Pricing Internet: The New Zealand Experience

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Abstract

New Zealand's research and educational network connects to Internet via an expensive trans-Pacific satellite link to FIX-West. Initially subsidized by NASA, the link is now self-funding. The link is managed by a consortium of universities and research institutes, which has instituted a volume based charging regime to recover total operating costs from the participating institutions. Individual sites pursue independent policies for recovering these costs from users, so that Internet users in New Zealand face a variety of pricing regimes. New Zealand therefore provides a useful laboratory for examining the impact of pricing on Internet usage.

The paper documents the evolution of New Zealand's Internet pricing scheme and the cost recovery policies utilized by the main sites. The characteristics of the traffic to and from these sites is analyzed. A simple model of demand for Internet services is developed, which establishes a link between the rate of growth of international traffic and pricing regime. The model is estimated using monthly data on traffic across the international link, in an attempt to assess the impact of pricing regime on demand for Internet services. Comparisons are drawn with the experience of Australia and Chile. Our results provide some insight into the likely impact of commercialization on the future of Internet.

The Internet is, by far, the greatest and most significant achievement in the history of mankind.

Harley Hahn 1994

My guess is that changes involving Internet will lead to the biggest communications shambles of all time, and a big breakdown will soon cause the network to collapse under the weight of its users... The problem and the delight of Internet is that no one is in charge.

Gareth Powell 1994

1 Introduction

The two quotations above encapsulate the dilemma posed by Internet. With considerable hyperbole, Hahn [2] proclaims the enormous potential of Internet to enable structured global communication between millions of users. Powell [6] alerts us to the possibility that Internet's very success will be its undoing. As more and more users flock to avail themselves of the free benefits of Internet, the voluntary network will be unable to provide the capacity to meet the demand, and the system will collapse under the weight of users.

The uncomfortable reality that a free good can invite essentially unlimited demand has slowly dawned on system administrators around the world. In December 1992, the National Science Foundation announced that it would cease funding the Internet backbone in the near future, setting in train a process of commercialization of the Internet in the US. Similarly the Australian government has gradually withdrawn from directly funding the network. A working party of the Australian Science and Technology Council [1] advocated widening access to Internet and abandoning policies restricting commercial use. They concluded that the Australian network should be self-funding, although they recommended against universities and research institutions recovering costs from their users.

From the beginning, the New Zealand government declined to specifically fund research computer networks. Consequently, the development of Internet in New Zealand has been self-funding, and the various institutions have cooperated to develop a mechanism for cost recovery to fund the network. Individual sites pursue independent policies for recovering these costs from users, so that Internet users in New Zealand face a variety of pricing regimes. Consequently, New Zealand provides a useful laboratory for examining the impact of pricing on Internet usage.

In the next two sections, we outline some of the history and structure of Internet in New Zealand and detail the different pricing regimes which prevail at various institutions. In Section 4, we develop a simple model of Internet demand which relates the growth rate of demand to the traffic price. In the following section, we estimate this model on traffic data from New Zealand, in an attempt to assess the impact on demand of the various charging regimes. We then compare the New Zealand experience with that in Australia and Chile. We discuss our conclusions in Section 7.

2 New Zealand's national research and education network (TuiaNet)

The current New Zealand national research and education network evolved from three separate networks established in the 1970s and 1980s [3, 5]. It is known as TuiaNet and comprises two interconnected Frame Relay networks. One of these component nets connects the seven New Zealand universities while the other connects various government owned research institutes. TuiaNet joins Internet via a single link between FIX-West and Waikato University in New Zealand. This link was established under the PACCOM programme and was initially partly funded by NASA. It has been fully funded by New Zealand Internet users since January 1994.

The two components of Internet in New Zealand are funded by different mechanisms. Sites connected to the Frame Relay network are assigned to one of three "management groups," the descendants of the three original networks. Each management group pays the Frame Relay charges incurred by the sites in that group. The costs of links between sites in different management groups are shared by the appropriate groups in proportion to the Committed Information Rates of the various sites involved. Management groups are free to recover their costs from their member sites in any manner they choose. The management group comprising the New Zealand universities is called Kawaihiko and recovers its Frame Relay costs by a system of fixed charges. Six universities each pay two thirteenths of the total cost while the remaining, and smallest, university, Lincoln University, pays just one thirteenth.

