Scope and Timing of Deployment: Moderators of Organizational Adoption of the Linux Server Platform

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Abstract: Market selection of product compatibility standards has long been explained through aggregate positive-feedback theoretical models of economic utility. Explaining aggregate patterns of organizational standards adoption requires two additional steps — not only differences between organizations, but also differences within organizations.

Here we present a qualitative study of how organizations do (or do not) adopt a new computer server platform standard, namely Linux using PC-compatible hardware. While discussions of Linux typically focus on its open source origins, our respondents were primarily interested in low price. Despite this relative advantage in price, incumbent standards enjoyed other advantages identified by prior theory, namely network effects and switching costs.

We show when, how and why such incumbent advantages are overcome by a new standard. We find that Linux adoption within organizations began for uses with a comparatively limited scope of deployment, thus minimizing network effect and switching costs disadvantages. We identify four attributes of information systems that potentially limit the scope of deployment: few links of the system to organizational processes, special-purpose computer systems, new uses and replacement of obsolete systems. We also identify an organizational level variable — internal standardization — which increases scope of deployment and thus the attractiveness of the incumbent standard.

Keywords: standards adoption; network effects; switching costs; computing platforms; MIS decisions; open source

1. INTRODUCTION

Economic theories have suggested how individual consumers make decisions between two or more *de facto* product compatibility standards. Positive network effects — mediated by the supply of third party complements — make the more popular standard more attractive to potential adopters (Katz and Shapiro, 1985, 1986). However, in many cases, adopters choose standards (or their associated products) for much simpler reasons — they have a relative advantage on some dimension of price, performance or features (Liebowitz & Margolis, 1994, 1997).

The research on network effects generally examines choices between contemporaneous standards rather than successive generations (see Sheremata, 2004 for a rare exception). However, potential users often consider adoption of a new standard in light of an investment in a prior standard, with switching costs discouraging adoption of a new standard (Klemeper, 1989; Greenstein, 1993). Given the advantages incumbent standards generally hold in network effects and prospective switching costs, a new standard must enjoy some relative advantage on another dimension to attract new adopters. For example, successive generations of videogame consoles displaced investments in earlier consoles and software libraries by offering superior graphics and realism of play (Gallagher & Park, 2004).

Within this accepted theory, there are some gaps in our knowledge. *De facto* competition models tend to cover aggregate decisions of rational individual adopters, and do not suggest which adopters will be the first to adopt. Based on an empirical study of organizational information technology (IT) standards, we suggest that there are at least three ways in which organizational standards adoption differ from consumer ones. First, such organizational standards decisions involve multiple decision-makers and perspectives. Also, a large organization will typically employ multiple standards simultaneously. Finally, there are important differences in the attractiveness of a new standard. between systems within a single organization.

To try to explain such differences both between and within organizations, we focus on two research questions:

- *First*, how do organizations adopt new standards?
- *Second*, how can a new standard can get adopted despite the network effects and switching costs that favor a successful incumbent technology?

As an example of an organizational standards decision in which a new standard has recently gained broad acceptance in the face of established incumbent technologies, we consider the selection of server platform standards. Using a qualitative study of management information systems (MIS) departments in 14 organizations, we look at the choice between three major server platforms: Windows, proprietary Unix, and Linux-based systems. Using inductive theory generation, we generate a set of propositions about factors that directly or indirectly influence organizational IT standards adoption.

We identify a new construct — scope of deployment — which considers the degree to which the adoption decision is coupled to other internal and external factors, including the organization's IT architecture, business processes and supply of third-party complements. We show how the scope of deployment moderates the impact of external network effects and internal switching costs, in that new standards are most likely to be adopted for uses with a limited scope of deployment. We also suggest that the goals of internal technology standardization directly conflict with the opportunities offered by trial adoption of new standards.

2. THEORY

Research that directly considers how organizations adopt of IT standards is comparatively rare (see West 1999 and Hanseth and Braa, 2000 for notable exceptions). However, we can draw on two related literatures. The first considers the economic motivations for standards adoption, originally arrived from atomistic theories of individual consumers. The second focuses on organizational technology adoption, but often ignores the key factors (such as the hardware-software paradigm) that drive standards adoption in the eonomics literature.

