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Abstract

This paper examines network externalities in the Japanese market of routers. Although all routers adopt the same interface, i.e. TCP/IP protocol, implementation of the interface depends on the vendor. Thus compatibility of routers is not perfect among vendors. Cisco's implementation is said to be the de-facto standard owing to its overwhelming market share. This fact suggests that network externalities are at work in the router market. First we conducted a survey of major router users asking the reasons for vendor choice to examine network externalities. Results imply that network externalities work. Second we estimated a hedonic price model. Results show that share variable has a significant and positive effect on price, which suggests there are network externalities. However, the latest characteristic variable also has an effect on price sufficiently large as to overcome network externalities. Third we applied the logit model to router choice using individual users' choice data. Estimation results also show that share variable has a significant effect on choice probabilities.

Key Words: Network Externalities, Router, Internet, Hedonic Price Model, Discrete Choice Model

JEL Classification Numbers: D12, L11, L13, L96

1. Introduction

Following the rise of the Internet, the major mode of communication changed from voice telephony communication to data communication using IP packets. As a result, routers have largely placed telephone switches on major networks. Sales of routers in Japan rose from 55 billion yen to 217 billion yen from1995 to 2002.

In the router market, the market share of the incumbent vendor, Cisco, is extremely high. Cisco's share worldwide reaches around 80% and its profit rate is also extremely high and stable. Router market structure is clearly different from the telephone switch market in which there was no such dominant vendor. Why does Cisco keep a dominant position? Why cannot competitors take away part of the market from Cisco?

The goal of this paper is to explain the dominance of Cisco by network externalities.[1]

This paper proceeds as follows. Section 2 describes the router market in Japan; section 3 shows the results of the survey; section 4 and section 5 present results of estimations of network externalities using a hedonic price model and logit model respectively, and section 6 concludes.

Our result shows that network externalities seem to work in Japan's router market. However we do not separate switching costs from the network externality in this estimation. Thus our result is limited to the case in which switching costs are not so large as to overcome all effects.

2. Overview of the Japanese Router Market

Routers are equipment that route IP packets in the Internet network. Routers read IP addresses on the heads of IP packets and send packets to the next routers or other devices. Routers are usually classified into three

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[1] Few papers examine network externalities in the router market, although Forman and Chen (2003) focus on the market for routers and switches in the United States, especially concerning network effects and switching costs.

categories: high-end routers for carriers, mid-range routers for large companies and low-end routers for households or SOHO (small office and home office).   Following the rise of the Internet, the router market increased in all three categories.

Cisco kept high share level during the 1999-2001 period as shown in Figure 1.   Though it decreased slightly during this period, Cisco still kept more than 80% share in the high-end router market.   Its share in the mid-range router market is also over 70%.   It should be noted that a new entrant, Juniper, suddenly appeared and took some part of market share in 2001.

Not only share, but also profit rate of Cisco is high as shown in Figure 2.   Cisco's average profit rate is the highest, 20%, and its standard deviation is the lowest among major U.S. network equipment vendors as Figure 3 shows.   We found that Cisco's share is high and its profit rate is very stable and high in comparison with other vendors.

This fact is consistent with the results of a survey of the four major Japanese vendors in 2002.   Based on the survey we have two hypotheses for why Cisco is so profitable.   Hypothesis One is that the strength of Cisco comes from excellent management activities such as acquisition strategy, good distribution policy and marketing promotion   see Gawer and Cusumano (2001)).   Cisco finds the needs of users in advance of other vendors and develops/provides the product or service quickly.   If it has no time to develop new products by itself, it merges with other companies.   Cisco merged with 23 companies in 2000, two companies in 2001, and five companies in 2002.   Because other network equipment vendors, especially Japanese vendors, usually develop new products by themselves, they cannot respond in a timely way to users' needs.   Cisco's excellent management could generate its high share and profit rate.

Hypothesis Two is that the strength of Cisco can be explained by network externalities.   In the market in which network externalities work, only one standard can survive in market competition to become a so-called

de-facto standard.   Thus the company that controls the standard can be a monopolist.[2]

Network externalities in the router market come from two sources: incompleteness of compatibility of routers and availability of operational and technical expertise.

(1) Incompleteness of compatibility

Computers in the Internet network communicate using a protocol called TCP/IP.   TCP/IP protocols are standardized by the IAB (Internet Architecture Board) and IETF (Internet Engineering Task Force), which are subordinate organizations of the non-profit association called ISOC (Internet SOCiety).   Therefore, TCP/IP is an open standard and all routers can be compatibly connected to each other.   When standards are open, one company does not become dominant because of network externalities.

However, since implementation of TCP/IP protocol depends on vendors, interconnection is easier among the same vendor's routers. Therefore users tend to choose the vendor with the highest market share because outside routers to be connected are more likely to be the same vendor's routers.