When it was established, the US end half circuit of the international link was funded by NASA. New Zealand sites funded the NZ end half circuit. The Kawaihiko funding model was used at first, with each university, apart from Lincoln, meeting two thirteenths of the cost of this circuit and Lincoln paying the remaining one thirteenth. Each university was permitted to generate 300 megabytes of international traffic each month. This regime was replaced by a system of volume charges in May 1991. Apart from changes in certain prices, this system remains in place today. Its key feature is that each New Zealand site is charged for international traffic entering and leaving that site. Certain types of traffic, primarily news feeds and domain name serving, are regarded as overhead costs and are not charged to individual sites. Sites are charged for each 100 megabytes of traffic, with an 80% discount offered for traffic at off peak times (8 pm till 9 am). As the various traffic types have become prioritized they have been discounted at various rates. Low priority traffic (FTP and MAIL) attracts a 30% discount, high priority traffic (TELNET and FTP commands) no discount and other traffic a discount of 15%.

3 The pricing regimes

Internet traffic is generated, not by institutions, but by individuals at those institutions. Any analysis of the impact of pricing on Internet usage must therefore consider the prices faced by individuals. We distinguish between two types of individuals at each site: the local system administrator and local end users. The system administrator faces a price for each 100 megabyte chunk of international traffic set by TuiaNet. He or she then chooses the level of access provided (availability of GOPHER and MOSAIC, the number of users granted Internet access, and so on) and the price, if any, that end users must pay for Internet traffic. Each end user faces the price set by the system administrator and chooses a level of Internet usage.

The diversity of cost recovery regimes in place at New Zealand sites makes New Zealand a useful laboratory for studying the impact of pricing on Internet usage. We shall restrict our attention to the group of seven New Zealand universities.

These sites split into three main categories. The Computing Centers at the Universities of Lincoln, Otago and Victoria absorb all costs incurred by the majority of users on site. At the Universities of Auckland, Canterbury and Waikato, Computing Centers impose volume charges on departments. These departments are then free to recover their Internet costs in any manner they choose. Each month Massey University charges departments a fee dependent on the number of registered users rather than the quantity of traffic they generate.

In more detail, the pricing regimes at the different institutions are:

- **University of Auckland:** Sites connecting to the Internet through the University of Auckland pay an annual connection fee of $500 covering routing and some administration costs. External clients face the same traffic charges as university departments. This traffic charge is set in order to cover both the volume charges Auckland pays for international traffic and its fixed costs such as its share of Frame Relay charges.

- **University of Canterbury:** The University of Canterbury charges $5 per megabyte of international FTP and MAIL traffic to all users on site. Outbound international mail attracts an additional charge of $0.10 per message, but all national traffic is free to users. Costs incurred by staff and postgraduate students are charged back to individual departments which can, if they so decide, recover those costs from individuals. Other users are charged directly. External sites feeding their international traffic through Canterbury, such as Lincoln University, pay a proportion of Canterbury's international traffic costs equal to their share of international traffic.

- **Lincoln University:** Lincoln is connected to the Internet through the University of Canterbury. The cost of this access is dependent on the volume of international traffic fed through Canterbury (see above). Lincoln does not attempt to recover the cost of international traffic generated by its feeder sites. Furthermore, costs are not passed on to users on site. In order to restrict Internet traffic undergraduate students have access only to news and electronic mail facilities.

- **Massey University:** Sites which feed their international traffic through Massey University pay a facilities maintenance fee in addition to volume charges. There are no volume charges facing users on site, but costs are recovered from departments through a fixed monthly fee of $5 per user. No attempt is made to influence the volume of traffic generated by users, either internal or external to the university.

- **Otago University:** Sites feeding their international traffic through the University of Otago must pay an annual fee. However, costs incurred by traffic generated on site are absorbed by the university: end users are not charged. No steps are taken to influence the volume of international traffic generated on site.