2.1 Economics of standards

To explain adoption decisions made between two or more competing technology standards, the most influential stream of research is that on the economics of standards. Such research identifies the roles of positive network effects and switching costs in cementing the lead of an established standard, with both effects mediated through the provision of specialized complementary assets (such as software libraries). Early and oft-cited examples of this stream include Katz and Shapiro (1985, 1986), Farrell and Saloner (1985), Teece (1986) and David (1987).

One benefit accruing to producers of established standards is the presence of "switching costs." Among the first to consider such costs was von Weizsäcker (1984), who modeled how users would consider the net present value of anticipated future switching costs. Klemperer (1987) classified switching costs into three categories: transitory transaction costs, learning costs (e.g. IT worker skills), and contractual costs (e.g. contract termination penalties) deliberately introduced by vendors to build barriers to subsequent competitors. The exploitation of these costs by vendors has been referred to as "lock in" (Shapiro and Varian, 1999) or "groove in" (Arthur, 1996).

The other hypothesized factor in the economics of standards adoption is the role of positive network effects that accrue to all adopters of a popular standard.[1] Katz & Shapiro (1985) showed how an indirect network effect — the availability of software to support a given hardware standard — would make the more popular standard more attractive to future adopters. Both network effects and switching costs for a given standard are increased for products which require complementary assets (such as software) that must be adapted (or "specialized") for that standard (Teece 1986).

The empirical support for network effects is limited. Aggregate studies have imputed a network premium as the gap between price paid and that predicted from product features and other likely measures: if a higher market share led to a higher price, then researchers concluded that the higher price paid was accounted for by the positive-feedback value that accrued to buyers due to the larger network of adopters (Brynjolfsson and Kemerer 1996; Gallaugher and Wang, 2002). The importance of switching costs was supported by Greenstein (1993, 1997), who showed that U.S. federal government agencies preferred compatibility in their subsequent computer purchases of mainframe computers from 1971-1983. However, Liebowitz and Margolis (1994, 1999) dispute the empirical support for network effects and customer lock-in, attributing the success of various winning standards to relative advantage.

Finally, organizational standards decisions often focus on an architecture of related hardware, operating system and middleware standards which form a computer "platform" (Morris and Ferguson, 1993; Bresnahan and Greenstein, 1999). Control of the value of the platform rests with the control of complementary assets, which for a personal computer means the programming interfaces for pre-packaged application software (West and Dedrick, 2000). Historically,

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1 Such effects were originally referred to as "network externalities." However, after the analysis of Liebowitz and Margolis (1994) suggested that actual externalities are rare, subsequent researchers have used the term "network effect" (e.g. Shapiro and Varian, 1999).

vertically integrated computer companies controlled all layers of the platform, but with Unix (and later Linux) firms outsourced provision of the operating system, while "Wintel" PC makers delegated control of the entire platform to suppliers (West 2003).

2.2 Organizational technology adoption

A variety of approaches have been used to consider how organizations adopt information technology standards for their own internal use. Generally, these studies fall into two camps: those that use network effects to predict aggregate market share, and those that attempt to predict firm decisions without regards to network effects.

As an example of the former, Tam & Hui (2001) combine network effects with other product and manufacturer attributes to predict aggregate market share for mainframe and minicomputer vendors (which generally use a single *de facto* platform standard within a given product category). Similarly, Gallaugher and Wang (2002) use a combination of network effects and product attributes to estimate the hedonic (quality-adjusted) price for a variety of web server packages

At the other extreme, Chau & Tam (1997) treat the Unix-compatible operating systems standard (aka "open systems") as an innovation in the context of Rogers (1983) and Tornastky and Fleischer (1990), but do not measure network effects or switching costs as a predictor of switching propensity. While not directly related to standards, the diffusion of innovation (DOI) framework of Rogers (1962, 1983) framework does offer insights into differences between adopters and thus potentially predicts who might be the earliest adopters. Also, Moore (1991) has argued that the DOI adopter categories can be used to predict whether a new technology will win widespread adoption.