(2) Availability of operational and technical expertise

Techniques and know how are necessary to operate routers. Techniques and know how depend on vendors, because operations (command line) and trouble shooting are different among vendors.[3]   Users can easily utilize operational techniques of the dominant vendor because there are many supporting materials such as mailing lists, BBS, and guide books pertaining to the vendor.   On the other hand, supporting materials for

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[2] See Rohlfs (1974) and Katz and Shapiro (1994)
[3] The vendor provides an interface that changes Cisco's command to its own command for Cisco users.   That means command lines are different from each other and implies that network externalities work.

small vendors' routers are not easy to obtain. Users therefore prefer the dominant vendors' products. Also, when the vendor is dominant there are plenty of technical experts in the market. Therefore users easily find technical experts if they use the dominant vendors.[4]

In addition, the presence of switching costs might contribute to stability of the share of Cisco. It is a natural hypothesis that switching costs are present in the router market because of incomplete compatibility. When compatibility is not perfect, it is rational for users to employ the same vendor through their network equipment. Extra adjustment costs are needed to connect one vendor's router to other vendor's. Theoretically speaking, switching costs are distinguished from network externalities because the degree of switching cost depends on users' router equipment history, not market share of the vendors. Even if the vendor's market share is only 2-3%, switching costs might be large when the user has purchased all routers from the vendor.

We tested network externalities in the router market in two ways: user survey and econometric analyses.

3. Survey of Vendor Choice

First we investigate through questionnaire surveys whether or not users recognize network externalities in router markets.

We chose heavy users of routers and sent a multiple-choice

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[4] We can see two other facts implying network externalities. One is that, in the low-end router market, Cisco's share is not so high (about 40%). That is because low-end router functions are simple and have no compatibility difficulties. Second, in the switch market Cisco's share is not so high. The functions of switches are simple, so compatibility is not such a big problem. Switches are used only inside LANs, so users do not consider which vendors other users use. In the low-end router market and switch market, network externalities do not work.

questionnaire asking about their reasons for vendor choice. We obtained 756 responses (64.1% response rate) from 1179 firms, Internet service providers (ISPs) and universities (see Table 1). The list of firms is composed of 207 finance companies and 649 listed firms with assets of more than 100 billion yen. The list of ISPs comprises 50 firms with no less than 10,000 subscribers and 51 randomly selected firms that do business nation wide. The list of universities comprises 99 national universities and 123 private universities. We conducted this survey in December 2002.

We showed them eight candidates of vendor choice reasons:

1 Compatibility with outside routers

2 Getting information from other users

3 Compatibility with inside routers

4 Accumulation of vendor expertise in your company

5 Functions or stability

6 Low price

7 Vendor support

8 Others

Choices 1 and 2 are network externality factors. Choices 3 and 4 are switching cost factors and choices 5 to 8 are quality and price; that is, ordinary characteristics of the product. We expect that choices 1 and 2 are chosen if network externalities work. The results for Cisco users and other vendor users are shown in Figure 4.

Figure 4 shows that about 20% of Cisco users choose network externality factors (choices 1 and 2), but only 5% of other vendor users choose these factors. Switching cost factors (choices 3 and 4) also are more important for Cisco users than for other users. On the other hand, function, stability and support (choices 5 and 7) don't show large differences. Twenty percent of other users choose low price (choice 6), as opposed to only 2.5% of Cisco users. In summary, users choose Cisco because of network externality factors and switching costs factors, and users choose other vendors because of their low price. This result implies that network

externalities work in the router market.

To see the behavior of independent expert users, we limited samples to only ISPs, which have needs for the latest technology.   Large companies tend to choose affiliate vendors and universities might choose routers for special reasons such as education or research.   But ISPs are independent and choose the most excellent product.

Figure 5 shows that over 50% of Cisco users choose vendors based on compatibility with other users.   Non-Cisco users choose functions or stability in addition to low price.   This implies that the quality of the product is an important factor for expert users and the network externalities are working even for the expert users with much technical knowledge of routers.

We should note that switching cost factors are also important for users.   The results show that Cisco's switching costs are larger than that of other users.   One of the reasons for this is that Cisco's products were introduced to the market long before other vendors.   Cisco users use Cisco products longer than other users, and switching costs depend on how long the user has used those vendor's products so far.

4. Hedonic Price Model

Some empirical researches examined network externalities using a hedonic price model.   Brynjolfsson and Kemerer (1996) and Gandal (1994) studied network externalities of spreadsheet software in the United States, and Tanaka (2002) examined the mobile phone market in Japan.   Asai and Tanaka (2003) studied the personal computer market in Japan.   Finally, Tanaka, Yasaki and Murakami (2003) estimated network externalities of spreadsheet software, word processing software, and routers in Japan.   If there are network externalities, users have more willingness to pay for products with a larger share.   Thus, if there is positive correlation between the share and the price, we can assume evidence of network externalities.

