Prometheus, Vol. 18, No. 2, 2000

Internet Adoption and Use[1]

GARY MADDEN, SCOTT J. SAVAGE & GRANT COBLE-NEAL

ABSTRACT *Network economics suggests that Internet growth may be explained by an externality. This study empirically tests for the presence of such an externality, and analyses a cross-section of Internet subscribers to identify adopter characteristics, and applications fuelling early subscription. The results confirm that the establishment of a secure base of commercial users generates endogenous growth. Further, the analysis of Internet subscribers suggests that access pricing and the availability of valued applications are important factors for inducing subscription.*

Keywords: Internet user characteristics, pricing, universal service

Introduction

The Internet was created in the 1960s by the United States (US) Defense Department to allow networked collaboration with universities and private contractors on research projects.[2] The proliferation of other networking groups such as the US Department of Energy, the National Aeronautics and Space Administration and the US National Science Foundation (NSF), prompted the NSF to integrate these isolated networks through an overarching backbone network (NSFNET). As the number of publicly funded agencies using NSFNET increased, the network's common interconnection standard, transmission control protocol and Internet protocol, eventually became the standard for Internet communication among US government departments.

Figure 1 shows that after an initial period of rapid growth between 1969 and 1971, Internet take-up slowed to a steady growth path underpinned by a secure subscriber base of large public and private organisations. E-mail, file transfer and gopher activities dominated Internet use. Access to information required the user to have knowledge of the location of databases, so limiting the network's value. However, by 1991 the development of hypertext transport protocol (HTTP) generated a new wave of non-US and private Internet subscribers. HTTP provides interactive connections (or links) between sets of related information at different sites, allowing subscribers without detailed knowledge of database locations and content to 'surf the world wide web (WWW)'.[3]

These improvements, along with enhanced computer and networking technology, increased personal computer (PC) penetration, and private provision of network infrastructure is associated with an increase in computers connected to the Internet (hosts) from 1.8 million in 1993 to 56 million in 1999.[4] However, host growth is also sustained by a network externality, whereby the value of the network to existing subscribers is enhanced as other users subscribe. This effect, which may explain the sharp rise in host numbers, has facilitated a shift away from text file applications such as e-mail to bandwidth intensive applications involving graphic user interfaces, and high-resolution pictures. This study empirically tests for the presence of a network externality by examining host adoption during the diffusion of the Internet from 1993 to 1997. Another

ISSN 0810-9028 print; 1470-1030 online/00/020161-13

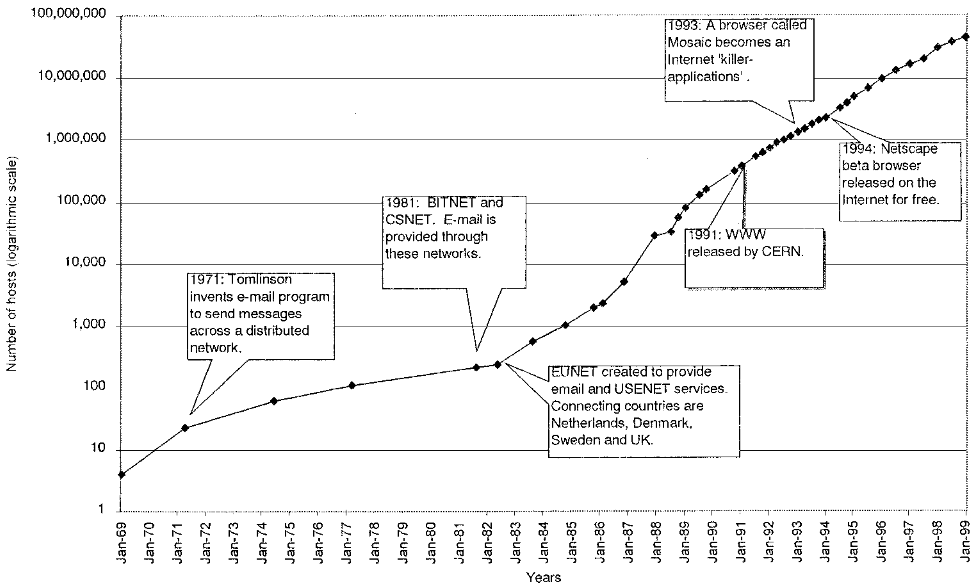

Figure 1. Internet host growth 1969–1999.
Source: Network Wizards (1999); Leiner, B.M., Cerf, V.G., Clark, D.D., Kahn, R.E., Kleinrock, L., Lynch, D.C., Postel, J., Roberts, L.G. and Wolff, S., (1998). A Brief History of the Internet, http://www.isoc.org/Internet/history.

empirical model of Internet use studies Australian Internet subscriptions to provide insight into which factors underlie subscription. Australia is an interesting case study as it traditionally adopts new technology early.[5] Toward this end, data obtained from a web-based survey are used to construct a range of economic, socio-demographic and Internet application variables to predict Internet use. Conclusions and policy implications are presented in a final section.

