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Abstract

This paper examines the importance of compatibility on buyer behavior in the market for LAN equipment over the period 1996 through 1998. I provide evidence that switching costs drive firm establishments to purchase LAN equipment from incumbent vendors. Because LAN equipment is a networked good, incumbency affects vendor choice both when it occurs at the same establishment and/or at other establishments within the same firm. Moreover, compatibility across different product lines within the same vendor also influences vendor choice. This manifests itself in a buyer tendency to purchase routers and switches from the same vendor. These propositions are explored in data on purchases of LAN equipment utilizing open standards such as the Ethernet networking protocol, and represent the first econometric measurement of compatibility effects within products utilizing open standards. These findings show that there are strong economic incentives to offer broad product lines, and provide some rationale for the acquisition strategies of major vendors.

1 INTRODUCTION

A key component of the strategies of many manufacturers of computing networking equipment has been to offer broad product lines. Cisco Systems, Nortel Networks, and Lucent Technologies all pursued aggressive acquisition strategies in the latter half of the 1990s to become a "one stop shop" of networking gear. These firms believed the ability to provide a full line of routers, switches, and other networking gear would provide them with a competitive advantage over their competitors. In particular, Cisco has aggressively acquired other networking firms, most notably in the multibillion dollar acquisitions of firms like StrataCom ($4.7 billion), Cerent Corporation ($6.9 billion), and Arrow Point Communications ($5.7 billion), among others.

For such a strategy to be successful, several conditions must hold. First, it requires that incompatibilities across the products of different vendors create switching costs (Klemperer 1995) for buyers. Second, broad product line strategies depend on networking equipment being a network good that exhibits *network externalities*. The combination of switching costs and network externalities implies that legacy investments will affect not only a buyer's vendor choice for similar hardware, but also affects purchasing decisions across other products, so that, for example, an installed base in routers also influences switch vendor choice. Moreover, unlike most goods that exhibit switching costs, legacy investments across an *entire* organization influence vendor choice at a *particular* establishment in the firm.

Despite the importance of switching costs and networking externalities on product choice in hardware and software, there have been relatively few empirical papers that examine this phenomenon. Greenstein (1993) and Breuhan (1997) examine the role of switching costs on product choice in mainframes and PC software. Gandal (1994) and Brynjolfsson and Kemerer (1997) examine the effects of network externalities on spreadsheet prices, while Kauffman et al. (2000) examine how network externalities can create switching costs that inhibit adoption of a new electronic network in banking. More recently, several papers have examined switching costs and brand loyalty within the context of consumer behavior in electronic markets (e.g., Brynjolfsson and Smith 2001; Chen and Hitt 2001; Johnson et. al. 2000; Moe and Fader 2000).

This paper examines how product compatibility affects vendor choice in the market for routers and switches, two major classes of local area network (LAN) equipment. This paper contributes to the existing empirical literature on switching costs and network externalities in three ways.

First, the paper demonstrates how an existing installed base in one product can spill over and affect purchasing decisions in another. Previous work had examined switching costs in only a single-product environment. In particular, this work shows that as switches diffused widely throughout the late 1990s, the combination of switching costs and network externalities drove firms to purchase switches from their incumbent router vendor. Second, the paper shows that, within the context of multi-establishment firms, incumbency affects vendor choice both when it occurs at the same establishment and/or at other establishments at the same firm. These first two findings show that in networked information systems, the legacy problem is much more severe than commonly thought. Lock-in can occur due to prior investments of completely different products, or from the investments of other establishments within the same firm.

Finally, the paper shows how incumbency can influence vendor choice in a key component to IS infrastructure. LAN equipment has facilitated the rapid growth in the use of personal computers and the explosion in popularity of the Internet. Moreover, these products employed so-called *open standards* like TCP/IP or Ethernet protocols that are commonly supposed to facilitate interoperability across heterogeneous products. This research raises a caution flag for optimists who believe Internet protocols will greatly alleviate interoperability problems.

These hypotheses are tested by estimating a nested logit model of vendor choice. In this model, the probability of choosing a particular vendor is made a function of buyer characteristics and the extent of previous buyer-vendor interaction. To estimate these models, data from the Harte Hanks CI Technology database is used. The data set includes over 28,000 observations from firms in the finance and services sectors over the period 1996 through 1998.