(1) Data

Details about variables used for estimations are as follows

PRICE: We obtained price from price lists of vendors in 2002. The price of routers depends on functional options. In this case, dependent variable is list price with full functional options. We chose products with system band width which indicates the ability of managing IP packets over 25 Mbps. Although retail prices are better data, we could not obtain these prices because the retail price is determined in the private negotiations between the vendor and users. Price variable is logged because its distribution is skewed to the right.

SHARE: Share represents network externalities. Unit base share (percentage) by vendor come from a user survey. To avoid the simultaneous problem we use one-year-lagged share. We expect that coefficient of share is significantly positive to support the presence of network externalities. The value of the coefficient indicates how much impact the network externalities have.

Characteristic variables: Functions of routers are broadly classified as basic functions, lines that the product supports, redundancy and quality of service (QOS) (see Table 2). All variables except for system bandwidth are dummy variables. The system band width variable is logged.

74 samples were obtained and about half of them are Cisco products (see Table 3).

(2) Results of regressions

The results of regressions are presented in Table 4. In case 1 all independent variables are included. In case 2 we reduced the independent variables until all coefficients were significant and with the expected sign.

The coefficient of SHARE, which measures network externalities, was positive and significant in both cases. The result of a robustness check of T value of SHARE coefficient is presented in Figure 6, which shows distribution of T value of SHARE coefficients for all combination of characteristic dummy variables. T value of SHARE coefficients is over 2 in most cases. Accordingly, network externalities as measured by vendor share significantly increase the price of router products. The coefficient of SHARE is 0.004 in case 2. That is, a one percent increase in share is associated with a 0.4% increase in price (70% difference in share means a 28% difference in price.) That difference of price is consistent with the results of our user survey.

However, the effect of network externalities is not overwhelming compared with other characteristic variables. The latest interface, POS OC-192, is highly evaluated by users and the coefficient of OC192 is 0.533 in case 2. That means introducing this new technology raises price roughly by 50%. Because coefficients of EGB, REDUNP and MPLS are also large, competitors could overcome Cisco by introducing such technologies in a timely manner. Juniper is said to have adopted such a strategy. It allocated resources to development of an ultra-high-end router and introduced new products with MPLS technology. Such a strategy succeeded and as a result Juniper gained some share, although it is a new entrant (see Figure 1: high-end router market structure). According to hearings to the vendors, carriers and very large ISPs needed a seriously high-end router, and Juniper met such needs first.[5]

This result suggests that network externalities work in the router market in Japan, although the effect is not overwhelming compared with new technologies.

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[5] It is said that MPLS was evaluated highly by telecom career and large ISPs . Cisco also had MPLS technology at that time, but Juniper succeeded to meet the demand more timely.

5. Logit Model

In recent years there are some empirical studies of network externalities using the logit model. Ohashi (2003) and Park (2003) estimated network externalities of the VCR market in the United States. Rysman (2003) showed that network externalities work in the market for Yellow Pages. They all employ the logit model and estimate its reduced form using share variable as a dependent variable. This form of the logit model was developed by Berry (1994). Because we have an individual data set from our user survey, we use an original, conditional logit model (see MacFadden (1974), Amemiya (1985)).

When choice probability of product j of user i is P_{ij}, P_{ij} is given by

$$P_{ij} = \frac{\exp(v_j)}{\sum_{k=1}^{J} \exp(v_k)}, \qquad v_j = \boldsymbol{b}X_j - \boldsymbol{a}p_j + \boldsymbol{g}S_{g|j \in g} .$$

X_j represents characteristic variables of product j. In this case, they are system bandwidth, number of supported lines, and quality of services of the product j. p_j is the price of the product j, and $S_{g|j}$ g is share in a previous year of vendor g which produces product j. In summary j is the net utility for product j. We choose , and to maximize the joint choice probability (most likelihood method). If the coefficient of share is significantly positive, it implies that network externalities work in the router market.

It is assumed that there is no correlation between utilities obtained from each choice in the conditional logit model. But this assumption is not realistic. For example, users who chose Cisco's product A will choose other Cisco products, not other vendors' products, when users cannot get product A. In such a case, the nested logit model is appropriate.