Network Externality and Early Internet Adoption

An externality is a cost or benefit resulting from any action (related to either consumption or production) that affects someone who did not fully consent to it.[6] The joint consumption of communications services by at least two agents generates both a network and call externality.[7] A network externality arises as the utility (value) that an existing subscriber derives from a communications service increases as others join the network.[8] Consider the typical two-way telephone star network in Figure 2. A phone call from A to B is composed of AS (access to the switch of subscriber A), BS (access to the switch of subscriber B) and switching services as S.[9] In this n customer network, existing subscribers face $[n \times (n-1)]$ potential connections. An additional ($n+1$th) subscriber provides direct positive externalities to all other subscribers to the network by adding $(2 \times n)$ potential connections thorough the provision of a complimentary link to the star (say ES to the existing link).[10]

As shown in Figure 2, network externalities allow enhanced interaction at no extra charge to existing subscribers, rendering positive external benefits to society. The network externality concept has fundamental importance for many socio-economic and public policy matters in communications. For instance, consider the promotion of universal telephone or Internet services. Economists argue that the policy is justified as

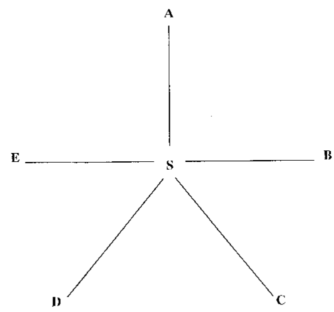

Figure 2. A simple telephone star network.
Source: N. Economides, 'The Economics of Networks', *International Journal of Industrial Organization,* 14(6), October 1996, pp. 673–699.

long as new subscribers pay the incremental cost of expanding the network to accommodate them (even when they do not pay their share of average costs). However, low income, or remotely located, subscribers may be unwilling to pay the entire incremental costs of service. Here, a price below cost could be justified because the monetary losses are outweighed by the total utility (welfare) that all subscribers derive from the expansion of the service. Since subscribers would like to be connected to as large a network as possible, theoretically, this argument could justify the extension of universal services across national borders.[11]

Artle and Averous[12] show that the network externality can sustain continual growth even when price, population and income are stationary. New subscribers join the network from the existing stable population which increases the incremental utility of the service and induces marginal non-subscribers to join. This process leads to self-propelling, or endogenous growth, and suggests that current period (*t*) subscription levels are positively influenced subscription levels in the previous period (*t*–1). Such endogenous growth is particularly important during the early adoption stage of a new network such as the Internet. For Internet services such as e-mail there is zero marginal value to any individual unless there is some minimum number of subscribers already using the service. Therefore, the viability of new networked services depends on 'altruistic' early adopters prepared to incur very large costs and low value for the benefit of subsequent subscribers. However, the viability of a new network relies on the spontaneous existence of an initial critical mass of subscribers. Intuitively, early adopters must derive a high level of value from the good, even though it has limited use. Prei*β*l[13] argues that a high value may stem from established relationships between early users, as in the case of ARPANET users. In that sense, early adopters place the greatest value on the network and bear a proportionately greater part of the development cost than later adopters. Moreover, for networked services, the value to individual users must be derived from interaction with other subscribers. Therefore, early adopters appear in clusters and are identified by shared characteristics such as location, industry or profession. Clusters provide the threshold that induces a growing proportion of the population to become users of the innovation.[14] For the Internet, clusters may be indicated by ownership of critical components of the installed base, such as computers, networking technology, compatible software and the interconnecting infrastructure. Indeed, Figures 3 and 4 show that a positive relationship exists between host density and network reach, reflected in PC and telephone main line density for a sample of 52 countries at 1996.[15] Figure 5 shows that network capacity, proxied by integrated services digital network (ISDN) density, is closely correlated with host density.[16] Thus, network reach and capacity may be key factors explaining adoption.

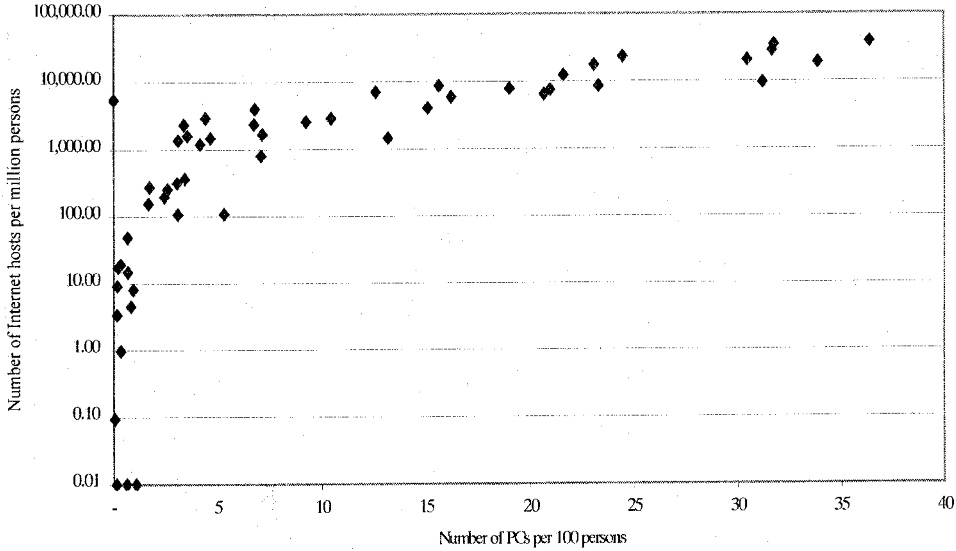

Figure 3. Host and PC density in 1996.
Note: scale on vertical axis is logarithmic. *Source*: International Telecommunications Union (ITU) (1999), 'Challenges to the Network, Internet for Development', ITU, Geneva.