As with most papers attempting to measure the importance of past behavior on current purchase decisions, this paper faces the econometric identification problem of disentangling the effects of *state dependence* versus *unobserved heterogeneity*.[1] Buyers may continue to purchase from the same vendor either because of vendor lock-in or because that vendor's product is particularly well suited to the buyer. This problem will be mitigated somewhat when cross-product incumbency effects are examined; unobserved heterogeneity is more likely to drive persistence in buyer behavior within rather than across products.

2 TECHNICAL BACKGROUND

Routers diffused widely with the founding of Cisco Systems in the 1980s. Routers are used to direct packets of information across a network; however, they also have functionality that also enables them to monitor and manage network traffic efficiently. This added functionality comes at a cost in the form of the additional time it takes for routers to route packets.

Switches were introduced in the mid-1990s in part as a solution to the cost and latency problems of routers. Like routers, switches are used to direct packets of information across a network. Their design often results in faster packet forwarding and lower hardware prices than routers, but without the added functionality of routers.

Because routers and switches perform the same basic function, routing data packets, they are sometimes used as substitute products. Despite relatively rapid diffusion of switches, few adopters of switching technology abandoned routers entirely. Most buyers of switches maintained some routers in their network, and most purchased routers concurrently with their switches. This is because the network management and security features of routers remained necessary. Routers, because of their added functionality, form the "brains" of the network. Thus, routers and switches are also commonly employed as complements.

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[1]This problem has been examined extensively elsewhere; for example, see Heckman (1981).

3 THEORETICAL BACKGROUND AND RESEARCH HYPOTHESES

Klemperer (1995) describes how a buyer's desire for compatibility between existing systems and new purchases can lead to switching costs when changing vendors. Switching costs can cause buyers to exhibit brand loyalty and so increase the likelihood of repeat purchases from incumbent vendors. Klemperer lists several types of such switching costs, although in the market for LAN equipment they are most likely to arise from two sources: (1) need for compatibility with existing equipment and (2) costs of learning new brands.

Klemperer also notes the potential effects of switching costs in multiproduct competition. If buyers value variety and prefer to purchase systems consisting of multiple components and if there are switching costs to purchasing products from different vendors, then vendors that sell single products only may be at a disadvantage to those who produce a full product line and who can enable buyers to avoid switching costs in multiproduct purchases.[2]

This theory leads us to expect several patterns of buyer behavior. The first hypothesis is that we expect buyers with an installed base of routers at the establishment to be more likely to purchase new routers from the incumbent vendor. Similarly, we expect switch incumbency at the establishment to affect a buyer's choice of switch vendor.

> *Hypothesis 1: Buyers face costs in changing router vendors. Buyers will be more likely to purchase from a router vendor with incumbency at the establishment, relative to an identical buyer without incumbency.*

> *Hypothesis 2: Buyers face costs in changing switch vendors. Buyers will be more likely to purchase from a switch vendor with incumbency at the establishment, relative to an identical buyer without incumbency.*

When buyers that are part of multi-establishment firms purchase networking equipment, they must be concerned not only with the local installed base of equipment at the buyer's establishment but also with the installed base of networking gear used throughout the firm. Thus, the second set of hypotheses is that installed base external to the site but within the firm will influence vendor choice.

> *Hypothesis 3: Buyers face costs in choosing a router vendor different from that installed in other establishments throughout the same firm. Buyers will be more likely to purchase from a router vendor with incumbency throughout the firm, relative to an identical buyer without incumbency.*

> *Hypothesis 4: Buyers face costs in choosing a switch vendor different from that installed in other establishments throughout the same firm. Buyers will be more likely to purchase from a switch vendor with incumbency throughout the firm, relative to an identical buyer without incumbency.*

The next two hypotheses relate to the effects of compatibility across products within the same vendor. Hypothesis five states that installed base in routers will influence the choice of switch vendor.

> *Hypothesis 5: Buyers face switching costs in choosing different router and switch vendors. Buyers will be more likely to purchase from a switch vendor with router incumbency at the site or throughout the firm, relative to an identical buyer without incumbency.*

Along the same lines, the costs of switching suppliers should influence vendor choice among buyers purchasing multiple products simultaneously, independent of installed base effects.