Products whose utilities are highly correlated are classified as the same group g. We assume that the grouping is based on the vendors. The

choice probability of group g, P_{ig}, and the choice probability of product j after choosing group g, $P_{i,j|g}$, are given by

$$P_{ig} = \frac{\left[\sum_{j \in g} \exp\left(\boldsymbol{n}_j / \boldsymbol{l}\right)\right]^{\boldsymbol{l}}}{\sum_{g=1}^{G}\left[\sum_{j \in g} \exp\left(\boldsymbol{n}_j / \boldsymbol{l}\right)\right]^{\boldsymbol{l}}}, \quad P_{i,j|g} = \frac{\exp\left(\boldsymbol{n}_j / \boldsymbol{l}\right)}{\sum_{k \in g} \exp\left(\boldsymbol{n}_k / \boldsymbol{l}\right)}.$$

The choice probability of product j, P_{ij}, is given by

$$P_{ij} = P_{i,j|g} \cdot P_{ig}.$$

   is a parameter of correlation within group g.   lies between 1 to 0.   As the parameter   approaches zero, the within group correlation goes to one. And as the parameter   approaches 1, the within group correlation goes to zero, which means that the nested logit model becomes equal to the conditional logit model.   (= 1-) can be interpreted as a correlation coefficient.

(1) Data

         Details about data used for estimations are as follows

Product *j* : Products with minor version changes are classified as the same product.   For example Cisco 3600, 3602, 3620 are regarded as the same product as Cisco36xx series.   As a result we have 17 products.

PRICEj: The list price of product *j* is used (unit is 10 million yen).   Average price is used when the product consists of several minor change versions.

SHAREg : One-year-lagged share of vendor *g* is used.   We obtained share

data from our user survey.

Characteristic variables : We use four characteristic variables whose coefficients in the hedonic price model are significant, LWAN, EGB, PRQ and MPLS (see Table 2).[6]

(2) Results of regressions

The results shows that the coefficients of nested logit model are more significant than those of the conditional logit model (see Table 5). Since the ramda, , is significant and is high (=1 - =1 - 0.232 = 0.768), there is a correlation within the same vendor choices. This implies that nesting makes sense.

The coefficient of SHAREg is positive and significant. Vendor's share of the previous period increases the current choice probability of the routers. We can interpret it as evidence of network externalities.

The coefficient of LWAN is not significant. EGB and PRQ increase significantly choice probability as expected. However, MPLS decreases significantly choice probability in contrast to expectations. That might be because MPLS is needed only by carriers and very large ISPs, not by most large firms.

The effect of SHAREg of the nested logit model is much larger than that in the hedonic price model. The coefficient of SHAREg in the nested logit model is 3.246. It means that if the difference of share is 70%, the effect of network externalities is 2.3 (= 3.246 × 0.7). Since it is too large compared with the effect of price, EGB and PRQ, new technologies or price reduction cannot overcome the network externalities effect. This result is not consistent with the results of the hedonic price model, which shows that new technologies can overcome network externalities effects.

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[6] We do not use OC192 as an independent variable in the logit model in spite of the results of the hedonic price model. That is because we obtained no sample that used routers with OC192.

One possible interpretation is that the value of estimation of the logit model is larger than true values, because switching cost effects are mixed. Users have difficulty changing vendors in the presence of switching costs, so users choose the same vendors in the next period with high probability even if there are not network externalities. The share variable here includes switching cost effects beside network externalities. Switching cost effects should be estimated separately to examine network externalities precisely.[7]

6. Conclusion

This paper conducted three analyses to examine the network externalities in the router market of Japan.

A user survey shows that users choose Cisco because of network externalities.

A hedonic price model shows that a 1% point larger share increases the list price by 0.4%. This can be interpreted as evidence of network externalities. Innovation, however, can beat the network externalities effect.

The logit model shows that share in the previous period increases the choice probability, which can be evidence of network externalities. But the estimated coefficient is much larger than that of the hedonic price model. This is because the switching cost effect is mixed. We should separate network externalities from switching cost.

In summary, we conclude that the dominant share of Cisco in the Japanese market for routers is partly explained by network externalities.

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[7] Another possibility is that Cisco products are chosen because of hidden characteristics. But it is not likely, because characteristics are not a reason to choose Cisco as shown in the Figure4 and Figure5. On the other hand, many Cisco users chose switching cost as an important choice factor.

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Figure 1   Share of Router Market in Japan (unit base)