Clearly, Internet subscription is dependent on the scale of the installed base of compatible technology, network externalities and consumer valuations. The relative importance of these factors is determined by estimating a 'macro' model which relates Internet host penetration to lagged host penetration, whilst controlling for network reach and capacity.

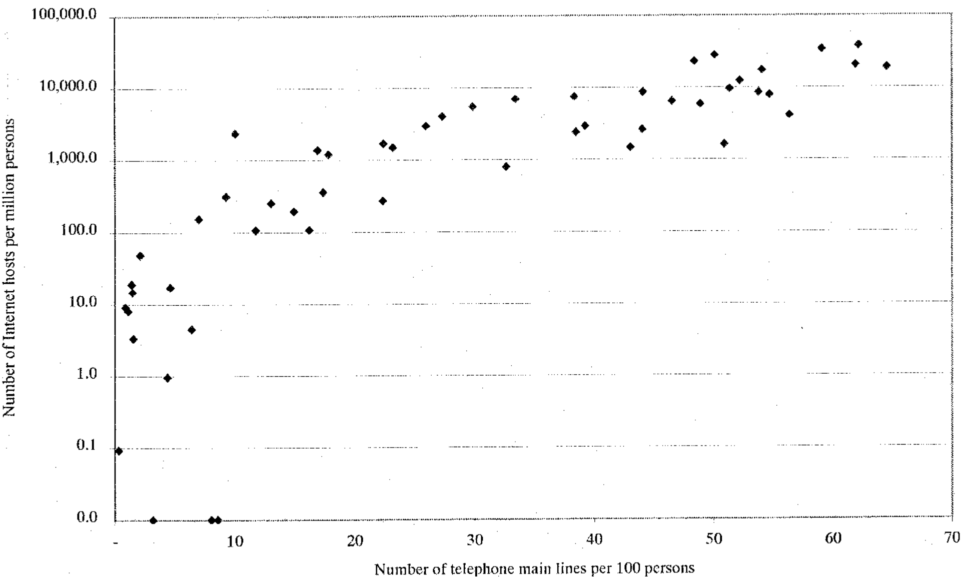

Figure 4. Host and main line density in 1996. *Note*: scale on vertical axis is logarithmic. *Source*: ITU (1999) Challenges to the Network, Internet for Development, ITU, Geneva.

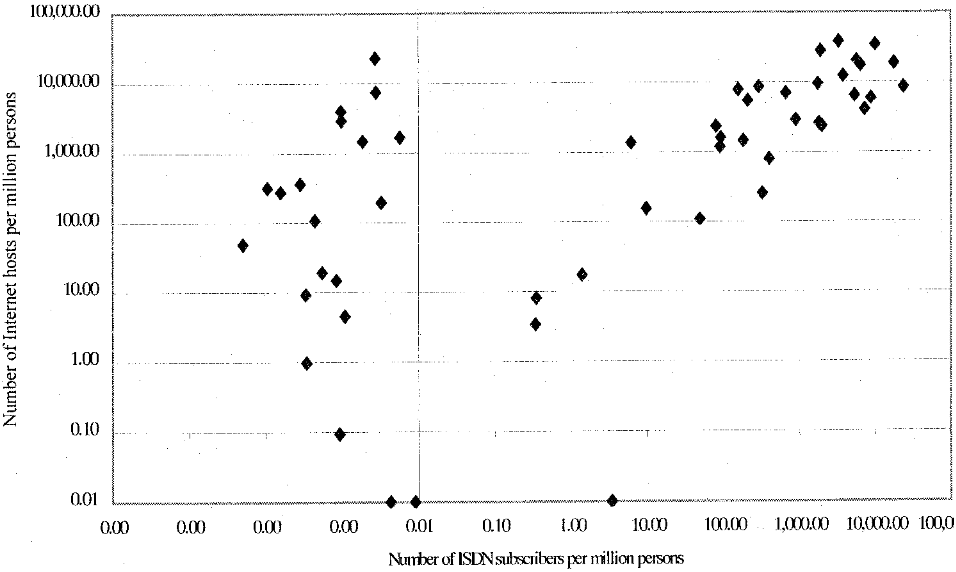

Figure 5. Host and ISDN density in 1996.
Note: scales are logarithmic. *Source*: ITU (1999) 'Challenges to the Network, Internet for Development', ITU, Geneva.

An econometric model of Internet host take-up is:

$$\text{HOST}_{it} = b_0 + b_1\text{PCD}_{it} + b_2\text{TELE}_{it} + b_3\text{ISDN}_{it} + b_4\text{HOST}_{it-1} + e_{it} \quad (1)$$

where i is a country index, t is a time index, b_i are parameters to be estimated, HOST (host density) is Internet hosts per person, PCD (PC density) is PCs per person, TELE (teledensity) is telephone mainlines per 100 persons, ISDN (ISDN density) is ISDN connections per person, and e is a white noise error term.[17] The lagged value for HOSTS measures the network externality effect. PCD, TELE and ISDN are proxies for connectivity (or network reach) and b_1, b_2, $b_3 > 0$ is expected. The network externality effect is assumed positive, so $b_4 > 0$ is expected.