> *Hypothesis 6: Buyers face switching costs in choosing different router and switch vendors. Buyers purchasing routers and switches simultaneously will face costs of purchasing from different vendors.*

[2]Buyers may value variety if, for example, a vendor's products are horizontally differentiated heterogeneously across segments of the router and/or switch markets.

4 STRUCTURE OF THE MODEL

Buyers in this model are assumed to be individual sites within a firm. All sites i associate some utility with a choice j, U_j^i. Utility takes the form of a random utility model (e.g., McFadden 1981), $U_j^i = u_j^i + \varepsilon_j^i$. Thus, a site's utility for a choice is decomposed into two components: (1) a deterministic component u_j^i that is a function of site as well as choice characteristics and (2) an error term ε_j^i that is a residual that captures the effects of unmeasured variables.

A choice in the model consists of (1) a 0/1 decision of whether to purchase a router; (2) a 0/1 decision of whether to purchase a switch; (3) if a router is purchased, a choice of router vendor; and (4) if a switch is purchased, a choice of switch vendor. Buyers choose a router or switch vendor rather than a particular model of networking equipment. This is due to limitations with the data set, for the data do not identify model.

In this paper, the assumption is that utility is additively separable into components that vary with the decision to purchase a router (r), the decision to purchase a switch (s), the choice of router vendor (v), and the choice of switch vendor (w). Each decision j can be indexed by a quadruple subscript (r,s,v,w). Under these assumptions the utility function can be written as

$$U_j^i = \alpha' R_r^i + \beta' S_{r,s}^i + \gamma' V_{r,s,v}^i + \delta' W_{r,s,v,w}^i + \varepsilon_{r,s,v,w}^i$$

where α, β, γ, and δ represent parameters to be estimated and the vectors R_r^i, $S_{r,s}^i$, $V_{r,s,v}^i$, and $W_{r,s,v,w}^i$ represent variables affecting the decision to purchase a router and switch and the decisions of router and switch vendor, respectively. Following the literature on the nested logit model (e.g., McFadden 1981), we assume that the error term $\varepsilon_{r,s,v,w}^i$ follows a generalized extreme value distribution. I further assume that the decision process can be nested according to Figure 1.

The joint probability of a particular choice j in this model will be

$$P_j^i = P_r^i P_{s|r}^i P_{v|s,r}^i P_{w|v,s,r}^i$$

where P_j^i is the joint probability of choosing a particular (r,s,v,w) combination, P_r^i represents the marginal probability of purchasing a router, $P_{s|r}^i$ is the probability of purchasing a switch conditional on router choice, $P_{v|s,r}^i$ is the conditional probability of purchasing from a particular router vendor, and $P_{w|v,s,r}^i$ is the conditional probability of purchasing from a switch vendor.

The generalized extreme value distribution implies that given choices (r,s,v), the conditional probability of making a choice of switch vendor w^* takes the following form:

$$P_{w^*|v,s,r}^i = \frac{\exp(\delta' W_{r,s,v,w^*}^i)}{\sum_{w \in C_{v,s,r}} \exp(\delta' W_{r,s,v,w}^i)} \quad [1]$$

where $C_{v,s,r}$ denotes the set of choices available to the buyer at the node defined by (v,s,r).

At the next level up, the probability of choosing router vendor v^* will be

$$P_{v^*|s,r}^i = \frac{\exp(\gamma' V_{r,s,v^*}^i + \lambda I_{r,s,v^*}^i)}{\sum_{v \in C_{r,s}} \exp(\gamma' V_{r,s,v}^i + \lambda I_{r,s,v}^i)} \quad [2]$$

