electronic entertainment applications (e.g. video streaming for television; on-line gaming and web browsing for non-electronic leisure pursuits) in the SOHO/ residential market, the total amount spent is constrained by the available budget for leisure activities (Galbi, 2001; MacKie-Mason, Shenker and Varian's (1996) "competition for 'eyeballs"). In the business market, uptake is constrained by the extent of extra productivity gained from timeliness of electronic data transmission, additional volume of data available, and the budget for capital (human and physical) and labour (i.e. human time) to process that information.

In order to incentivise more users to substitute ADSL for dial-up, new and more bandwidth-intensive and/or time-dependent applications need to be developed. Further, while new innovations around a GPT build incrementally upon the additional benefits of the GPT, marginal value of these applications must be greater to the user than the marginal costs of subscribing, within the budget constraints of the users, and require substitution away from other applications (Mantell, 2000). While many new incremental innovations around Internet use are emerging (e.g. the 'smart fridge' that restocks itself via automated Internet ordering), it may be that there just are not sufficient applications available as yet, or new applications requiring high capacity bandwidth being developed that will induce large numbers of users to substitute away from existing budget allocations to purchase the applications and hence the technologies required to use them. If the 'equilibrium level of growth' that we observe in both the dial-up and ADSL markets in New Zealand is attributable principally to the learning effects associated with the GPT from the first wave of users, then we have not yet reached the point at which the second wave of usage-induced innovation leads to a second surge in uptake. That is, the bandwidth-intensive and time-dependent applications necessitating ADSL purchase that will provide net benefit to the vast majority of users are either not yet available, or not yet sufficiently diffused themselves to spur high levels of uptake. This is reinforced by new dial-up subscriptions per month outnumbering new ADSL subscriptions on a ratio of about 11 to 1. Existing applications do not, as yet, meet the net benefit test for sufficient users to justify switching to ADSL, but as learning effects continue, and new applications emerge, we expect a continuing conversion as experienced users cross their individual utility thresholds.

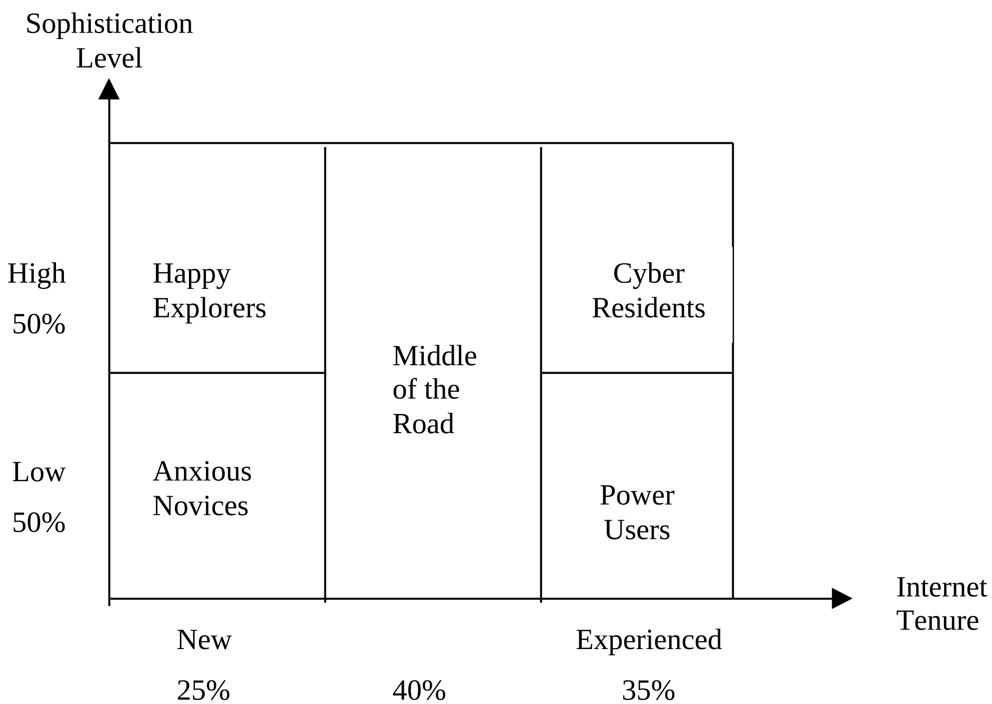
Discussion Item 3.