- **Victoria University of Wellington:** Fixed and traffic charges for sites feeding their traffic through Victoria University are calculated independently, with sites paying an initial connection fee of between $1000 and $6000 and an annual access fee of $1300 (all prices are as at May 1993). Sites pay $0.50 for each megabyte of incoming traffic which traverse the Frame Relay network. International traffic attracts an additional charge equal to the price Victoria pays for use of the international link with any discounts for low priority or off-peak traffic being passed on to sites.

  Victoria absorbs all Internet costs incurred by users on site, except for electronic mail generated by individuals with "external" client status. A fee of $100 per annum entitles these external clients to email traffic of up to two megabytes per month. Excess traffic is charged by volume. Some effort is made to influence the volume of traffic generated on site. Local users generating large volumes of traffic are "encouraged by friendly advice and follow up if necessary" to take advantage of off-peak times. Students currently have restricted access to Internet.

- **University of Waikato:** Local sites feeding Internet traffic through the University of Waikato are charged on the basis of traffic volume in the same manner as departments on campus. Departments are free to recover their costs from individuals in any manner they choose. Students may gain access to Internet on a user pays basis. International FTP traffic is charged at the rate of $3 per megabyte while TELNET and GOPHER are charged at $5 per megabyte. National TELNET and GOPHER traffic attract a fee of $1 per megabyte. International email attracts charges of $0.10 and $0.20 for inbound and outbound traffic respectively. Messages in excess of 10 000 bytes are charged at the rate of $4 per excess megabyte. Non-mail traffic receives a discount of 80% between 8 pm and 9 am.

4 A simple static model

Information on the number of Internet users at each New Zealand university is not available, making it difficult to analyze traffic magnitudes across the seven sites. Measures of institution size, such as operating budgets and student numbers, do not make good proxies. Some sites have substantial numbers of private sector Internet account holders as they are the principal Internet access provider in their region. However, an individual in Wellington can access Internet through Victoria University, the Wellington City Council or the commercial operation ACTRIX. These variations will not be reflected in statistics such as operating budgets or student numbers. Therefore, we concentrate on measures of activity, such as growth rates, which are comparable across sites of different sizes.

Consider the following simple model of site behaviour. A local area network has n users and a budget of M dollars allocated for Internet activity. The site faces a price of p dollars per megabyte of Internet traffic and purchases a connection to Internet with bandwidth B units. Prices are normalized such that this link costs B dollars. Each end user is charged q dollars per megabyte of traffic by the local system administrator. Suppose each individual has initial wealth of m_0 dollars and receives an "Internet grant" of m dollars from the system administrator. Users have identical utility functions $u = u(x, w)$, where x is the number of megabytes of Internet traffic and w is wealth, in dollars. The analysis is further simplified by assuming that end users face a budget constraint of the form

$$m_0 + m = (q + c + r)x + w,$$

involving a congestion cost of c dollars per megabyte of traffic and nonpecuniary costs of r dollars per megabyte representing, for example, time spent searching databases. The individual's optimization problem yields first order conditions

$$\frac{u_1(x, m_0 + m - (q + c + r)x)}{u_2(x, m_0 + m - (q + c + r)x)} = q + c + r,$$

from which we can derive the individual demand function

$$x = x(q + c + r, m_0 + m).$$

Total traffic is therefore

$$E = n \cdot x(q + c + r, m_0 + m).$$

Suppose the congestion cost is given by $c = kE/B$ for some constant k and further suppose that the number of users is sufficiently large that an individual does not regard an increase in his or her own traffic as causing any increased congestion. Therefore, in equilibrium total traffic E satisfies

$$E = n \cdot x(q + kE/B + r, m_0 + m).$$

Consideration of the system administrator's budget constraint further determines equilibrium behaviour. Using the notation introduced earlier, site behaviour is constrained by

$$M + qE = B + pE + nm.$$

Solving the previous two equations simultaneously yields purchased bandwidth

$$B = B(q, m; p, r, k, m_0, n)$$

and equilibrium total traffic

$$E = E(q, m; p, r, k, m_0, n)$$

as functions of the given arguments. Notice that these arguments split naturally into two types: p, r, k, m_0 and n are essentially beyond the control of the local administrator while q and m are the administrator's choice variables. Having set q and m, system administrators must then watch end users generate their optimal volume of traffic.