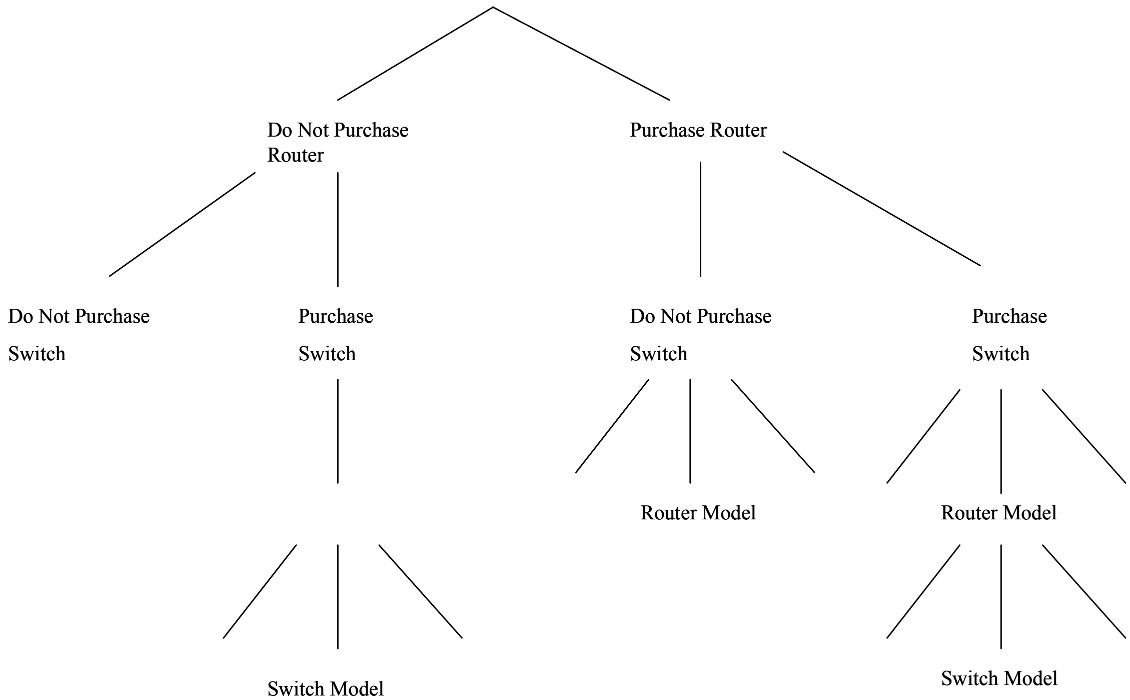
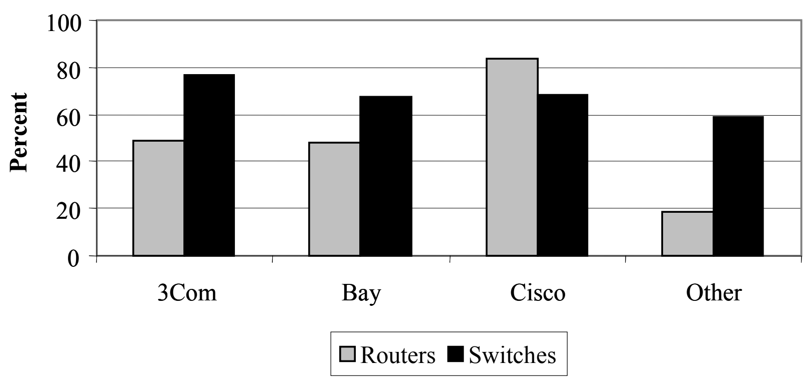


Figure 1. Networking Gear Choice Model

where $I^i_{r,s,v} = \log\left[\sum_{w \in C_{r,s,v}} \exp(\delta' W^i_{r,s,v,w})\right]$ is the inclusive value, the expected aggregate value of choice *v*. The coefficient on the inclusive value, λ, measures the dissimilarity of alternatives available to the buyer given different choices *v.* McFadden (1981) has shown that the choice structure given by Figure 2 is consistent with expected utility maximization if and only if the inclusive value parameter in [2] lies within the unit interval.

The choice probabilities $P^i_{s|r}$ and P^i_r are constructed analogously to [2], with inclusive values from lower levels of the tree serving as components of the expected utility of upper level choices. I estimate the model using sequential maximum likelihood.



Notes: Sample is 1996-1998. Shows conditional probability of purchasing from incumbent vendor in a year, among those sites purchasing routers and switches. Other includes all vendors besides 3Com, Bay Networks, and Cisco (including Cabletron).

Figure 2. Loyalty Rates for Routers and Switches

5 DATA

5.1 Sample

Data on technology usage was obtained from the CI Technology Database (hereafter CI database) over the period 1995 through 1998. The unit of observation in the CI database is a site.[3] To keep the analysis of manageable size, data was obtained from the CI database on SIC codes 60-67 (Finance, Insurance, and Real Estate), 73 (Business Services), 87 (Engineering, Research, Management, and Accounting), and 27 (Printing and Publishing). The sample contains data on all sites of over 100 employees from the CI database over the sample period. All sites are from the United States.