Each approach has its limitations. The network effects models do not explain which firms are most likely to adopt a new standard (or when). The diffusion of innovations approach builds upon established theory in this regard, but ignores the large body of work establishing the importance of network effects in standards adoption. As a generalization of a person-centric communications model, it also has another limitation, in that it tends to assume the adoption decisions of individuals. However, within an organization, many technologies are "too big and complex to be grasped by a single person's cognitive power—or usually, to be acquired or deployed within the discretionary authority of any single organizational participant" (Eveland and Tornatzky, 1990: 133).

Also, both literatures tend to adopt a simplifying assumption that the decision process is based on either utility maximization or bounded rationality. Both, in turn, assume that organizations make rational decisions to best achieve an established objective such as profits or utility. However, there is a large body of research in MIS that shows that organizational technology decisions are often made based on factors such as the internal distribution of decision power and inter-organizational politics (e.g., Dutton, 1981; Markus, 1983; Pinsonneault and Kraemer, 1993, 1997; Davis 2000).

Finally, even knowing which organizations will adopt new IT standards does not explain how those standards diffuse within the organization. As modeled in the network effects literature, an individual consumer adopts a single VCR standard with an investment in hardware and content exclusively in that format. However, such an assumption is unrealistic for a large organization, in which multiple competing standards may be simultaneously utilized for various purposes and organizational subunits.

Ideally, then, to explain organizational adoption of standards, we would want to be able to predict not only when a given class of organization will adopt a new standard, but also where and why. By explaining inter- and intra-organization heterogeneity of adoption propensity, we would both be able to interpret the pace of standards adoption and also offer managerially relevant predictions as to where adoption is most likely to happen next.

3. RESEARCH DESIGN

3.1 Platform Choices, Standards and Implementations

We chose to study the organizational choice of a computer platform as defined by Bresnahan and Greenstein (1999). Such a platform decision is a crucial standards-related decision for organizations, as it both constrains and is constrained by the choice of internal software systems, off-the-shelf application software, hardware peripherals, and related skills and services. At the same time, optimizing the platform decision is made more complex by the coupling of both hardware and operating system selections, since not all operating systems are available with all hardware systems.

Among such decisions, we chose to study server platforms for two reasons. First, at the time of our study there was a wide range of economically viable platform standards: unlike the single dominant desktop platform, for servers there were three major categories: Unix, Wintel and Lintel (Table 1). Second, the three competing platforms reflect three distinct standards strategies — Unix servers using proprietary RISC-based processors, servers based on proprietary Microsoft Windows and commodity Intel-compatible hardware (“Wintel”), and those using the open source Linux operating system and the same commodity hardware (“Lintel”).

One theoretical confound is whether firms conceptualize platform adoption as adopting a set of standards or a specific implementations of those standards. The relationship of two constructs is clearly different between the case of an “open” multivendor standard or a proprietary *de facto* standard, and these differences were particularly salient for the operating system portion of the server platform.

Organizations often favor open standards because they believe in principle that the standard will allow them a choice of implementations, reducing lock-in; they may also believe such openness will attract adoption and thus a supply of complementary products (Gabel, 1987; West, 2006). Vendors must thus weigh appropriating rents through lock-in against the benefit that (perceived or actual) openness has in attracting adoption (West, 2003).

At the same time, organizations don't directly use open standards, but rather the implementations of those standards. Adoption-related attributes such as support services are actually associated with a particular implementation (Krechmer, 2006). The lines between a standard and its implementation are further blurred in the case of a proprietary *de facto* standard.[2] If a for-profit entity has provided specifications for attaching third party complements, but discouraged other firms from implementing those APIs to host the same complements (as with Windows), then attributes of the *de facto* specification are tantamount to those of its only implementation.[3]

Defining Linux as a standard or an implementation is especially problematic. Many open source projects (such as the sendmail mail transfer agent or the BIND domain name server) are focused on providing a single implementation of external standards established through formal standardization efforts: for these Internet standards, the existence of an implementation aids the standardization process, but there is an assumption or even formal requirement for multiple implementations (West and Dedrick, 2001). However, the developers of Linux have eschewed

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[2] This is one reason why some researchers and standardization professionals are loathe to refer to any *de facto* proprietary software as a standard, even if it performs the same technical role of modularity and enabling complementary products as does a multivendor standard. Recent research has suggested that previous bifurcation between the extremes of "open" and "proprietary" standards is oversimplified, and stakeholders disagree in the importance they ascribe to the various dimensions of "open"-ness (Krechmer, 2006; West, 2006).