We now consider the short run comparative statics; that is, assuming B is fixed. Since

$$\frac{\partial E}{\partial q} = \frac{\partial E}{\partial r} = \frac{n x_1 B}{B - nkx_1},$$

it follows that the elasticity of total traffic volume E with respect of search cost r is

$$\sigma = \frac{r}{E}\frac{\partial E}{\partial r} = \frac{rx_1 B}{x(B - nkx_1)}.$$

This depends upon q provided that

$$\frac{\partial \sigma}{\partial q} = \frac{B^2 r}{x^2(B - nkx_1)^2}((1 + nkx_1)xx_{11} - x_1^2) \neq 0.$$

The price faced by end users q affects the responsiveness of traffic volume to changes in search cost provided that $(1 + nkx_1)xx_{11} \neq x_1^2$.

The simple intuition behind the model is that the growth of demand is driven partly by falling seach costs. Different charging regimes affect the relative impact of falling search costs on total costs, and hence may affect the growth rate of demand. For example, suppose that the search costs r falls from \$2 to \$1.80. A user of Internet at Victoria observes a fall in total cost per megabyte from \$2 to \$1.80: a 10% reduction (assuming zero congestion costs). Meanwhile, a user at Canterbury, who faces $q = \$5$ sees a fall in total price from \$7 to \$6.80: a fall of less than 3%. Hence, we would expect, other things being equal, that the growth rate of demand at Canterbury would be lower than that at Victoria.

5 Empirical results

Waikato University manages the international link on behalf of TuiaNet. Records of international traffic to and from each New Zealand site are made available each month as part of the charging process. This data, which spans the period from January 1991 to November 1994, is analyzed in the present section. Traffic figures are disaggregated by type of traffic (FTP, TELNET, MAIL and "OTHER"), direction of flow and by the end of the link (local or foreign) which initiated the connection.

We begin by analyzing the growth rates of total traffic for the New Zealand universities. Traffic is assumed to grow about a deterministic, exponential trend.

We allow the disturbances to be contemporaneously correlated and also allow for first order autocorrelation within sites. That is, we estimate a seemingly unrelated regression, fitting the model

$$x_t^k = \alpha^k + \beta^k t + \epsilon_t^k, \quad \epsilon_t^k = \rho^k \epsilon_{t-1}^k + \nu_t^k, \quad k = 1, \ldots, 7,$$

where x_t^k equals the logarithm of total traffic to and from site k in period t. The sample of 42 observations begins in May 1991 when volume charging was introduced and extends through to November 1994.

Parameter estimates (Table 1) indicate that the monthly growth rate, $e^{\beta} - 1$, ranges from 5.6% to 12.7%. These are substantial differences in monthly growth rates, which imply enormous cumulative changes over a period of three and a half years. The lower rate is achieved at the University of Canterbury, which recovers all costs from end-users. On the other hand, the University of Otago, which does not charge end-users, has a growth rate which is more than twice as large. These observations lend support to the view that charging regime affects demand. Unfortunately, the other sites tend to confound the issue. The growth rates of the other sites cluster around 7%, part way between the two extremes. These observations include some sites with end-user charging and some without.

To focus attention on significant differences, we use the following algorithm to reduce where reasonable the number of independent growth rates. At each iteration, calculate the Wald test statistic W^{ij} for each null hypothesis of the form $H_0 : \beta^i = \beta^j$. Select the pair (i, j) for which W^{ij} is smallest. Provided $W^{ij} < 5.024$, reduce the number of independent growth rates by one by setting $\beta^i = \beta^j$. Estimate the restricted model and repeat the procedure. Note that each W^{ij} is asymptotically $\chi^2[1]$ and that $\Pr(\chi^2[1] > 5.024) = 2.5\%$. The algorithm thus proceeds whenever the proposed reduction satisfies the requirements of a Wald test with a 2.5% significance level. The outcomes of this procedure are shown in the appendix. The resulting reduced model yields the growth rates (with standard errors in brackets) shown in Table 2.