An observation in the database contains the stock of technology goods installed at the site. To infer purchase decisions, the change in quantity installed from year to year for each vendor is calculated. Unfortunately, the data do not contain model information on LAN equipment, so the particular model purchased cannot be identified.

Because of missing data, many observations had to be dropped. Sites that were not in the database for two consecutive years and for which inferences on purchase quantities could not be made were dropped. For many smaller vendors in the database, the number of purchase observations was too small to estimate the effects of installed base; sites purchasing from or who had an installed base from these smaller vendors were dropped. The vendor decision of firms that purchased routers from 3Com, Bay Networks, and Cisco and that purchased switches from 3Com, Bay Networks, Cabletron, and Cisco were examined

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5.2 Variables

Variables in the model can be divided into three categories: (1) those influencing the vendor decision directly and that indicate the degree of prior buyer/vendor interaction; (2) those influencing the vendor decision directly and that control for buyer heterogeneity; and (3) those influencing the decision of whether to purchase a router or switch.[4] This section describes the first set of variables. Descriptions of the second set of control variables are included in Table 1.[5]

The variables *IRTR* and *ILSW* are dummy variables indicating that the site has an installed base of routers and switches from a particular vendor. These variables will measure the importance of incumbency at the site level. If previous buyer-vendor interaction has an important effect on vendor choice, then we expect that the coefficients on these variables will be positive. The variables *PCLSW* and *PCRTR* are defined as the percentage of a particular vendor's switches and routers installed throughout *a firm*. Thus, these variables test whether firm-wide (as opposed to site-wide) installed base effects are important.

The variable *RSCOMP* measures potential effects of compatibility within a vendor's product line. *RSCOMP* is an indicator variable that is one when a choice includes the same router and switch vendor. If product compatibility across routers and switches is important to buyers when making a vendor choice, then we should expect the coefficient on this variable to be positive if there are costs to having different router and switch vendors.

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[3]See section 6 for a description of site.

[4]Unfortunately, information on router list or transaction price is not available. Variations in price, as well as any incentives vendors may provide to reduce buyer switching costs, will be absorbed in the vendor-specific constant. They will influence the unobserved component of the model only insofar as relative price varies across products or incentives vary across customers for a particular vendor.

[5]To conserve space, descriptive statistics on the third set of variables, those describing the decision to purchase, are not included. These variables included information on the size of installed base of routers and hubs, the change in the number of network nodes, the types of Internet applications used, dummies indicating used of advanced networking technologies (e.g., FDDI or fast Ethernet), industry dummies, and year dummies. Also, the results from the first and second stages of the model that estimate factors determining whether the site will purchase are not reported.

Table l. Means, Standard Deviations, Minimums, and Maximums for Sample

	Description	Mean	Standard Deviation	Minimum	Maximum
Variables measuring previous buyer/vendor interaction					
IRTR	Indicates installed base of routers at site	0.020	0.141	0	1
ILSW	Indicates installed base of switches at site	0.003	0.054	0	1
PCRTR	Percentage of vendor's routers installed in firm	0.075	0.241	0	1
PCLSW	Percentage of vendor's switches installed in firm	0.025	0.142	0	1
RSCOMP	Indicates choice of identical router and switch vendor	0.150	0.357	0	1
Variables measuring buyer heterogeneity					
DHQ	Indicates site is firm-wide or regional firm headquarters	0.125	0.331	0	1
STIME	Indicates second-time purchaser of networking gear	0.079	0.270	0	1
TOTNODES	Total network nodes	148.0	360.8	0	15,691
TOTPROT	Total network protocols	0.780	0.679	0	6

Source: Harte Hanks Market Intelligence and author's calculations

6 RESULTS

6.1 Univariate Statistical Evidence

Figure 2 shows the loyalty rates of corporate sites that are purchasing routers and switches. A site represents an individual geographic location within a firm, and is similar to the concept of establishment used in government statistics. A loyalty rate shows the conditional probability of purchasing from the incumbent vendor, given that the site is purchasing routers or switches that year.

