Hedonic Pricing Analysis of DSL Internet Services in Taiwan

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Abstract

This paper studies the pricing of DSL services in Taiwan. DSL service is an overwhelmingly popular mode of Internet access in Taiwan, and the net penetration in Taiwan is ranked the tenth in the world. Both the stage of Taiwan's Internet development and the popularity of the DSL service make Taiwan a good choice for such study. The characteristics of DSL services which are economically meaningful to both the ISPs and household users were first selected through a hedonic approach. Then Box-Cox methodology was used to determine the appropriate data transformation that best fits a regression model. The circuit fee and the number of static IPs are found to be the two most important characteristics that affect the pricing, with the circuit fee being the key factor due to its substantially larger coefficient. In addition, a dummy variable which represents Taiwan Fixed Network, a smaller player in the arena, turned out to be significant. Its negative coefficient indicates that the DSL service offered by TFN's was priced lower than the industry average. This reduction in price could be a result of TFN's decision of entering a price-war. This study offers insights to how DSL services are priced in regions with similar profiles as Taiwan.

1. Introduction

The commercialization of the Internet had excited the business world a decade ago, but the Internet access then was severely bogged down by the last-mile bandwidth, limiting the conceptualization and implementation of business applications on the net. The emergence of broadband service has significantly alleviated the problem. In Taiwan, the rapid growth of DSL service has been phenomenal in the past five years, and now it accounts for 73 percent of the household market of Internet access service, contrasting to 7 percent for cable Internet access, and the remaining for dial-up service [1]. This is a bit different from the U.S. market, in which two strong rivals, DSL and cable services, are still in battle for the crown of broadband market share [2]. Accordingly, this study would focus on DSL products rather than cable modem ones.

Accessing Internet through DSL is a 37.4 billion NT dollars industry in Taiwan alone [3]. Nevertheless, while the status quo and future applications have been widely discussed in the trade reports and relevant research, much less is known about what determine the pricing of DSL services. This paper attempts to identify the characteristics of DSL services that are the key factors in its pricing. A regression model is built and empirically tested to analyze the pricing of

DSL Internet services in Taiwan.

The organization of this paper is as follows. In the literature review, the DSL Internet access service market in Taiwan is briefly described, followed by an overview of the hedonic pricing analysis approach, and then the Box-Cox methodology for identifying the model that gives rise to the best-fit for the given set of data. The variable selection and data collection process is explained in the Methodology section, and the section is concluded with the final model. After a thorough analysis, the implications and conclusion are offered.

2. Literature Review

Based on the survey by Point Topic, by the end of September 2004, the number of DSL subscribers in Asia-Pacific region had reached 85.3 million, representing a 45% market share in the Internet access services. Ranked by country, Taiwan is only second to South Korea in the Net penetration by DSL service. The data of the third quarter, 2004 [1, 4] indicated that the number of DSL subscribers in Taiwan reached over three millions; however, the number of cable modem subscribers was only 350,000. Based on the analysis of ACI-Find, there was a rapid growth of DSL subscribers in 2004 due to the price reduction led by government intervention, and the speed promotion initiated by service providers [4]. The matured DSL subscription market in Taiwan had put forth a proliferation of download/upload speed combinations, the most popular one being the 2M/256k combination (2Mbps for download speed, and 256kbps for upload speed). The major service providers are listed in Table 1. Out of these six providers, Chunghwa Telecom has the largest market share, which is a result of its monopoly position prior to the deregulation of telecommunication industry in the 90's. It was a long-time state-owned enterprise and only became privatized in the 90's. As Chunghwa Telecom also owns most of the land-based infrastructure, many ISPs need to lease the physical lines or purchase bandwidth from Chunghwa Telecom. Taiwan Fixed Network is one exception, for it is in the physical line business, and it has a land-based infrastructure, though not as extensively as Chunghwa Telecom's. The legacy of the state-own telecommunication industry is expected to impact the pricing of DSL service.

Table 1. The primary DSL service providers in Taiwan

Primary ISPs	Abbreviation of ISPs	Network Operators
Chunghwa Telecom	Hinet	Chunghwa Telecom
Digital United Inc.	Seednet	Chunghwa Telecom
Giga Media	Giga	Chunghwa Telecom
Asia Pacific Online	APOL	Asia Pacific Broadband Telecom
Sony Network Taiwan Limited.	So-net	Chunghwa Telecom
Taiwan Fixed Network	TFN	Taiwan Fixed Network

2.1 Hedonic Approach

Hedonic approach is based on multiple regression method. The hedonic approach signifies the selection process of product characteristics that are used in the regression. Waugh (1928) first used this approach to price vegetables. Later, Court (1939) applied the approach to capture the characteristics of automobiles that affect pricing, where the characteristics were associated with consumers' "pleasure and comfort," through which the term hedonic was coined [5]. Hedonic approach attempts to guide the selection of characteristics by their economic meanings.