In the remainder of this section, we disaggregate the data in different ways in an attempt to discover a stronger link between demand and pricing regime. In each case, we present the results after restricting the number of independent growth rates. Tables 3 and 4 detail the estimated growth rates for inbound and outbound traffic respectively.

We also disaggregate by type of traffic. In Table 5, we present estimated growth rates for the traditional types of traffic — FTP, TELNET and MAIL. In this case, the estimates fall into three groups. Low growth rates are found at Canterbury and Massey. Although both institutions recover costs from end-users, only at Canterbury are charges related to volume. Once again, Otago shows dramatically higher growth (11%) than other the remaining sites, which cluster around 7%.

The remaining traffic category, OTHER, includes newer technologies like GOPHER and MOSAIC, which make Internet easier to use. For this class, the sites divide into two camps (Table 6). At three sites, OTHER traffic has been growing at 13% per month. However, at the remaining four sites, the monthly growth rate is twice as high at 25.9%. Given the superficial similarity of the institutions, these are significant differences. Unfortunately, it is impossible to provide a simple explanation based on charging. Both the slow growing and the fast growing group include institutions with volume charging.

Using local knowledge, it is possible for us to give some insight into the relatively slow growth of the demand for OTHER at the University of Canterbury. Officially, some of these services (GOPHER and MOSAIC) were "not available" at Canterbury until 1994, because the computer center's software did not enable them to charge end users. However, GOPHER was in fact enabled on the central computer for a specific seminar. The responsible consultant forgot to disable it when he left the university. However, its availability was only known to a select few users who discovered it by accident. While not acknowledging its availability publically, the computer centre were prepared to tolerate some use, provided the volume was low.

6 Some comparisons

In this section, we compare New Zealand's experience with that in Australia and Chile.

Australia

The Australian Academic and Research Network (AARNet) was established in 1980 [1]. It provides a backbone across Australia connecting the local area networks of universities, research agencies and other organizations. AARNet joins Internet via a link from Melbourne University and FIX-West.

NASA originally funded the US end half circuit. In 1990, 35% of AARNet's budget was directly funded by the Australian government, by 1994 such funding had fallen to 9% of the total budget and in 1995 AARNet is proposing to operate without any direct government funding at all. To date, the balance of AARNet's costs have been funded by charging connected organizations. There are two classes of AARNet clients. "Affiliate" clients pay an annual access fee. Mail-only clients pay a flat access fee and network-connected clients pay an amount related to the bandwidth of their connection into the network backbone. The second group of clients comprise the universities and CSIRO. They fund the balance of AARNet's operating costs once direct government grants and the access fees of affiliate members are accounted for. Individual universities contribute in proportion to their operating grants. The Australian experience with this funding regime has been one of considerable cross-subsidization between the two classes of clients. In 1993, affiliate members generated between five and ten per cent of AARNet's total traffic but contributed a quarter of its income [4].

International traffic data is available from Merit Network Inc., the manager of the NSFNET backbone. The data source used in this section comprises a monthly record of the number of bytes traversing the NSFNET backbone from

September 1991 to February 1994. Traffic figures are broken down by country and by direction of traffic. All traffic traversed the old T1 backbone in the first part of the sample period. From November 1991 to May 1992 Internet traffic was increasingly carried over the new T3 backbone. Data was not collected between June and November 1992 but, from December onwards, all traffic used the T3 backbone. Traffic figures from the transition period were excluded when performing the estimations below. The small sample size precludes any modelling of seasonal influences. In addition, the missing observations in the middle of the sample period render any stationarity tests of doubtful value. Without further comment, we assume traffic flows are stationary around an exponential trend.