High-End Router Market

Cisco ■ Juniper □ Others

Mid-Range Router Market

Cisco ■ Fujitsu □ Others
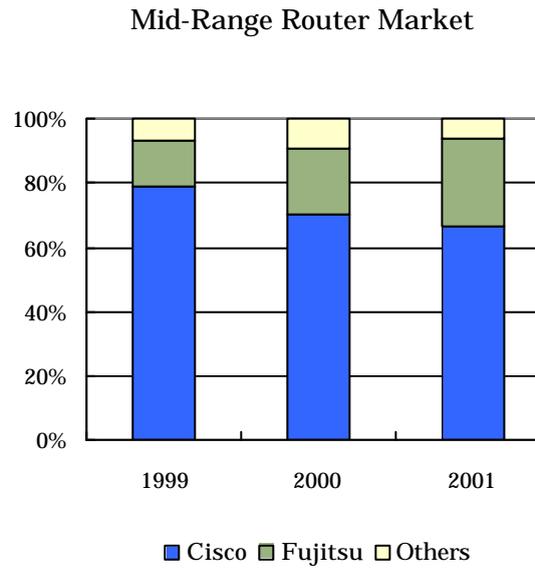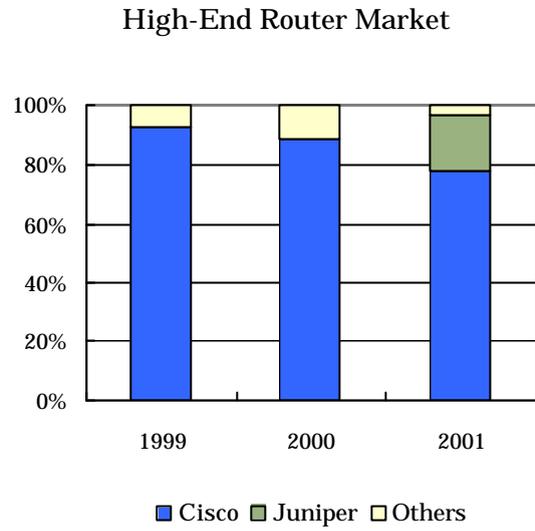
Source: Fuji Kimera Research Company

Figure 2 Profit Rate by Vendor ,1996-2002
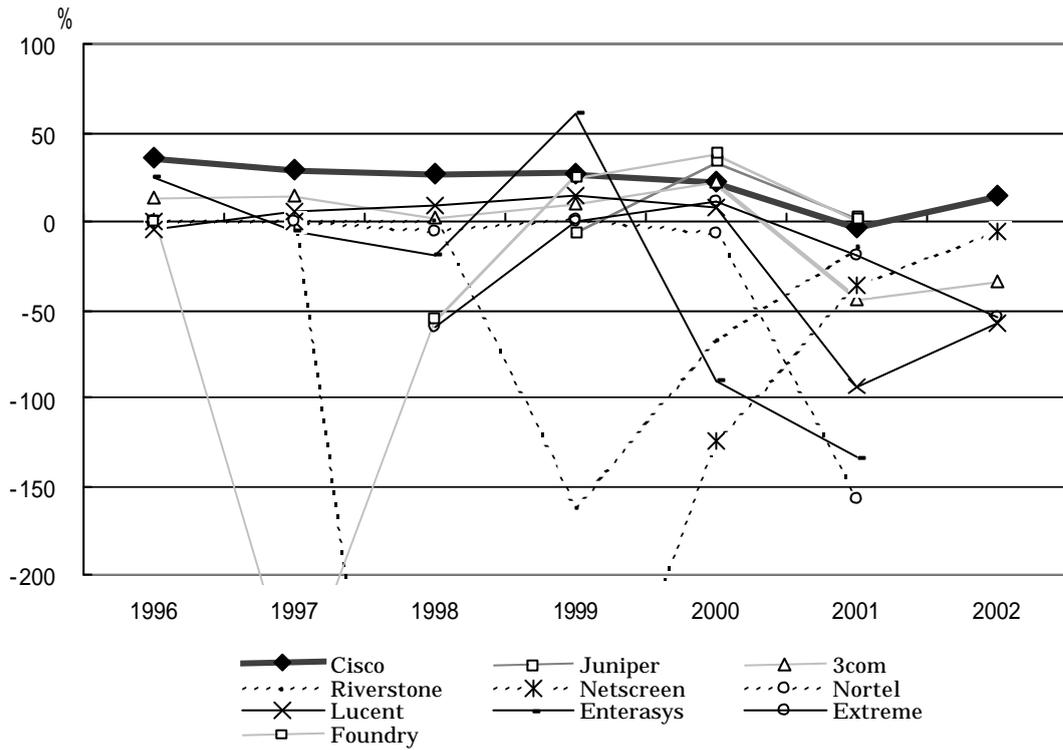
Note: Profit rate = (income before tax)/sales

Source: Data is available at http://:www.sec.gov.