For each of the "Big Three" vendors of 3Com, Bay Networks, and Cisco, loyalty rates for routers and switches are quite high, ranging from 47.8 percent to 83.5 percent in routers and from 67.3 percent to 76.5 percent in switches. Loyalty rates for routers of other vendors are low; many of their buyers eventually migrated to Cisco. Loyalty rates for switches of other vendors are higher.[6] In all, simple univariate analysis suggests buyer patterns are consistent with hypotheses 1 and 2.

Table 2 shows the distribution of vendor choices for buyers who jointly purchase routers and switches, and provides some evidence for hypothesis 6.[7] The table shows that among sites purchasing from one router vendor and one switch vendor, roughly 46 percent buy from the same vendor.[8]

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[6]The variance in loyalty rates for routers is greater than that for switches because some establishments with an installed base in Bay, 3Com, or other routers migrated to Cisco over the sample period. This was in part because many of the vendors in the other category exited the market.

[7] To be precise, the table shows the distribution of purchases from buyers purchasing one router and one switch. Results from sites purchasing from multiple router and switch vendors are qualitatively similar, however are difficult to display in tabular form.

[8]Note that this 46 percent is less than the percentage of observations along the diagonal because some purchases in the other category may include vendors different than the vendor the establishment has in its installed base.

Table 2. Frequency of Vendor Choice Among Firms Making Joint Router and Switch Choices, 1996-1998

Router/ Switch Vendor	*3Com*	*Bay*	*Cisco*	*Other*
3Com	50	2	0	4
	89.3%	3.6%	0%	7.1%
Bay	6	59	7	9
	7.4%	72.8%	8.6%	11.1%
Cisco	70	71	156	109
	17.2%	17.5%	38.4%	26.8%
Other	18	10	3	22
	34.0%	18.9%	5.7%	41.5%

Source: Harte Hanks Market Intelligence and author's calculations
Notes: First row of line provides frequency. Second row of line shows probability of purchasing from switch vendor conditional on concurrently purchasing from router vendor.

6.2 Parameter Estimates

Table 3 presents the parameter estimates of the nested logit model.[9] To conserve space, only the results from the router and switch vendor decision are presented. These results depict the vendor decision, conditional on the decision to buy routers and/or switches. The coefficients on the variables measuring prior buyer-vendor interaction are allowed to vary based on whether the buyer is a standalone site or part of a larger firm. The model is estimated over the entire sample period.[10]

The middle column of Table 3 shows the parameter estimates from the lowest level of the nested logit model, the one that indicates switch vendor choice. The presence of an incumbent switch vendor appears to have an important effect on a buyer's decision, providing support for hypothesis 2. Firm-wide incumbency may also play a role in the switch vendor decision, as shown by the variable *PCLSW*, however the effects are weaker and just barely insignificant at the 10 percent level. Thus, the coefficient estimates provide some support for hypothesis 4.

Hypothesis 5 suggests that the presence of an incumbent router vendor may also have an effect on the switch vendor decision. The effect of router vendor incumbency at a site (*IRTR*) is significant; however, it is less powerful than the effects of switch incumbency. Firm-wide router incumbency (*PCRTR*) appears not to be important in determining a site's switch vendor. Because firm branches are most likely to connect to other sites and to the outside world through routers (rather than switches), the insignificance of firm-level effects on switch vendor choice are unsurprising.

Further confirming the importance of vendor product-line compatibility and providing evidence in support of hypothesis 6 is the coefficient on the variable *RSCOMP*. *RSCOMP* shows that sites purchasing routers and switches simultaneously are likely to purchase them from the same vendor. The variable is a "one-way" measure of the importance of compatibility, i.e., router vendor choice may feed into the simultaneous decision of switch vendor but not the other way around. However, because of the structured way in which networks are commonly built, this limitation is not a major concern.

[9]A potential problem with use of the nested logit model is that the order in which decisions are nested determines the error process and can affect estimation of the parameters. The model was estimated according to an alternative nesting structure in which router decisions are nested beneath switch decisions, however one of the inclusive value parameters was outside of the range consistent with utility maximization. Based on this evidence and because strong priors exist that the error structure consistent with Figure 1 is the correct one for this model, the results from the baseline model of Figure 1 are presented. The results of the model with this alternative nesting were also consistent with hypotheses 1 through 6.