Equation (1) is estimated on annual data for 52 countries for the period 1994–1997. Summary statistics for model variables are presented in Table 1. Average host density for the sample data is 0.005 hosts per person and ranges from zero (Burkina Faso, Gabon, Oman and Syria) to 0.077 hosts per person (US). PC density is substantially higher, ranging between 0.093 (Gabon) per person and 0.407 PCs (US) per person. ISDN ranges from zero per person (Gabon, Burkina Faso) to 0.035 per person (Germany). TELE ranges from 27.4 mainlines per 100 persons (Burkina Faso) to 66.1 mainlines per 100 persons (Switzerland). All variables are positively correlated with host density.

Ordinary least squares (OLS) model estimates for equation (1) are reported in Table

Table 1. Summary statistics

Variables	Mean	Std deviation	Maximum	Minimum	Correlation
HOST	0.005	0.010	0.077	0.000	—
ISDN	0.002	0.005	0.035	0	8.11
PC	0.093	0.105	0.407	0.002	0.88
TELE	27.377	20.590	66.060	0.260	0.25

Table 2. Estimated Internet host equation

Variable	Estimate	Standard error	t ratio
CONSTANT	− 0.9119E-4[a]	0.7809E-4	− 1.67
Network reach			
PCD_{t-1}	− 0.0047	0.0067	− 0.70
TELE	0.1973E-4	0.1032E-4	1.91
ISDN	0.0435E-9	0.0753	− 0.58
Network externality			
$HOST_{t-1}$	1.7582[b]	0.1536	11.51
Sample size	208		
Adjusted R^2	0.97		
LM(1)	3.72		
Het	123.6[b]		

Note. Standard errors are adjusted using White's (1980) heteroskedastic-consistent variance-covariance matrix.

[a] 'E' is a scientific shorthand notation. For example, 0.5E-1 is read as 0.05.

[b] Entries with this superscript denote significance at the 1% level. LM(1) is the Lagrange Multiplier statistic for serial correlation. Het is Ramsey's test for heteroskedastcity using the square of the fitted values. PCD_{t-1} is PC density lagged by one period to avoid simultaneity problems.

2. The adjusted R^2 indicates that the model explains 97% of the variation of host growth. The lagged values of HOST dominate the model and imply strong support for the underlying network growth due to the presence of a network externality. No network reach coefficients are significant. This externality causes endogenous network growth, even though other system drivers, such as prices and income, remain unchanged.[18]

Internet Use

Whilst the supply of information technology and telecommunications (ITT) is necessary for Internet adoption, the provision of required infrastructure does not assure its adoption. The value Internet subscribers derive from network services, such as e-mail, depends on the number of network subscribers. Intuitively, there is a minimum subscriber base to provide sufficient value to induce new subscription.

However, threshold adoption is only achieved when early Internet adopters find the services it offers useful. For example, e-mail has a relatively low cost, near instant delivery and superior presentation quality when compared to facsimile transmission.[19] Figure 6 demonstrates how a consumer might choose among facsimile, e-mail and postal services to maximise utility derived from generic service attributes, convenience (c) and quality (q). The slope of the rays depicts the ratio of convenience to quality attributes. A, B and C are maximum convenience–quality combinations obtained by devoting the entire budget to facsimile, e-mail and postal services, respectively. The efficiency frontier is the outer boundary of the attainable combinations of the attributes, given the budget constraint. The curves (u_1,u_2,u_3) map attribute combinations to which the consumer is indifferent, for a given utility level.[20] The highest tangency point between the efficiency frontier and the individual's indifference curve is the constrained maximum. The consumer achieves optimal utility by consuming (c_1–0, q_1–0) units of e-mail (via the Internet) and (c_2–c_1, q_2–q_1) units of post.

An important factor influencing the optimal combination is ITT ownership. Once ITT is purchased, the availability of online applications increases the value derived from ITT ownership. Thus, widening the array of available services increases demand for