To be economically meaningful or interpretable, variables chosen for the regression equation are the product characteristics "which not only absorb producers' resource cost but also generate value to users" [6]. The following three principles were proposed by Triplet:

1. The selected variables are homogeneous economic building block from which heterogeneous goods are priced.
2. The selected variables are valued by both buyer and seller.
3. The price represents the valuation of all the variables combined.

2.2 Box-Cox Methodology

Multiple regression method is a linear model which estimates how the dependent variable is predicted by the independent variables. Box-Cox methodology provides a means to relax the assumption of linearity by determining the adequate data transformation that gives rise to the best goodness-of-fit.

Box-Cox methodology is an objective estimation method, through which subjectivity could be eliminated in the choice of functional form for the independent variables [7]. The criteria that Box-Cox methodology employs to estimate the goodness-of-fit is based on Equation 1.

$$L_{max} = -\left(\frac{n}{2}\right)\ln\left(\text{Residual } SS/n\right) + (\lambda - 1)\sum \ln(Y) \quad (1)$$

,where n = the total number of observations, Residual SS= the sum of the square with respect to specific λ, and λ is a parametric variable.

The Box-Cox methodology is about finding the λ that would maximize the criteria L. The λ which corresponds to L_{max} is denoted by λ^*, and the confidence interval for λ^* is $\lambda^* \pm (1/2)\chi_1^2(1-\alpha)$. The optimal model is represented by Equation 2a or 2b, with λ^* plugged in.

If $\lambda \neq 0$,

$$\frac{(Y^{\lambda}-1)}{\lambda} = B_0 + \sum_{i=1}^{m} B_i \frac{(X_i^{\lambda}-1)}{\lambda},$$ where m = the number of variables. (2a)

If $\lambda = 0$,

$$\ln(Y) = B_0 + \sum_{i=1}^{m} B_i \ln(X_i),$$ where m = the number of variables. (2b)

To determine where L_{max} lies, λ is typically stepping through an interval of 1/4, 1/3, or 1/2, between +2 and -2 [8]. Plotting L against λ would help determine L_{max} and the corresponding λ^*.

3. Methodology

This section explains the method of data collection, describes how independent variables are selected based on the hedonic approach, and how λ^* is determine by following the Box-Cox methodology.

3.1 Initial Variable Selection

The data for DSL service offerings were collected through searching engines and corporate websites. Though they may be available in well-structured formats through commercial databases, this study chose the above unstructured venues for two reasons: to avoid costly membership fees for accessing commercial databases, and to make the best effort in securing the newest data.

The duration of data collection is from early September till the end of November of 2004. This study selected all of DSL services providers for data collection purpose. The data set consists of 47 observations. Based on Triplet's three principles of hedonic approach, the set of chosen variables is listed in Table 2.

Table 2. Initially selected variables.

Variables	Abbreviation	Explanation	Variable Type
Monthly Fee	MONFEE	Monthly rental charge for DSL modem	Numerical
Circuit Fee	CIRFEE	Circuit fee per month	Numerical
APOL	APOL	The network operator is Asia Pacific Broadband Telecom	Dummy
Taiwan Fixed Network	TFN	The network operator is Taiwan Fixed Network	Dummy
Contract duration	CTD	Usually 12 months	Numerical
Installation Fee	ISTFEE	For Modem and necessary software	Dummy
Download Speed	DNSPED	In kilo bits per second (kbps)	Numerical
Upload Speed	UPSPED	In kilo bits per second (kbps)	Numerical
Static IP	STCIP	Number of fixed IP assigned	Numerical
Dynamic IP	DYNIP	Number of IPs assigned on demand	Numerical
Gif(value of equivalence)	GIFT	Usually range from 500 NT dollars to 5000 NT dollars	Numerical

Almost all ISPs have the requirement of signing a contract to obtain the Internet service, except Seednet. Three carriers make up the entire fixed phone line market of Taiwan, representing a typical oligopoly, in which Chunghwa Telecom dominates (97.8). Since owning fixed phone line is a clear advantage in the Internet service market, and a larger market share means stronger bargaining power, the pricing model needs to take the market share of fixed phone line into consideration. As a result, two dummy variables are used to represent Asia Pacific Broadband Network and Taiwan Fixed Network, the two smaller carriers.

Some ISPs charge for the initial installation and setting up of the modem and necessary software, while others do not. When there is such charge, a value "1" is assigned to the dummy variable ISTFEE, "0" otherwise.

The available download speed for the Internet service is usually faster than the available upload speed, since most Internet surfers act as information receivers rather than information providers on the net, so symmetric download speed and upload speed for household market are not common in Taiwan.