We estimate the model

$$x_t^k = \alpha^k + \beta^k t + \epsilon_t^k, \quad y_t^k = \gamma^k + \delta^k t + \nu_t^k, \quad k = 1, 2,$$

as a seemingly unrelated regression, where

$$\begin{aligned}
x_t^1 &= \text{log(total traffic leaving} \\
&\qquad \text{the NSFNET backbone for Australia in period } t\text{)}, \\
y_t^1 &= \text{log(total traffic leaving} \\
&\qquad \text{Australia for the NSFNET backbone in period } t\text{)}, \\
x_t^2 &= \text{log(total traffic leaving} \\
&\qquad \text{the NSFNET backbone for New Zealand in period } t\text{)}, \\
y_t^2 &= \text{log(total traffic leaving} \\
&\qquad \text{New Zealand for the NSFNET backbone in period } t\text{)}.
\end{aligned}$$

There is no significant difference between the growth rates of the four traffic types. Testing $\beta^1 = \beta^2 = \gamma^1 = \gamma^2$ yields a likelihood ratio test statistic of $LR = 2.73$, so that the restricted model

$$x_t^k = \alpha^k + \beta t + \epsilon_t^k, \quad y_t^k = \gamma^k + \beta t + \nu_t^k, \quad k = 1, 2,$$

can confidently be estimated. The results give some useful data on relative traffic flows. For instance, the (constant) ratio of traffic entering New Zealand to that entering Australia is $\exp(\alpha^2 - \alpha^1) : 1$. Table 7 displays the population-adjusted relative volumes of different traffic flows, normalized so that traffic into Australia equals one unit.

Merit provides another interesting measure of Internet usage: the number of networks, by country, configured for announcement on the NSFNET infrastructure. We fit the model

$$x_t^k = \alpha^k + \beta^k t + \epsilon_t^k, \quad k = 1, 2,$$

where

$$\begin{aligned} x_t^1 &= \log(\text{total Australian networks configured in period } t), \\ x_t^2 &= \log(\text{total New Zealand networks configured in period } t). \end{aligned}$$

The difference in growth rates is highly significant (the test of $\beta^1 = \beta^2$ has likelihood ratio statistic of $LR = 59.6$). The number of Australian networks is growing by 3.8% per month, while in New Zealand the nmber of networks is growing by 6.5% per month.

In summary, we have found that Australian and New Zealand international Internet traffic are growing at the same rate, but that New Zealand traffic per capita is only 31% of Australia'a. Furthermore, Australia transmits proportionately more traffic than does New Zealand. However, the number of networks configured in New Zealand is growing significantly faster than the number of networks in Australia.

Chile

A TCP/IP network linking all Chilean universities to Internet was proposed in 1991. Operating costs of REUNA, as the network was to be known, would have to be met by member institutions and their clients. When the universities failed to agree on a cost sharing rule, three universities decided to create their own TCP/IP network, called Unired, with Internet connectivity. These two networks were established in January 1992. Within sixteen months ten universities had joined REUNA and six further sites had connected to Unired. REUNA controls the networking policies of its members and prevents subscribers from also joining Unired. As a result, the two Chilean national networks are not directly interconnected and (domestic) traffic between subscribers to the rival networks must traverse the Internet backbone.

The five founding members of REUNA originally paid for their local links and one of them, the Chilean research commission, paid for the international link. When more sites connected it was proposed that costs of the national network would be shared in proportion to institutions' operating budgets and that a charge per megabyte on inbound and outbound traffic would fund the international link. Following opposition from users, the volume charges now take the form of coarse charging brackets. Off peak traffic attracts a discount. This mechanism is similar to that successfully implemented in New Zealand.

Unired's original charging regime was identical to that proposed by REUNA. Following the opposition to REUNA's proposal, Unired dropped the international volume charge for academic and non-profit customers. Those customers pay a fixed fee for access to Unired, while commercial subscribers must still pay a volume charge on international traffic. This regime has much in common with that instituted in Australia.

While the catalyst for the split from REUNA may have been disagreement over cost sharing rules, it cannot have been disagreement over the concept of volume charging itself: the initial charging policies of the rival networks were both based on volume charging. The split seems to have had more to do with the competitive relationship between Chile's largest universities. The University of Chile dominated early networking in Chile and this influence continued in the development of REUNA. Unired, however, is dominated by the Catholic University. University politics, and not pricing philosophies, seem to have caused the split between REUNA and Unired.