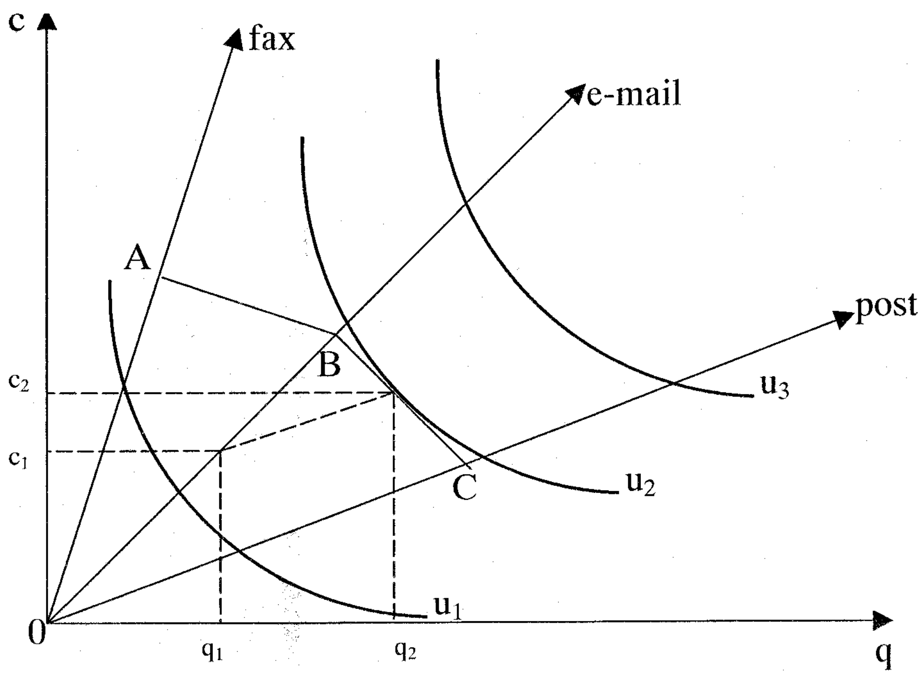

Figure 6. Consumer choice service-characteristic space.

ITT. In turn, increased market size permits viable competition and spreads the cost of development across a larger subscriber base, resulting in reduced unit cost.[21] These factors drive successive refinements in ITT, greater sales volume of existing services and an explosion in the variety of new services.

Accordingly a ‘micro’ model examines how Internet users react to prices, income, the relative attractiveness measured in terms of the Internet’s service attributes, and types of applications offered. Micro data relating to early adopter characteristics and revealed preferences are obtained from a survey posted on the Communications Economics Research Program’s web site.[22] An incentive to satisfactorily complete the questionnaire was offered through a draw in a lottery to respondents. Further, the questionnaire is layered in its design so that the ‘observed’ information requests vary with respondents revealed Internet use and demographic profile. Focus group feed back, prior to posting the survey, showed the layered design substantially improved both response accuracy and questionnaire completion. The document was posted to the web page from 13 October to 3 November 1997. To activate the survey questionnaire respondents are required to click on a hyperlink. During the period of the survey the questionnaire was successfully completed by 471 of the respondents. Respondents are asked to supply information on their Internet use, pricing plan, socio-demographic background and applications used.

Preliminary analysis of the results indicates that average weekly Internet use is 8 hours. The average monthly payment, excluding those receiving free access, is $32.[23] The most common pricing plan reported is a monthly access fee, with an additional usage-based fee for service beyond a given hours threshold. This plan accounts for one-third of all Internet accounts, whilst flat-rate and usage-sensitive plans account for 18% and 11%, respectively. Of particular interest are intensive users. More than 60% are aged between 16 and 35; 18% of this group are students and 35% are self-employed.

Both groups spent most time on e-mail and chat lines, although the students indicated that file downloads accounted for a significant additional proportion of time spent online. Further, these users have been accessing the Internet for more than 3 years.

A multiple regression model is employed to explain variations in Internet usage based on pricing scheme, household income, nature of employment and applications accessed:

$$\text{HOURS} = \beta' X + \varepsilon \tag{2}$$

where HOURS is the actual Internet hours of use, β is a vector of parameters and X is a vector of explanatory variables. X consists of the sub vectors PRICE, INCOME, SOCIAL, INTEREST and HOME. PRICE contains information about Internet pricing schemes. INCOME consists of total monthly cost of Internet access and household income.[24] SOCIAL contains socio-demographic information about respondents, for example, respondent's occupation, education and age. INTEREST is a vector of variables indicating the level of respondent interest in Internet applications, such as Internet telephony and video conferencing (on a five point scale). HOME is a vector of variables comprised of Internet applications (e-mail, file transfer and chat lines), items purchased online (games, magazines and music), ownership of home technology (PC, modem, scanner) and the range of uses requiring a PC.[25] Finally, ε is a unique component to the individual not reflected in these data (see Table 3).

Table 4 reports coefficient estimates for hours of Internet use equation. Diagnostic testing reveals that the model performs well. An F-test rejects the hypothesis that all slope parameters are jointly equal to zero. Standard errors are adjusted using White's homoskedastic-consistent variance–covariance matrix.[26]

The sign of the estimated PRICE coefficient is negative and conforms to *a priori* expectation. The marginal effects suggest that Internet users on flat-rate component pricing plans are more likely to be in the very high Internet use band relative to respondents without flat-rate plans. Similarly, respondents on usage-sensitive only pricing plans are less likely to be high Internet users.

The significance of GAMES and EMAIL variables suggest respondents who use the Internet mainly for playing games or communicating through e-mail are likely to have higher hourly levels of Internet use. The positive sign on EMAIL is intuitive. Respondents who use the Internet mainly to participate in e-mail communication spend more time on the network.

Model results show that the impression of the typical Internet user as a young residential consumer misrepresents the population. Internet usage is also significantly determined by self-employed adults who maintain personal or business related web sites, correspond by e-mail, and participate in discussion groups. Such applications involve varying levels of interaction within social and professional relationships. Further, e-mail and chat line messages permit asymmetric interaction, giving busy recipients greater control over when to respond. This continues a trend established in communications media, where recording devices such as answering machines and VCRs allow consumers to 'time shift' consumption opportunities. Paradoxically, the ability to interact asymmetrically combined with the rapid delivery inherent in networking applications, such as electronic data interchange and e-mail, introduces a level of flexibility which may be of greater benefit for business people. Moreover, the common networking protocol offers the potential to exploit economies of scale and scope typical of larger organisations.