Static IP is a valuable resource for power users, as most of them have the need of setting up a server, which requires a fixed IP address to provide uninterrupted services on the Internet. With a dynamic IP service, IP addresses are assigned whenever the user logs in, and there is no guarantee that the same address will be assigned.

Bundling DSL services with gifts is a common practice in Taiwan. The value of gifts

ranges from 500 to 5000 in NT dollars, depending on the terms of the service.

3.2 Further Screening of Variables

The selection of variables is refined by statistical justification. The further screening of variables is necessitated by the desire to eliminate potential colinearity. Pearson's correlation method is used to perform the first step of screening. Pair-wise correlations revealed a strong colinearity between UPSPED and CIRFEE, with ρ= 0.868, and between UPSPED and DNSPED, with ρ=0.746, while ρ=0.411 between CIRFEE and DNSPED. In consequence, UPSPED is eliminated, for its highly colinearity with two explanatory variables.

Subsequent screening involves regressing 9 out of the remaining 10 independent variables on MONFEE. The variables with significant coefficients were retained for the final model.

$$\begin{aligned} MONFEE = & -302.171 - 127.842 \times TFN + 1.366 \times CIRFEE - 6.204 \times CTP \\ & (-2.168)^{**} \quad (-1.772)^{*} \quad (11.366)^{**} \quad (0.913) \\ & -74.974 \times ISTFEE - 0.0158 \times DNSPED - 49.906 \times STCIP + \\ & (-0.893) \quad (-1.389) \quad (3.079)^{**} \\ & 11.021 \times DYNIP + 0.01944 \times GIFT \\ & (1.154) \quad (1.007) \end{aligned}$$

$$\text{Adj-}R^2 = 0..778 \quad F\text{-statistic} = 21.117$$

(Note: t-statistics are in parentheses; * denotes significance at the 0.1 level, and * denotes significance at 0.05 level.)

It turned out that only TFN, CIRFEE, and STCIP passed the significance test. Based on previous literature, they were entered to the final pricing model [8, 9, 10, 11].

3.3 Model and Evaluation

After the variables for the final pricing model were determined, the Box-Cox methodology was employed to learn the appropriate data transformation. The values of L and λ are tabulated in Table 3, where the λ value associated with the maximum value of L, L_{max}, is denoted by λ^*, which is -0.67, and the 95% confidence interval for λ is from -2.59 to 1.25, which is a justification for using λ=0 and λ=-1 on both independent and dependent variables because L values for λ=0 and λ=-1 respectively are comparable to that of λ^*.

Table 3 shows the analysis results for both the inverse, and the double ln regression models, which correspond to λ = -1, and λ = 0 respectively. In inverse and double ln regression models, variables equal to zero are approximated by 0.000001 [10].

Table 3. L_{max} for DSL service market.

λ	L_{max}
2	-253.91
1	-234.22
0	-228.11
-0.5	-225.78
-0.67*	-225.53
-0.8	-228.39
-1	-230.08

-2	-254.15
-3	-288.71

According to Table 4, the adjusted R^2 and F-statistics of the double ln regression model are about the same as those of the inverse regression model, and their results of t-testing on coefficients are approximate, so these two models have nearly equal explanatory power to variances.

A key criterion for comparing across regression models is the goodness-of-fit. The mean squared error (MSE) is one of the widely accepted indicators for this comparison. As shown in Table 5, the inverse regression model provides better fit with the data set, as the MSE is smaller. Therefore, inverse function is the preferred model.

Table 4. The analysis results for the inverse and the double ln regression models.

	Inverse Model			**Double ln Model**		
Variable	Coefficient	t-stat	Standardized Coefficient	Coefficient	t-stat	Standardized Coefficient
TFN	$-1.062*10^{-9}$	-3.98	-0.288	-0.02851	-3.23	-0.24
CIRFEE	1.615	11.75	0.825	1.323	11.35	0.836
STCIP	$2.842*10^{-4}$	1.268	0.092	0.001703	0.83	0.16
Constant	-0.615	-4.48		-2.536	0.01	
Adjusted R^2		0.774			0.751	
F-stat		53.543			47.203	
L_{max}		-230.08			-228.11	

Table 5. Mean squared error for the inverse and double ln models.

	MSE
Inverse	3.5*10-^{7}
Double ln	0.076

4. Analysis and Implications

In the final inverse function model, there are three explanatory variables. Among them, CIRFEE is the most important one, as the corresponding coefficient is significant and has the largest magnitude. On the surface, this means that the monthly subscription fee increases with circuit fee, and seemingly circuit fee is the cause for higher monthly fee. However, the true cause

for higher monthly fee is probably an upgraded service that dictates a higher circuit fee. The circuit fee structure in Taiwan can be rather peculiar, because most circuits are owned by the Titan, Chunghwa Telecom. Its rivals are in disadvantage unless the regulatory agency intervenes, which does not occur very often and usually takes a time-consuming judicial process.