7 Conclusion

We are not sure whether to be pleased or dismayed with the results presented here. One positive lesson for the doomsayers is that New Zealand's experience establishes the viability of a self-funding national education and research network. Cost recovery has not inhibited the growth of Internet in New Zealand, especially when compared to our close neighbour Australia. Moreover, volume based charging to end users has not extinguished the demand for Internet services, although it may have moderated demand.

When compared with Chile, New Zealand's experience is heartening. It shows that a cooperative voluntary organization (like Internet) can organize a combined resource efficiently and resolve conflicting interests constructively. Being a non-commercial club of computer users has not prevented TuiaNet from implementing an efficient and stable mechanism of cost recovery, which respects individual differences without compromising the integrity of the overall system.

Our dismay concerns the ambiguity of the impact of user charging. Our analysis of New Zealand traffic provides some evidence in support of the hypothesis that pricing affects demand, and also some evidence which does not support that view. Similarly, we find no significant difference in the growth rates between Australia and New Zealand, although there is a significant difference in the volume of traffic in the two countries. We hasten to add that this cannot be explained by technological backwardness in New Zealand, which has long been noted for the rapid diffusion of information technology.

Within New Zealand, there are highly significant differences in the growth rates between different sites. In particular, one of the sites with the most developed charging regimes (Canterbury) consistently exhibits the lowest growth rates of demand. As members of that institution, we would like to disclaim the obvious explanation that the University of Canterbury has a lower research activity. Canterbury attracts the highest proportion of research grants from the national contestable pool and likes to think of itself as the most research oriented of the seven universities.

Whatever their causes, large differences in monthly growth have serious implications for any cost allocation method which is independent of volume. Different monthly growth rates imply huge cumulative differences in traffic volumes over a sustained period. For example, total traffic volume at Canterbury in November 1994 was 8.8 times the volume three years earlier. In comparison, traffic volume at Otago grew 57 fold over the same period. In New Zealand, only the costs of the international link are allocated on the basis of traffic generated. The sites pay fixed shares of the cost of the domestic component. This allocation rule is likely to become increasingly unacceptable to institutions whose share of total volumes is rapidly declining.

Although three sites in New Zealand charge their departments on the basis of traffic generated, we are not aware of any instance in which the charges are passed on to individual end users. As Canterbury end users, we believe that volume charges do affect our behaviour. We are aware of the monthly charges incurred, and the relative prices of different mechanisms. Feedback to Computer Centre suggests that other users are also aware of, and respond to, the costs of their Internet activities. There is also casual evidence of substitution in response to price differences. Canterbury has an atypically high usage of TELNET, which is currently not subject to a volume charge. This is simply because the software does not permit monitoring of individual usage. In the course of our research, we encountered many similar anecdotes suggesting that users are responsive to the available opportunities. We suspect that such idiosyncratic factors may be quite important in influencing demand in this rapidly changing sphere. However, they make it very difficult to isolate the economic determinants.

New Zealand's experience should provide some encouragement as the inevitable international commercialization of Internet proceeds. It leaves plenty of scope for further work to ascertain the relative importance of price in determining demand.

Appendix

In this appendix, we record the steps of the reduction algorithm applied to the estimated growth rates of traffic over TuiaNet. Table 8 describes the application of this procedure to total traffic. The steps of the reduction procedure when it is applied to inbound and outbound traffic are shown in Tables 9 and 10, respectively. Table 11 shows the results when it is applied to the total of FTP, TELNET and MAIL traffic. Applying it to OTHER traffic yields the outcome shown in Table 12.