Table 3. Independent variables

Variable	Description	Expected sign
Price		
$PRICE_1$	= 1 when ISP payment is a combination of a flat-rate monthly fee and a usage fee beyond a certain threshold of hours, 0 otherwise	≤ 0
$PRICE_2$	= 1 when ISP payment is a usage fee plus an additional fee per megabyte downloaded, 0 otherwise	≤ 0
Income		
BILL	= average total monthly ISP charge for Internet access	≥ 0
$INCOME_2$	= gross weekly household income if greater than or equal to $15,600 and less than $31,200 per annum, 0 otherwise	≥ 0
$INCOME_3$	= gross weekly household income if greater than or equal to $31,200 and less than $52,000 per annum	≥ 0
$INCOME_4$	= gross weekly household income if greater or equal to $52,000 per annum	≥ 0
Social		
AGE	= respondent age	≥ 0
DEGREE	= 1 when highest educational award is degree/diploma, 0 otherwise	?
FULLTIME	= 1 when employed full-time, 0 otherwise	?
GENDER	= 1 when female, 0 otherwise	?
MANAGER	= 1 when employed as a manager or administrator, 0 otherwise	?
PARA	= 1 when employed as a quasi-professional, 0 otherwise	?
PROFESSIONAL	= 1 when employed as a professional, 0 otherwise	?
SECONDARY	= children in the household attending secondary school	?
SEMPLOY	= 1 when respondent is self employed, 0 otherwise	?
STUDENT	= 1 when respondent is studying full-time, 0 otherwise	?
Interest		
SOFTWARE	= interest in downloading software (1–5 scale)	≥ 0
TELEPHONE	= interest in Internet telephony (1–5 scale)	≥ 0
VIDEO	= interest in video conferencing (1–5 scale)	≥ 0
XRATED	= interest in viewing X-rated material (1–5 scale)	≥ 0
Applications		
CHAT	= 1 when respondent participates in chat lines/discussion groups, 0 otherwise	≥ 0
EMAIL	= 1 when Internet is used for communication by e-mail, 0 otherwise	≥ 0
FILE	= 1 when Internet is used for file transfer, 0 otherwise	≥ 0
GAMES	= 1 when Internet is used to play games, 0 otherwise	≥ 0
HOBBY	= 1 when Internet is used to conduct Web searches related to hobby interest, 0 otherwise	≥ 0
NEWS	= 1 when Internet is used to access online news services, 0 otherwise	≥ 0
PHONE	= 1 when telephone calls are conveyed via the Internet, 0 otherwise	≥ 0
XXX	= 1 when Internet is used to access X-rated content, 0 otherwise	≥ 0
Shopping		
BOOKS	= 1 when respondent has purchased books online, 0 otherwise	≥ 0
MUSIC	= 1 when respondent has purchased music online, 0 otherwise	≥ 0
PC	= 1 when respondent has purchased computer games online, 0 otherwise	≥ 0
TRAVEL	= 1 when Internet is accessed mainly to buying travel; 0 otherwise	≥ 0
Technology		
LINE	= 1 when respondent has a dedicated line for Internet access, 0 otherwise	≥ 0
PAGE	= 1, if respondent has own web page, 0 otherwise	≥ 0
PCAGE	= age of PC	?
SCAN	= 1 when respondent owns a scanner, 0 otherwise	?
Use		
WORD	= 1 when home PC is used for word processing, 0 otherwise	≥ 0

Table 4. Estimated Internet use equation

Variable	Estimate	Standard error	*t* ratio
CONSTANT	2.309	0.622	3.711[a]
Price			
$PRICE_1$	− 0.451	0.132	− 3.422[a]
$PRICE_2$	− 3.518	0.336	− 10.471[a]
Income			
BILL	0.117	0.392	2.985[a]
$INCOME_2$	0.200	0.330	0.607
$INCOME_3$	− 0.272	0.297	− 0.916
$INCOME_4$	− 0.262	0.306	− 0.856
Social			
AGE	0.021	0.029	0.720
DEGREE	0.122	0.150	0.814
FULLTIME	− 0.162	0.177	− 0.914
GENDER	− 0.192	0.168	− 1.144
MANAGER	− 0.055	0.173	− 0.319
PARA	− 0.105	0.173	− 0.606
PROFESSIONAL	0.212	0.175	1.213
SECONDARY	0.088	0.085	1.038
SEMPLOY	0.703	0.219	3.205[a]
STUDENT	0.245	0.237	1.034
Interest			
SOFTWARE	0.041	0.058	0.711
TELEPHONE	− 0.017	0.059	− 0.282
VIDEO	0.257	0.074	3.494[a]
XRATED	0.049	0.046	1.057
Applications			
CHAT	0.563	0.183	3.072[a]
EMAIL	0.474	0.269	1.758[c]
FILE	0.057	0.138	0.412
GAMES	0.436	0.132	3.305[a]
HOBBY	− 0.043	0.123	− 0.352
NEWS	0.306	0.144	2.132[b]
PHONE	0.170	0.207	0.820
XXX	0.229	0.168	1.363
Shopping			
BOOKS	− 0.063	0.150	− 0.421
MUSIC	0.029	0.146	0.197
PC	0.201	0.131	1.538
TRAVEL	− 0.152	0.126	− 1.210
Technology			
LINE	0.116	0.131	0.882
PAGE	0.519	0.132	3.944[a]
PCAGE	− 0.036	0.050	− 0.721
SCAN	0.032	0.122	0.260
Use			
WORD	− 0.287	0.162	− 1.775[c]
Sample size	471		
Adjusted R^2	0.307		
F statistic	6.632[a]		
LM(1)	0.430		
Het	6.655[a]		

Notes: Standard errors are adjusted using White's (1980) heteroskedastic-consistent variance-covariance matrix.