[3] While there may effectively be only one supplier of Windows implementations, there are multiple implementations of the Windows platform, in that competing PC vendors provide their own hardware implementations that share a common OS implementation (see West and Dedrick, 2000: 207).

more than 20 years' formal multivendor standardization efforts for Unix (Isaak, 2006), and seem intent on continuing Linux as an implementation-defined *de facto* standard akin to Windows.

However, one key aspect of Linux implementations is common across all open source projects. Firms have both the technical ability and the economic incentive to create their own variant implementations of Linux, in a process called "forking" (West and Dedrick, 2001).[4] In this regard, the possibility of multiple (partially interoperable) implementations is always present. For Linux, these implementations are produced both by Linux distributors (such as Red Hat, Red Flag and SuSE) and non-profit projects (e.g., Slackware, Debian or Knoppix). In fact, the Linux Standard Base (cf. Wu and Lin, 2001) has been established to provide formal Linux standardization, in hopes of improving the application interoperability between these various *de facto* implementations.

Thus Linux is like Windows in that the standard is defined as a *de facto* standard rather than the formal (IEEE-sponsored) standardization used for Unix. Linux, however, is like Unix in that it is a true multivendor standard — reducing lock-in; in fact, the barriers to creating new implementations (and thus the threat of lock-in) is much lower than for Unix (West, 2003). Despite these differences, all three choices — Linux, Windows and Unix — function as a platform. Switching costs (for training, commercial software and internal software) are lower if firms make future computer choices within a given platform (Bresnahan and Greenstein, 1999). The organizations in our sample acted consistently with this view, in that selection of a platform appeared to be a long-term decision, but they more easily considered changing implementations within that platform.

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4 Some advocates (particularly of "free software") have claimed that "copyleft" licenses can be used to compel the return of individual changes and thus prevent forking. In practice, Linux forking continues to be a problem not because the changes are unavailable, but because the various forks are addressing heterogeneous needs and have weak incentives to adopt modifications irrelevant to their own needs.

3.2 Methods

While theoretical modeling is often use in the economics of standards literature, for our study of organizational standards adoption we selected an empirical approach, specifically a comparative case study approach (Benbasat et al. 1987; Yin, 1994). We used established procedures for inductively generating theory from qualitative case study data (Glaser and Strauss, 1967; Eisenhardt, 1989), which can capture the complexity of an organizational IT adoption decision (Orlikowski, 1993)

We conducted a series of in-depth interviews from November 2002 through October 2004. We interviewed the CIO or other senior MIS executive, and — where possible — another person in the MIS department who is closer to the actual technical issues raised, such as a system administrator. We hoped to both develop a more complete picture and provide a degree of data triangulation by comparing the responses of the two interviewees for consistency (cf. Benbasat, et al, 1987).

To draw inferences about a wide range of organizational adoption patterns, we used theoretical sampling (Glaser & Strauss, 1967: 45-77) to capture a range of variation on key organizational variables, organizational size and degree of adoption intensity. We continued to sample until we had interviewed organizations who were extensive users of each of the three major platforms, and represented a different range of adoption of the new Lintel standard—from non-adoption through complete internal standardization on that platform (Table 2).

We studied standardization within the boundaries of a given MIS department — either for the entire organization, or, in some cases, for an organizational subunit (e.g. a government research lab). In one case, we studied two subunits of a single organization — professional schools at separate campuses of the same public university. All 14 of our organizations were US-headquartered, and 11 of the organizations (or their subunits) were based in California.