That there are cohort effects evident in the personal characteristics of Internet users that are influencing the point at which ADSL will substitute for modem access.

Despite the net benefit test not being met sufficiently for the vast majority of users to justify switching to ADSL, there are a number of early uptakers for whom this test has been met, and who have already made the switch.

Marketing data from our index ISP classifies Internet users into five groups, based upon their tenure and level of sophistication in Internet use.

Figure 12. Internet User Classifications



By this classification, users enter the ‘Experienced’ classification after about three years of use. ‘Cyber Residents’ are high bandwidth consumers, using predominantly entertainment applications and enjoy the Internet experience as a lifestyle. High budget ‘Cyber Residents’ are the most likely SOHO/residential customer group to be early ADSL uptakers, as evidenced in Figure 12, and the highest consumers of bandwidth in both ADSL and dial-up products. ‘Power Users’, on the other hand, tend to be business users, with strongly functional needs, such as email, file transfer (documents, software updates, applications) and web browsing. While ‘Power Users’ may consume moderately large amounts of bandwidth, ADSL purchase is again budget-constrained. Business ‘Power Users’, benefiting from learning effects in order to make the budget decision, comprise the biggest ADSL group.

Our index ISP reports that while there are some ‘Happy Explorers’ prepared to begin their Internet experience with ADSL, these are few, and much more likely to be business customers with computer experience that raises their relative levels of computer sophistication, and hence Internet sophistication. An occasional SOHO/residential user with higher willingness to pay and some computer experience will enter at this point, buffered by the fixed price policy. Metered charging for business ADSL customers generally precludes commercial ‘Anxious Novices’ from entering with ADSL, although ‘insurance’ packages, allowing a trial, and reversion to dial-up if costs are prohibitive, is encouraging some to try this service. The low fixed price for dial-up access provides an ideal entry point for SOHO/residential ‘Anxious Novices’, and the continued growth of dial-up accounts parallelling the growth of residential computers (Figure 12) reinforces this as the option of first choice for SOHO/residential entry into the Internet market.

If the length of a customer’s Internet experience leads to distinctive uptake patterns, then it is possible that there may be some ‘cohort effects’ driving the likelihood to purchase ADSL. Cohort effects occur when users undergoing a common set of experiences develop characteristics specific to the time and/or place that they gain that experience, and that these learned characteristics cause them to move through other experiences in a pattern governed by the learning that their common experience has given them (Goolsbee and Klenow, 1999).

Learning effects coupled with the anecdotal evidence provided by our index ISP, indicate that likelihood to purchase ADSL may be correlated to the date when a user first encountered the Internet. Power Users and Cyber Residents all began their Internet experience with dial-up access, when this was the only available option. As such, they form part of a cohort of fewer than 400,000 users, whose usage patterns may be collectively similar due to the timing of their uptake. Many of these users may have already experienced incremental upgrades in data access speed through substitution of faster dial-up modems as these became available (see Appendix 2) and are aware of the incremental benefits of faster access, making them both more knowledgeable of the value of their time, and ‘culturally attuned’ to making investments in faster access equipment. In this respect, these users are more likely to perceive ADSL as just another modem substitution (albeit with a different pricing structure than dial-up) than a new Internet user, whose only experience is with a 56K modem and dial-up, for whom ADSL may appear as a completely new technology form. This cohort of early users may therefore be more likely to be represented in the ADSL uptake due to the number of times that they have substituted modems.

The strong correlation between Internet use and computer use may also lead to a cohort effect related to the amount of computer experience that combines with amount of Internet experience to also predict likelihood of subscribing to ADSL services.

The first residential computer users entered the market in the late 1970s to early 1980s as enthusiastic hobbyists using computers for recreational purposes – either for the technical challenge of constructing and using early hardware and software (late 1970s), or for gaming (early 1980s). This cohort became characterised by its ‘technical’ enthusiasm, fuelled by the strong challenge of pushing the new technology to its limits. As recreational users, personal time (up to the limit of availability) was not considered as a cost; budgets were significant only for equipment. Anecdotal evidence from our ISP suggests that there is an element of this cohort represented in the residential ADSL uptake, among the highest users, pushing the technology to the limit. This cohort may be more strongly predisposed to using ADSL just because it is there, and to find out what it can do.