[10]Year dummies are included in the first two stages of the model.

Table 3. Results from Demand Estimation: Choice of Router and Switch Vendor

Variable	Switch Vendor	Router Vendor
Variables measuring prior vendor interaction: standalone sites		
ILSW	1.6825**	. . .
	(0.4224)	. . .
IRTR	1.0093**	2.7147**
	(0.2693)	(0.4617)
RSCOMP	1.3109**	. . .
	(0.2158)	. . .
Variables measuring prior vendor interaction: multi-establishment firms		
ILSW	1.9066**	. . .
	(0.3506)	. . .
PCLSW	0.4403	. . .
	(0.2682)	. . .
IRTR	0.6577**	0.7380**
	(0.2787)	(0.2660)
PCRTR	0.0008	1.6999**
	(0.2726)	(0.2023)
RSCOMP	1.5241**	. . .
	(0.1712)	. . .
Variables measuring buyer heterogeneity		
DBAY	-0.1863	0.2684
	(0.2965)	(0.3345)
DCAB	-1.7680**	. . .
	(0.3744)	. . .
DCIS	-1.3139**	2.0704**
	(0.3152)	(0.2811)
DBAY × TOTNODES	0.0444**	0.0408*
	(0.0206)	(0.0242)
DCAB × TOTNODES	0.0410*	. . .
	(0.0235)	. . .
DCIS × TOTNODES	0.0733**	0.0419*
	(0.0194)	(0.0223)
DBAY × TOTPROT	-0.1520	-0.0678
	(0.1739)	(0.1971)
DCAB × TOTPROT	0.3027	. . .
	(0.1954)	. . .
DCIS × TOTPROT	0.0063	-0.2417
	(0.1647)	(0.1629)
DBAYS × TIME	0.0617	-0.7952**
	(0.2471)	(0.3624)
DCABS × TIME	0.6195**	. . .
	(0.3055)	. . .
DCISS × TIME	0.4885*	-0.7424**
	(0.2794)	(0.2987)
DBAY × DHQ	0.1713	0.5322
	(0.2950)	(0.3739)
DCAB × DHQ	0.3373	. . .
	(0.3520)	. . .
DCIS × DHQ	-0.2566	0.1469
	(0.3045)	(0.3321)

Variable	Switch Vendor	Router Vendor
INCL VALUE		0.7155** (0.3270)
N	28,088	28,088
Log-Likelihood	-713.0412	-577.8143

Source: Harte Hanks Market Intelligence and author's calculations.
Notes: *Indicates significance at 10% level. **Indicates significance at 5% level. Missing variables in router decision because there is no Cabletron interaction term.

The parameter estimates from the third level of the model, indicating router vendor choice, are depicted in the far right column of Table 3. In this level, variables measuring the effects of switch installed base on router purchases are not included. The reason is that because routers are more complicated than switches, the expectation is that product compatibility issues arising from an installed base of switches will be relatively unimportant.[11]

Router incumbency appears to have had an important impact on the router vendor decision. Among standalone sites, the importance of router vendor incumbency was strong and significant. Vendor incumbency at the site was significant although somewhat less important for sites that were part of a larger corporation; however, combined with firm-wide incumbency effects (*PCRTR*), the impact of vendor incumbency was very similar (2.438 vs. 2.715 for sites within firms that have an installed base comprised completely of one vendor). Thus, there is strong support for hypothesis 1. Firm-wide incumbency also appears to have an important effect on router vendor choice, providing support for hypothesis 3. Because branch office routers must be able to frequently communicate with other sites within the firm, this result is expected.

6.3 The Effects of Compatibility

The effects of incumbency vary with a site's characteristics. To measure the effects of incumbency while controlling for site heterogeneity, the parameter estimates of the above model are used to simulate the probability of choosing a particular router and switch vendor with and without vendor incumbency at the site level. Thus, the simulations show the impact of changing one factor—site-level vendor incumbency—on vendor choice. These simulations are performed for all sites purchasing routers and/or switches; sites that do not purchase networking gear are not included in the simulations. Tables 4 and 5 present the sample means of these simulations. Both tables examine the effects of incumbency when the site is and is not jointly purchasing routers and switches.