After using the initial interview protocol in a pilot study at four sites, both the site selection criteria and protocol evolved during our study to capture new patterns identified during the research. The primary data consisted of semistructured interviews based on a common protocol. Interviews were conducted in person (or, in a few cases, by telephone), and typically lasted from 45 to 90 minutes. Field notes were taken, and the interviews were tape recorded and partially transcribed. Basic organizational data was collected via questionnaire, with background data for companies compiled from standard sources such as Hoovers and Dun & Bradstreet. As needed, follow-up questions were asked by phone or e-mail.

The final set of propositions were developed through interpretation, discussion and anomaly resolution involving both authors, until we matched empirical patterns against multiple cases in the interview data against the propositions. Propositions each met the following criteria: they were based on comments of multiple respondents; each one was strongly emphasized by at least one respondent; and there was a consistent pattern of responses, or conflicting evidence could be explained by differences in context. We also identified a logical chain of evidence from research questions to case study data to proposition, as recommended by Benbasat et al. (1987).

4. FINDINGS

Our findings address the question of when a new standard with a perceived relative advantage is likely to get adopted in the face of switching costs and positive network externalities which favor incumbent standards. In this case, respondents saw the relative advantage of the new standard primarily in terms of cost, as Lintel servers are viewed as a low-cost alternative to proprietary Unix servers. On the other hand, the incumbent Unix and Windows platforms had substantial advantages in complementary assets, both in terms of software libraries and user skills, which presented a major hurdle for the Lintel platform.

In our interviews, we found that organizations were in fact weighing relative advantage, switching costs and network externalities in their adoption decisions, as theory predicts. Of greater interest, we found that these factors are moderated by the scope of technology use and the organizational decision process. The interaction of the primary and moderating factors thus influence (1) which organizations are more likely to adopt the new standard, and (2) when and how the standard will be adopted within these organizations.

The set of moderators are at the level of the information system (in this case the server) and its intended use. They include (1) whether it is a special purpose or general purpose use; (2) whether the application impacts only the MIS department, or whether it involves the core business of the broader organization; (3) whether the server is employed for a new use, or whether it involves switching an existing application over from another platform; and (4) the timing of deployment, particularly when existing hardware is becoming obsolete or needs to be replaced. Each of these moderators explains intra-organizational differences in where and when a new standard is adopted. Adoption is more likely when the scope of deployment is more limited, as in the case of uses that only affect the IS department, or in the case of special purpose computers. It also is more likely for new uses than for switching existing applications, or when existing hardware is due for replacement.

The second set of moderators factors involve the decision making process within the organization. These include (1) the skills, preferences and distribution of power among decision makers; and (2) whether there is a preference or official policy favoring internal standardization. Adoption of the new standard is more likely when it is compatible with existing skills and preferences of more powerful decision makers, but less likely when organizations have a policy of standardizing on a single server platform.

4.1 Factors Influencing Standards Adoption

As predicted by the foregoing theoretical discussion, we found that the main factors influencing adoption of the Lintel standard were its relative advantage and its compatibility with existing complementary assets. In addition, we found that support from third-party vendors was an important factor in encouraging adoption of a non-proprietary standard.

4.1.1 Relative Advantage

The relative advantage of Lintel platforms compared to those based on proprietary operating systems was perceived by MIS departments in terms of cost, performance, and fit to specific tasks.

Cost. The most often mentioned advantage of the Lintel platform was cost. The commodity PC hardware used by Lintel systems was much cheaper than proprietary RISC-based Unix systems, although not cheaper than Wintel servers using similar hardware. Seven of the eleven companies interviewed mentioned hardware cost as an important relative advantage of Linux.

The second advantage is software cost. Linux and its updates can be downloaded for free, making it cheaper than either a proprietary Unix OS or Windows. However, only three of the ten companies stated that the cost of software was a significant factor in their decision whether to adopt Linux, perhaps because most organizations valued guaranteed support levels that required service contracts priced similarly to proprietary license fees.[5]

Performance and reliability were often-cited factors in the decision process, but one in which interviewees had mixed views. Lintel platforms were generally perceived as more reliable than Wintel but less reliable than proprietary Unix platforms.