A second cohort is represented among the users of functional computer applications, who entered the computer market in the late 1980s, and early 1990s when personal computers began diffusing widely into offices, but had not yet become popular in residential environments. The strong functional approach to their early computer experiences may predispose this group to perceive the computer, and hence Internet uptake from the perspective of being a tool to facilitate getting a task done. Personal purchasing of Internet connections for this group may be based more strongly upon a cost-benefit trade-off than the curiosity and limit-pushing of the enthusiastic hobbyists. Reasoned defectors from within this cohort may well be a significant determinant of the slow overall uptake of ADSL, due to their functional approach to decision-making. Such users are unlikely to place a high value on the technology for its own sake. The entire Internet experience, and consequent learning rate of this cohort, may have been influenced by this computer uptake effect to the extent that their ADSL adoption rate may be different to that of the enthusiastic hobbyists.

The third cohort is comprised of 'entertainment seekers', whose introduction to computers has coincided with the growth of home computers as multimedia devices. Cultural conditioning for this cohort has come from a perception that the computer and the other infrastructure around it, including software applications and the Internet, are mere vehicles enabling the information-based entertainment product to be delivered. Whether the entertainment comes from a television, a compact disk, a play station or delivered over the Internet, and whichever applications process the information, is immaterial. It is the value of the content that drives the purchase decision. Having made the decision to purchase a particular content, the infrastructure necessary to deliver that content is purchased as a matter of course in order to facilitate consumption of the end product. This approach has been identified as a purchase model in the uptake of cable modems in environments where broadband access is bundled with cable television content (Howell, 2002). This purchasing pattern may also influence the ADSL purchasing behaviour of computer users who see the machine as merely an entertainment device, and the Internet as a means of accessing entertainment. This cohort may be more ready to purchase ADSL because it enables access to a specific information-intensive content (e.g. video on demand, MP3 files) which is valued in its own right. ADSL purchase in this case may be seen as akin to purchasing a printed newspaper because that happens to be the way access is gained to the news content. When the medium of information exchange is changed, a new infrastructure is purchased. Galbi (2001) also uses this analogy to explain the purchase of radios, television sets, video recorders and videotapes, and DVD players in order to access specific content. He places the Internet as yet another substitute infrastructure for accessing entertainment in this way.

As the third cohort make up by far the largest number of both computer users and Internet users in New Zealand[6], the purchasing effects of this third group are critical in moving ADSL diffusion beyond its initial base. That ADSL diffusion has not met early expectations may indicate that this group does not yet have sufficient information content available via the ADSL medium to justify purchase. Hence, the extent of diffusion depression attributable to a shortage of bandwidth-intensive applications, identified in discussion point 2, may be compounded by a shortage of content appealing to this cohort. Where business need or user interest intensity in the technology justifies it, the purchase will be made, as evidenced by the existing uptake patterns. But as yet the volume of content and range of applications available to the 'entertainment seekers' may be so small that their impact has not yet been felt. This poses significant challenges for ADSL in New Zealand, as it lacks the bundled content that appears to be driving broadband uptake via cable services in other jurisdictions.

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[6] Howell and Marriott (2001) show the highest proportion of Internet users by age group are in the 10 to 19 age group (81% of this age group access the Internet, and they form 14.9% of the population), followed by 20-29 year olds (69% access, forming 13.3% of the population). The first computer experience of this group will almost

Unless innovation can occur to create completely new applications, or ADSL can be bundled with content, then it may be difficult to incentivise the third cohort to buy.

For Further Research

Out findings in hypotheses 1 and 2, namely that learning effects exist in the use of Internet applications, and that vintage capital effects exist in the business Internet access market, can be tested against the Internet access data from other national markets. Our isolation of the results should allow other researchers to test their data irrespective of the split between ADSL and cable modem access in their markets.

In addition, we have included three discussion items where we perceive user surveys can provide further insights into the behaviours of the Internet access markets.

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