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Tables

Site	β	Growth rate (% per month)
Auckland	0.07836 (0.0064)	8.2
Canterbury	0.05438 (0.0042)	5.6
Lincoln	0.07534 (0.0030)	7.8
Massey	0.06827 (0.0057)	7.1
Otago	0.11968 (0.0076)	12.7
Victoria	0.07404 (0.0035)	7.7
Waikato	0.07958 (0.0089)	8.3

Table 1: Growth rates of total traffic

Site	β	Growth rate (% per month)
Canterbury	0.05322 (0.00427)	5.5
Auckland, Lincoln, Massey, Victoria, Waikato	0.07452 (0.00224)	7.7
Otago	0.1176 (0.0066)	12.5

Table 2: Growth rates of total traffic

Site	β	Growth rate (% per month)
Canterbury	0.05227 (0.00366)	5.4
Auckland, Lincoln, Massey, Victoria	0.07219 (0.00211)	7.5
Otago, Waikato	0.1196 (0.0118)	12.7

Table 3: Growth rate of inbound traffic

Site	β	Growth rate (% per month)
Canterbury	0.05560 (0.00417)	5.7
Auckland, Lincoln, Massey, Victoria Waikato	0.07634 (0.00260)	7.9
Otago	0.1174 (0.0070)	12.5

Table 4: Growth rate of outbound traffic

Site	β	Growth rate (% per month)
Canterbury Massey	0.05170 (0.00510)	5.3
Auckland, Lincoln, Victoria Waikato	0.06814 (0.00273)	7.1
Otago	0.1047 (0.0067)	11.0

Table 5: Growth rates of FTP, TELNET and MAIL

Site	β	Growth rate (% per month)
Canterbury Victoria Waikato	0.1219 (0.0042)	13.0
Auckland, Lincoln, Massey Otago	0.2306 (0.0102)	25.9

Table 6: Growth rates of OTHER traffic

Country	Population (1991)	Inbound	Outbound	Growth rate (per month)
Australia	16 850 540	1.00	0.69	8.1%
New Zealand	3 449 700	0.41	0.12	8.1%

Table 7: Relative volumes of different traffic flows for Australia and New Zealand

Iteration	(i, j)	W^{ij}	Reduction
1	(1,7)	0.0179	$\beta^1 = \beta^7$
2	(3,6)	0.0772	$\beta^3 = \beta^6$
3	(1,3)	0.450	$\beta^1 = \beta^3$
4	(1,4)	1.53	$\beta^1 = \beta^4$
5	(1,2)	21.8	None

Table 8: Reduction procedure: Total traffic

Iteration	(i, j)	W^{ij}	Reduction
1	(3,7)	0.00162	$\beta^3 = \beta^7$
2	(1,6)	0.00330	$\beta^1 = \beta^6$
3	(1,3)	0.318	$\beta^1 = \beta^3$
4	(1,4)	4.27	$\beta^1 = \beta^4$
5	(1,2)	23.0	None

Table 9: Reduction procedure: Inbound traffic

Iteration	(i, j)	W^{ij}	Reduction
1	(5,7)	0.150	$\beta^5 = \beta^7$
2	(4,6)	0.189	$\beta^4 = \beta^6$
3	(1,3)	0.187	$\beta^1 = \beta^3$
4	(1,4)	2.34	$\beta^1 = \beta^4$
5	(1,5)	15.8	None

Table 10: Reduction procedure: Outbound traffic

Iteration	(i,j)	W^{ij}	Reduction
1	(6,7)	0.171	$\beta^6 = \beta^7$
2	(1,6)	0.536	$\beta^1 = \beta^6$
3	(1,3)	2.30	$\beta^1 = \beta^3$
4	(2,4)	3.13	$\beta^2 = \beta^4$
5	(1,2)	8.52	None

Table 11: Reduction procedure: FTP, TELNET and MAIL traffic

Iteration	(i,j)	W^{ij}	Reduction
1	(4,5)	0.00770	$\beta^4 = \beta^5$
2	(2,6)	0.0358	$\beta^2 = \beta^6$
3	(3,4)	0.0667	$\beta^3 = \beta^4$
4	(1,3)	0.929	$\beta^1 = \beta^3$
5	(2,7)	1.68	$\beta^2 = \beta^7$
6	(1,2)	75.7	None

Table 12: Reduction procedure: OTHER traffic