[a] This denotes significance at the 1% level.

[b] This denotes significance at the 5% level.

[c] This denotes significance at the 10% level.

LM(1) is the Lagrange Multiplier statistic for serial correlation. Het is Ramsey's test for heteroskedastcity using the square of the fitted values.

Conclusions

The purpose of this paper is to test for the importance of a network externality in explaining Internet host growth, and to analyse Internet use by subscribers. The empirical evidence presented in this study confirms that the establishment of a secure base of commercial users and the Internet's open architecture has combined to generate the network externality effect. This positive externality has generated endogenous growth allowing a widening array of applications. Finally, the estimated Internet use equation suggests pricing of the Internet is important for subscription, however, the finding is conditional on the nature of applications valued by subscribers being available.

Economists say there is a network externality when the value of a good depends on the number of other people who use it. Generally, consumers would like to be connected to as large a network as possible.[27] We must address low income country concerns.

Received empirical studies pay considerable attention to the role of network externalities in models of the demand for telephone services. For instance, suppose the (point-to-point) demand for an outgoing telephone call from city i to city j (Q_{ij}) is determined by the price of the call (P_i), income in i (Y_i), incoming traffic from j to i (Q_{ji}). Network externalities for both city i and j are allowed for through the inclusion of NE_{ij} in the demand function, where NE_{ij} is proxied by the number of reachable telephones (a measure of market or network size). The greater the size of the market the more potential for calls, so a positive relationship is expected between Q_{ij} and NE_{ij}.[28]. However, Taylor[29] duly notes that a positive association between outgoing (Q_{ij}) and incoming traffic (Q_{ji}) could reflect reversion, as well as network and call externalities.[30]

The above study captures the indirect effect of network externalities by way of incoming traffic and potential telephone connections (that is, an increase in call volumes with network size implies an increase in the subscriber base). However, as described by Artle and Averous[31] the network externality can cause a network to grow endogenously, even though nothing may be happening to the objective drivers of the system, such as price and income.[32] This suggests that current period Internet host subscription is positively related to past period host subscription.

Notes and References

1. We thank Reg Coutts, Don Lamberton and participants at the Communications Research Forum, Canberra, 27–28 September 1999, for helpful comments.
2. J. K. MacKie-Mason and H. R. Varian, 'Pricing the Internet', in B. Kahin and J. Keller (eds), *Public Access to the Internet*, MIT Press, Cambridge, MA, 1995, pp. 269–314; and B. M. Leiner, V. G. Cerf, D. D. Clark, R. E. Kahn, L. Kleinrock, D. C. Lynch, J. Postel, L. G. Roberts and S. Wolff, 'A brief history of the Internet', http://www.isoc.org/Internet/history, 1998.
3. International Telecommunications Union (ITU), *Challenges to the Network: Telecoms and the Internet*, ITU, Geneva, 1997.
4. Network Wizards, http://www.nw.com , 1999; M. Sarkar, 'Internet pricing: a regulatory imperative', in L. W. McKnight and J. P. Bailey (eds), *Internet Economics*, The MIT Press, Cambridge, 1997.
5. In 1997, Australia ranked ninth in the world in Internet hosts per 100 persons and fifth in PCs per 100 persons. See ITU, *World Telecommunication Development Report*, ITU, Geneva, 1999.
6. D. Weimer and A. Vining, *Policy Analysis: Concepts and Practice*, Prentice-Hall, New Jersey, 1992.
7. A call externality arises as both agents derive utility from the telephone message but only the originating caller pays for the call. A. Larson, Dale Lehman and Dennis Weisman, 'A General Theory of Point-to-Point Long Distance Demand in Alain De Fontenay, Mary Shugard and David Sibley (eds), Telecommunications Demand Modelling, 1990, Amsterdam: North-Holland suggest that a single payment by the originating caller is justified because of the uncertainty differential between the originating and terminating end of a message. Agents may not always be willing to pay a charge for a call that is of uncertain origin. This can be overcome if the number (origin) of the incoming call is identifiable.