Table 4 examines the effects of site-level incumbency on the router vendor decision. It shows that, depending on the circumstances, vendor incumbency increases the probability of purchase from 14 percent to over 25 percent. Cisco incumbency at a site virtually ensures that a buyer will purchase Cisco again. Simulations showing firm-level effects (not included) showed similar results.

Table 5 shows the effects of site-level incumbency on switch purchases. Simulations showing firm-level effects showed similar results. The effects of incumbency on vendor choice are dramatic. The smallest mean increase in probability associated with incumbency is 27.4 percent. In most cases, the increase in probability is above 34 percent.

Table 5 shows something else of note. The distribution of switch market shares differs widely depending on whether a site is concurrently purchasing a router.[12] Firms concurrently purchasing a router are much more likely to purchase from Cisco and less likely to purchase from other vendors. Cabletron in particular fares poorly among sites simultaneously purchasing routing gear.[13] This result suggests that broad product lines are important, and is consistent with the strategy of major vendors to obtain switching

[11]This hypothesis was affirmed empirically in regressions that included the effects of switch installed base.

[12]Strictly speaking, of course, these probabilities do not represent true market shares, as they only represent probabilities of purchasing from a particular vendor, and do not include the effects of quantity or value at all. Still, they represent an important point.

[13]The low likelihood of Cabletron switch purchase among firms purchasing routers is compounded by the fact that observations in which firms purchased Cabletron routers were dropped. However, because the number of such observations was so low (see footnote 8), the bias created should be small.

Table 4. Effects of Incumbency at Site Level on Router Purchases

A. Sites not concurrently purchasing switch

Vendor	Probability with Incumbency	Probability without Incumbency
3Com	0.313	0.094
Bay Networks	0.391	0.142
Cisco	0.906	0.764

B: Sites concurrently purchasing switch

Vendor	Probability with Incumbency	Probability without Incumbency
3Com	0.336	0.110
Bay Networks	0.412	0.159
Cisco	0.888	0.731

Source: Harte Hanks Market Intelligence and author's calculations.
Notes: Probabilities calculated for sites purchasing routers in the given period. Probabilities represent sample means of probability of purchasing from vendor given that the site does and does not have an installed base with the vendor in question.

Table 5. Effects of Incumbency at Site Level on Switch Purchases

A: Sites not concurrently purchasing router

Vendor	Probability with Incumbency	Probability without Incumbency
3Com	0.699	0.304
Bay Networks	0.709	0.298
Cabletron	0.530	0.162
Cisco	0.614	0.236

B: Sites concurrently purchasing router

Vendor	Probability with Incumbency	Probability without Incumbency
3Com	0.579	0.230
Bay Networks	0.610	0.254
Cabletron	0.360	0.086
Cisco	0.761	0.431

Source: Harte Hanks Market Intelligence and author's calculations.
Notes: Probabilities calculated for sites purchasing switches in the given period. Probabilities represent sample means of probability of purchasing from vendor given that the site does and does not have an installed base with the vendor in question.

technology through acquisition. The results of Table 5 suggest that such firms may have been correct in their assessment of the importance of having a broad product line.

7 CONCLUSION

This paper examines the effects of compatibility on buyer choice in the market for LAN equipment. It shows that even controlling for buyer heterogeneity, the presence of an installed base of equipment affects the choice of vendor when purchasing routers and switches. Prior research is extended by showing that switching costs can assume a particularly harmful form when combined with network externalities. In such an environment, switching costs not only influence within-product choices at an establishment, but also reach across establishments and across product lines. Moreover, the paper shows that the use of open standards such as Ethernet or TCP/IP has done little to mitigate this problem. This finding confirms the demand-side incentive for the aggressive acquisition strategies pursued by some networking vendors. For IS executives, it also has potentially worrisome consequences for the future of the legacy problem in a networked world.

These initial results suggest several potential avenues for future research. One aspect of the buyer-vendor relationship left unexplored in this paper is the role of third-party network managers and IT outsourcing on vendor choice. IT outsourcing may strengthen the effects of incumbency if third-party firms are associated with particular vendors; alternatively, third-party network managers or designers may be able to help their clients overcome switching costs. Another potential course would be to examine the effects of switching costs on the diffusion of switching technology. The framework and data used here are well-suited to address these questions.

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