Figure 3 Mean and Standard Deviation of Profit Rate by Vendor

Mean

(%)

50.00	
0.00	
- 50.00	
- 100.00	
- 150.00	
- 200.00	
- 250.00	

Cisco Juniper 3com Lucent Extreme Enterasys Nortel Foundry Riverstone Netscreen

Standard Deviation

250
200
150
100
50
0

Cisco Juniper 3com Extreme Lucent Nortel Enterasys Riverstone Foundry Netscreen

19
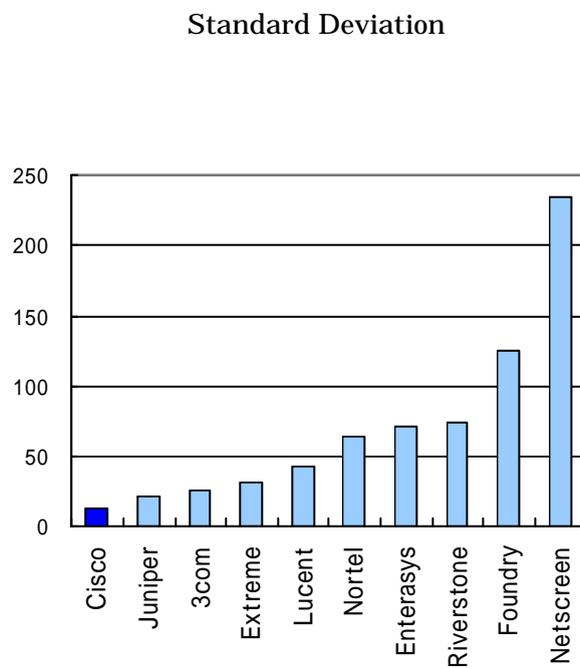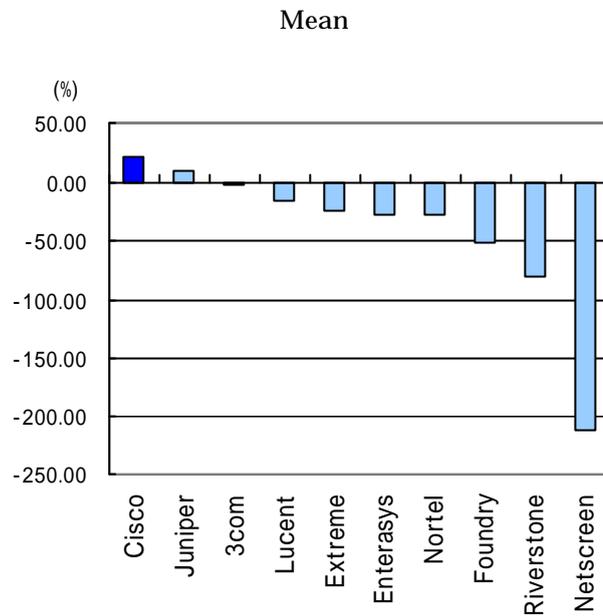
Figure 4 Results of User Survey (all samples)

Chart data:

Reason	Cisco users	Non Cisco users
Compatibility with outside routers	19.9	3.8
Getting information from other users	19.8	5.7
Compatibility with inside routers	23.2	16.7
Accumulation of vendor expertise in your company	30.8	13.1
Functions or stability	18.3	15.3
Low price	2.5	20.3
Vendor support	6	8.9
Other reasons	22	22.5

(%)

■ Cisco users □ Non Cisco users

Figure 5 Results of User Survey (ISPs only)

Compatibility with outside routers
- 14.6 (Non Cisco users)
- 54.9 (Cisco users)

Getting information from other users
- 27.1 (Non Cisco users)
- 31.9 (Cisco users)

Compatibility with inside routers
- 6.3 (Non Cisco users)
- 28.3 (Cisco users)

Accumulation of vendor expertise in your company
- 29.2 (Non Cisco users)
- 58.4 (Cisco users)

Functions or stability
- 62.5 (Non Cisco users)
- 38.1 (Cisco users)

Low price
- 31.3 (Non Cisco users)
- 2.7 (Cisco users)

Vendor support
- 16.7 (Non Cisco users)
- 3.5 (Cisco users)

Other reasons
- 6.3 (Non Cisco users)
- 9.7 (Cisco users)

0 10 20 30 40 50 60 70 (%)