8. J. Rohlfs, 'A theory of interdependent demand for a communications service', *Bell Journal of Economics and Management Science*, 5, Spring, 1974, pp. 16–37.
9. Despite the fact that service AS and BS look very similar and have the same industrial classification, they are complements and not substitutes. See N. Economides, 'The Economics of Networks', *International Journal of Industrial Organization*, 14(6), October, 1996 pp. 673–699.
10. R. Artle and C. Averous, 'The telephone system as a public good: static and dynamic aspects', *Bell Journal of Economics and Management Science*, 4, Spring, 1973, pp. 89–100; S. S. Oren and S. A. Smith, 'Critical Mass and Tariff Structure in Electronic Communications Markets', *Bell Journal of Economics*, 12(2), Autumn 1981, pp. 467–87; J. Rohlfs, *op cit*; N. Economides, *op. cit.*
11. Ideally, acceptable mechanisms for the recovery of subsidy dollars from pricing below cost should minimally distort the outcomes of a competitive market. Einhorn and Madden *et al.* suggest that such subsidies are most efficient when recovered through a broad based tax that does not distort the price ratio between any pair of goods. See M. Einhorn, 'Universal service: realities and reforms', *Industrial and Corporate Change*, 4, 1995, pp. 721–6; G. Madden, S. J. Savage and M. Simpson, 'Asia–Pacific telecommunications USOs: current practice and future options', *Prometheus*, 16, 1998, pp. 485–98.
12. Artle and Averous, *op. cit.*
13. B. Preiβl, 'Strategic Use of Communication Technology—Diffusion Process in Networks and Environments', *Information Economics and Policy*, 7, 1995, pp. 75–99.
14. P. Stoneman, (1993), *The Economic Analysis of Technological Change*, Oxford, Oxfordshire: Oxford University Press.
15. The sample is comprised of: Algeria, Argentina, Australia, Belgium, Burkina Faso, Colombia, Czech Republic, Denmark, Estonia, France, Gabon, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Kenya, Korea (Republic), Kuwait, Lebanon, Malaysia, Mauritius, Mexico, Morocco, Netherlands, New Zealand, Norway, Oman, Poland, Portugal, Senegal, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, Switzerland, Syria, Thailand, Tunisia, Turkey, United Arab Emirates, United Kingdom, United States, Venezuela, and Zimbabwe.
16. ISDN provides high bandwidth Internet access at 128 kbps.
17. An Internet host is any computer system connected to the Internet via full or part-time, direct or dial-up connections.
18. Artle and Averous, *op. cit.*; Rohlfs, *op. cit.*; D. Kridel, P. Rappoport and L. Taylor, 'An econometric study of the demand for access to the Internet', presented at the Twelfth Biennial Meetings of the International Telecommunications Society, Stockholm, 21–24 June 1998.
19. Facsimile transmissions are sometimes preferred to e-mail because they have a higher legal status.
20. Figure 6 shows that utility curves u_1 and u_2 are attainable, but u_3 is not. Faced with a choice between u_1 and u_2, the rational consumer is assumed to maximise utility by selecting u_2.
21. C. Antonelli, 'Economic theory of information networks', in C. Antonelli (ed.), *The Economics of Information Networks*, Elsevier Science, Amsterdam, 1992, pp. 5–28.
22. Since no national census or central registry of Internet users exists in Australia, sampling is necessarily non-probabilistic. As such, it is difficult to ensure that certain portions of the Internet subscriber population are either not excluded or otherwise disproportionately represented. This can create a problem of applying the results to the entire population when the not participating group is different in some manner from the participating group. Because there is no web-based broadcast mechanism that would enable participants to be selected or notified at random, it was decided to advertise the survey nationally through print media and by hyperlinks attached to selected ISP home pages. This procedure gave the survey exposure at sites that capture a substantial portion of all WWW user activity. These procedures mimic those employed by the Graphic, Visualisation and Usability Center (GVU, 1999) in conducting their 9th WWW User Survey.
23. Average monthly payment calculations use the price mid-point, with \$100 the upper limit.
24. Received theory predicts time online increases with income since the cost of Internet access represents a smaller portion of the household budget. However, time online may decrease for high income earners beyond some threshold of income since high income earners may have sub-

stantially reduced leisure time. See G. Madden, S. Savage and M. Simpson, 'Information inequality and broadband network access: an analysis of Australian household data', *Industrial and Corporate Change*, 5, 4, 1996, pp. 1049–66; K. Williamson, 'Extending universal service', *Info*, 1, 1999, pp. 177–86.

25. Chat lines are interactive text based messages accessible by multiple participants. As such, they are designed for spontaneous group discussions. The rationale is that uses such as word and data processing predisposes the respondent to spending time online.
26. H. White, 'A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity', *Econometrica*, 48, 1980, pp. 55–67.
27. This implies that when there are several different network providers, then it is very advantageous to consumers if the providers interconnect. See Shapiro, C. and Varian, H.R., *Information Rules: A Strategic Guide to the Network Economy*, Boston, Harvard University Press, 1998, Chapter 8.
28. Pacey, P.L., 'Long distance demand: A point-to-point model', *Southern Economic Journal*, 49(4), 1983, pp. 1,094–1,107. Larson *et al.*, *op. cit.*
29. D. Taylor, *Telecommunications Demand in Theory and Practice,* 1994, Amsterdam: Kluwer.
30. Call reversion suggests outgoing and incoming call volumes are substitutes, $Q_{ij}/Q_{ji} < 0$, whilst reciprocity implies outgoing and incoming calls are complimentary, $Q_{ij}/Q_{ji} > 0$.
31. Artle and Averous, *op. cit.*
32. Kridel *et al.*, *op. cit.*