The second important explanatory variable is TFN, a dummy variable, and a value "1" represents Taiwan Fixed Network. The corresponding negative coefficient suggests that with the similar service profile, i.e. when all other variables are held constant, its service is priced below market average. As a smaller player, perhaps Taiwan Fixed Network chose to compete on price. APOL, a dummy variable for Asia Pacific Online, was excluded from the model after further screening of variables; therefore its effect on the pricing is negligible. This means that a fierce price war may not be that inevitable after all even in an oligopoly market.

The last explanatory variable is STCIP, the number of static IPs provided. Most ISPs provide free dynamic IPs, and only APOL and TFN, two new entrants, offer static IPs. The positive corresponding coefficient for STCIP indicates that a DSL service is priced higher when static IPs are offered. In other words, static IPs mandate a price premium, as IP addresses are now a scarce resource. In Taiwan, the service to map dynamic IPs to registered domain names has been provided by Taiwan Network Information Center, abbreviated as TWNIC, and in other regions, similar organizations. This service can remedy the scarcity of static IPs. Users who for economic reasons are unable to have static IP service, but desire to provide continuous network services, can benefit from such service.[12].

5. Conclusions

In this research, through hedonic approach and Box-Cox methodology, key characteristics of DSL Internet services, which determine the price, were identified. They are the circuit fee, the number of static IP addresses provided, and a dummy variable TFN. The appropriate data transformation for Taiwan market was found to be when $\lambda = -1$, which leads to an inverse function modeling. The most important explanatory variable in this model is the circuit fee, which along with monthly fee determines the total expense on accessing Internet per month for a household. The typical monthly expense for Internet access ranges from 499 NT dollars for dialup service alternative of 256k/64k, to around 1000 NT dollars for the main stream DSL service of 2M/256k. Still another important finding is that the corresponding coefficient for the dummy variable, TFN, is significant and negative, implying that Taiwan Fixed Network priced their services below market average.

5.1 Future Research

The effect of service quality can also be an important factor that determines the pricing of DSL services. Its effect over a long period of time is especially worth studying by a longitudinal research. However, due to time limitation, this variable was not considered. In addition to Taiwan, other countries with high network penetration in the Asia-Pacific region, and in the Scandinavia can be investigated to have a broader understanding. To establish a benchmark, U.S. data can be used, as Internet was invented there.

References

[1]. ACI-FIND, Taiwan's Broadband Status Quo for Household Market(Chinese Version) 2004,Institute for Information Industry http://www.find.org.tw/0105/howmany/howmany_disp.asp?id=91.

[2]. *Sharing the broadband market*, 2004,DSL Forum and Point Topic http://www.dslforum.org/PressRoom/Q3_2004_DSL_Data.pdf.

[3]. ACI-FIND, The Survey of Taiwan's Accessing Internet Household Market(Chinese Version) 2004,Institute for Information Industry.

[4]. ACI-FIND, the number of xDSL subscribers reaches over 3 millions(Chinese Version) 2004,Institute for Information Industry http://www.find.org.tw/0105/howmany/howmany_disp.asp?id=89.

[5]. Court, A.T., Hedonic price indexes with automotive example, in The Dynamics of Automobile Demand. 1939, General Motors: Detroit, MI. p. 99-117.

[6]. Triplet, J.E., "The Economic Interpretation of Hedonic Methods". *Survey of Current Business*, 1986. **66**(1). 36.

[7]. Berndt, E.R., The Measurement of Quality Change: Constructing an Hedonic Price Index for Computers Using Multiple Regression Methods, in The Practice of Econometrics: Classic and Contemporary. 1991, Addison-Wesley. p. 127-131.

[8]. Lynch, B.D., H. Raghav, and W.T. Lin, "Economic Analysis of Micorcomputer Hardware". *Communications of the ACM*, 1990. **33**(10). 119-129.

[9]. Brynjolfsson, E. and C.F. Kemerer, "Network externalities in microcomputer software: An econometric analysis of the spreadsheet market". *Management Science*, 1996. **42**(12). 1627.

[10]. Rao, H.R. and B.D. Lynch, "Hedonic Price Analysis of Workstation Attributes". *Communications of the ACM*, 1993. **36**(12). 95-102.

[11]. Gandal, N., "Hedonic price indexes for spreadsheets and an empirical test for network externalities". *The Rand Journal of Economics*, 1994. **25**(1). 160.

[12]. TWNIC, Dynamic DNS Service to Resolve the Problem of Building Site with Dynamic IPs 2004,Taiwan Network Information Center http://www.twnic.net.tw/NEWS/374.html.