■ Cisco users □ Non Cisco users

Figure 6 Robustness Check: T Value of SHARE Coefficient

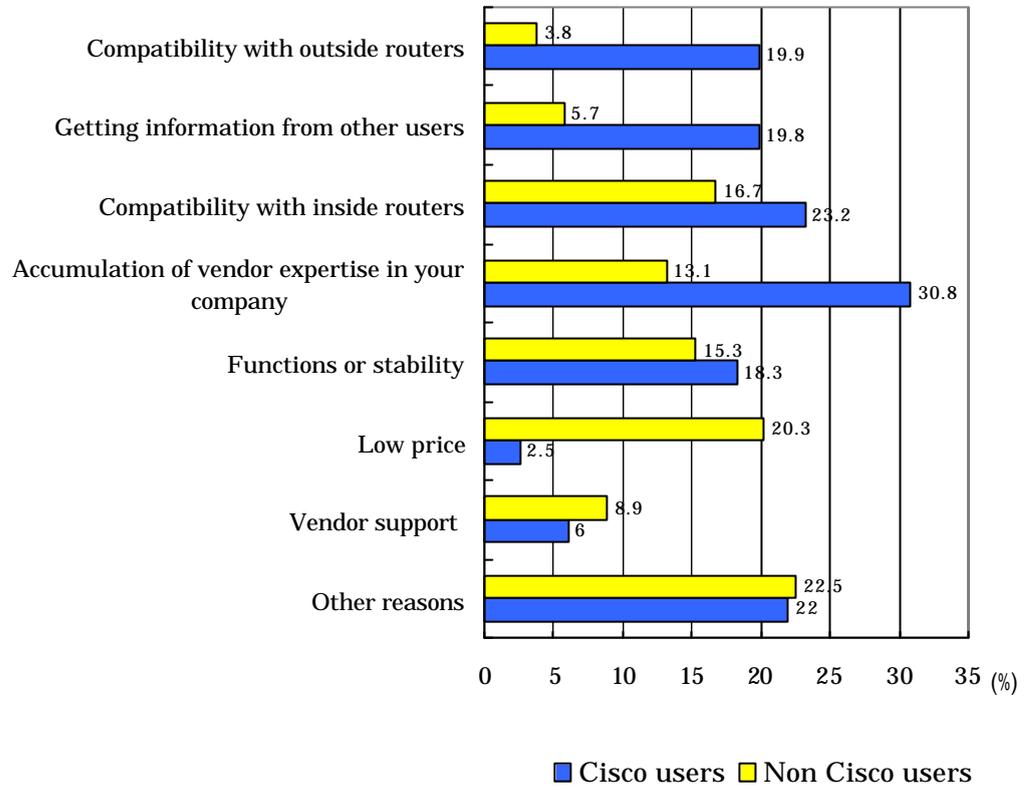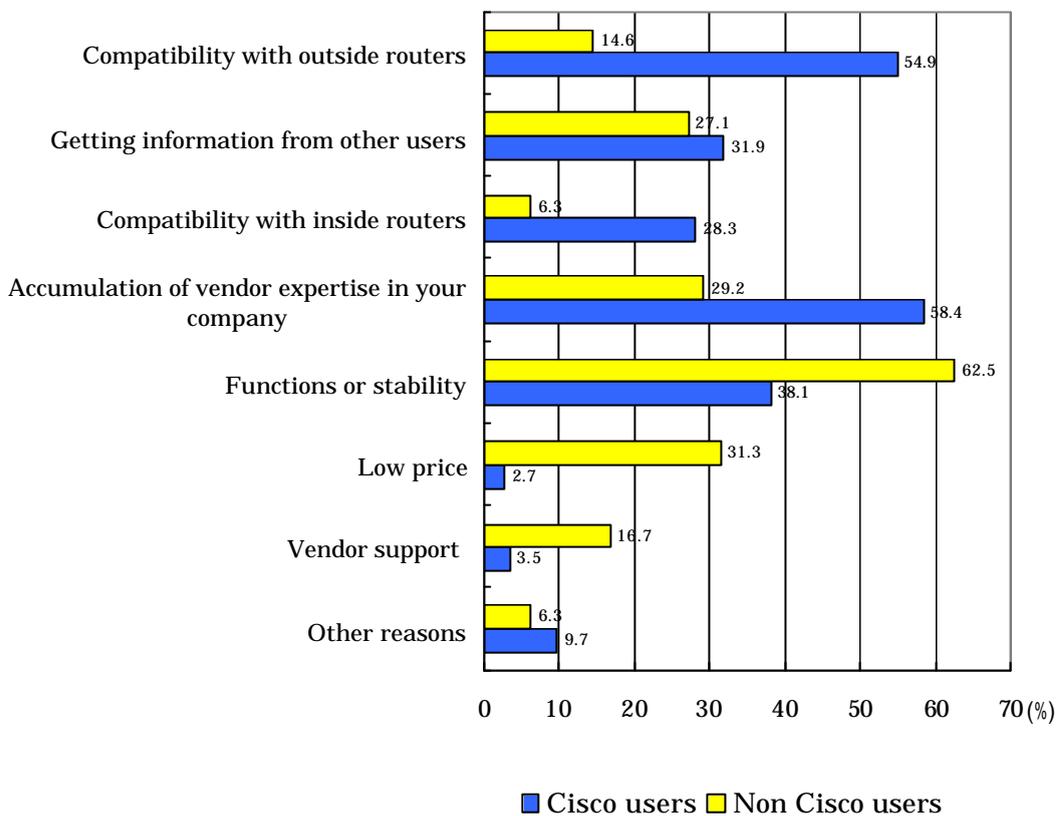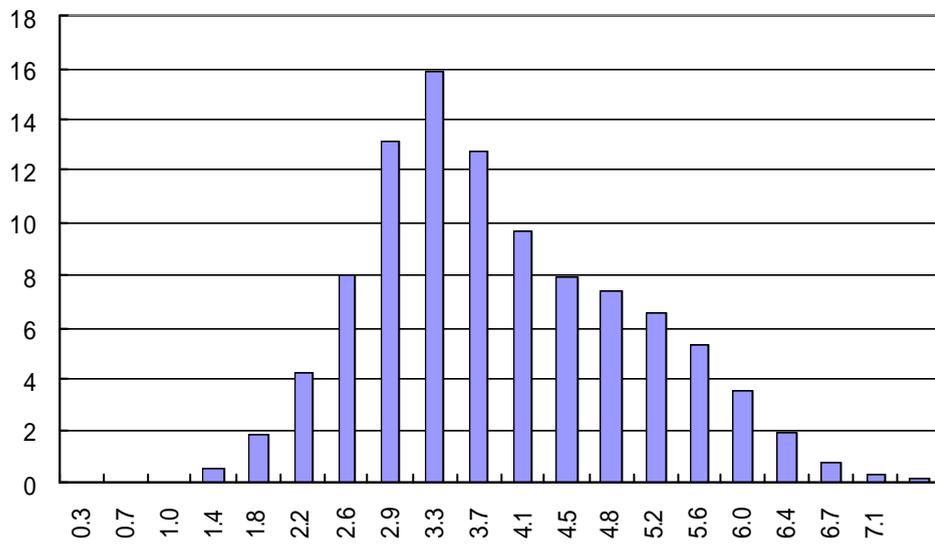Note: Constant, SHARE and LWAN are always included.   131071 (= 2^{17}-1) cases.

Table 1 Sample Distribution

	Sent	Replies
Large Companies and Universities	1078	712
ISP	101	44
Total	1179	756 (64.1%)

Table 2 Definition of Variables

	Variables	Code
Log of list price	ln (price (unit = 1,000 yen))	PRICE
Network externalities	lagged share (unit = percent)	SHARE
Basic	ln(system band (unit = Mbps))	LWAN
Line	POS-OC3	OC3
	POS-OC12	OC12
	POS-OC48	OC48
	POS-OC192	OC192
	ATM-OC3	ATMOC3
	ATM-OC12	ATMOC12
	ATM-OC48	ATMOC48
	Fast Ether	E100
	Gigabit Ether	EGB
	10 Gigabit Ether	E10GB
Redundancy	Power	REDUNP
	Routing	REDUNR
QoS and others	RSVP	RSVP
	IPv6	IPV6
	MPLS	MPLS
	Priority Queing	PRQ
	Class or Weighted Queing	CWQ
	RED	RED
	NEBS Reference	NEBS

Table 3 Sample Distribution by Vendor

Vendor	Data Points
Cisco	39
Fujitsu	9
Juniper	13
NEC	7
Hitachi	8
Total	76

Table 4 Results of Hedonic Price Model

Variable	Case 1 Coeff.	Case 1 T stats.		Casa 2 Coeff.	Casa 2 T stats.	
C	5.6126	13.62	***	11.93	55.89	***
SHARE	.0055	2.62	***	.004	2.85	***
LWAN	.2377	2.91	**	.335	7.62	***
OC3	.2901	1.47				
OC12	.1947	1.03				
OC48	.0423	0.15				
OC192	.7735	3.22	***	.533	2.50	**
ATMOC3	.0774	0.32	**	.223	4.38	***
ATMOC12	.2533	1.56				
E100	.003	0.01				
EGB	.444	2.25	***	.595	4.24	***
REDUNP	.8772	4.64	***	.602	3.69	***
REDUNR	.1483	0.58				
IPV6	-.9837	-2.83	***			
MPLS	-.9490	3.16	***	.522	2.97	***
RSVP	.253	.81				
PRQ	.7601	2.41	***			
CWQ	-.1388	-.32				
RED	-.3671	-.77				
NEBS	-.2156	-1.12				
n	76			76		
F	81.6503			162.715		
R^2	.9652			.9437		
Adjusted R^2	.9533			.9379		

** Significance at 5% level

*** Significance at 1% level

Table 5 Results of Logit Model

Variable	Conditional Logit			Nested Logit		
	Coeff.	T stats.		Coeff.	T stats.	
LWAN	-.004	-.07		.027	1.06	
PRICEj	-.148	-4.31	***	-.038	-3.32	***
EGB	.162	1.05		.327	6.90	***
PRQ	.781	2.05	**	.589	2.76	***
MPLS	-.528	-3.22	***	-.494	-8.70	***
SHAREg	2.866	11.55	***	3.246	18.64	***
				.232	8.95	***
n	356			356		
Log-likelihood	-2.5346			-2.3292		

** Significance at 5% level

*** Significance at 1% level