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[5] The role of price could be seen in NorthU and SouthU, who said that Linux did not have cost advantage because Microsoft's education discounts meant that its server products cost almost the same as Red Hat's products.

The concern with performance was not absolute, but relative to the requirements of specific applications. Several organizations were unwilling to switch mission critical applications without proof that the Lintel platform reliability matched that of proprietary Unix systems. On the other hand, most organizations were willing to utilize Lintel servers for uses such as print and file servers, web servers, and for applications that provide their own error recovery. We do have some evidence that this perception is changing. For instance, Semico in 2002 was only using Lintel servers for limited tasks, but in a follow-up discussion in 2005, the CIO reported that adoption was much more widespread in the organization.

Fit to specialized tasks. It was clear that Linux fit some tasks especially well, given its Unix roots. This includes Internet applications in particular, which helps explain why the rapid diffusion of Linux paralleled the Internet boom of the late 1990s. As ISP's CIO stated,

> [The original partners] all pretty much agreed that Unix was the way to go—it's one of the core infrastructures for the Internet, and so they just realized that that's where all the Internet services and products were most mature, and so they wanted to continue with that.

We offer the following proposition regarding the perceived relative advantage of a new standards.

> *Proposition 1: A new standard is evaluated on relative advantage for a specific task, and is more likely to be adopted if it has a clear advantage in terms of cost, performance or fit for that task.*

4.1.2 Compatibility

The decision to adopt open source platforms appears to be greatly influenced by the compatibility of the new technology with current technologies, skills and tasks. Greater compatibility lowers switching costs, as it is easier to redeploy existing assets to the new standard.

Applications. Every firm agreed that compatibility with current applications was a major concern in the adoption decision. For most, the issue was the availability of third party applications; a few sites were concerned with compatibility with internally developed applications, where the organization would have to pay any conversion cost.

The importance of application compatibility supports research on the role of complementary assets (Farrell and Saloner, 1985; Katz and Shapiro, 1986). The impact does not depend as much on the overall pool of complementary assets as on whether the new platform is compatible with applications that the site is now using, considering or developing. Consistent with West (2005), for server standards we found that most users satisfice (require specific applications) rather than preferring the platform with the largest variety of applications.

Skills: Compatibility with internal IT skills and with skills available in the labor market were another key issue: because Linux is a Unix clone, adopters were concerned with the internal and external supply of skilled Unix administrators. Our respondents were split between organizations that primarily used Unix-based servers — so-called "Unix shops" — and those that were primarily Windows-based ("Microsoft shops"). In Tushman and Nadler's (1986) terms, the transition to Linux is incremental for Unix shops where skills are easily transferable, but discontinuous for Microsoft shops that lack such skills.

For smaller organizations in particular, compatibility with current skills was a major concern. SouthU's CIO said development systems were not chosen for their acquisition costs, but "the x-ty thousand dollars a year plus training to have someone write in it." On the other hand, those companies that were already heavy Unix users (Semico, Biotech and NewMedia) stated that this greatly eased the shift to Linux. A fourth (ISP) selected Linux at the time of inception, largely due to the Unix background of the CIO (our informant).

The CIO of NewMedia felt that having his engineers make a transition from Solaris to Linux was not difficult, but that going to Windows would be harder. By contrast, FastFood has a mix of mainframe, Unix and Windows servers, but is predominantly a Microsoft shop with Windows skills: the interviewee predicted this would be an obstacle to widespread adoption of Linux. Both FastFood and SouthU felt that it would be more difficult to find system administrators with the necessary skills to handle the more complex requirements of a Linux environment. From these findings, we offer the following proposition:

> *Proposition 2: MIS managers will choose standards that are compatible with existing applications and skills. A new standard is more likely to be adopted the more that existing applications and skills can be redeployed to that standard.*

4.1.3 Vendor support

The Linux operating system is not owned by any one organization, but developed by an open source community. A potential concern about adopting an open source platform is the lack of support services from a single reputable vendor, as is available on proprietary platforms. As the CIO of SouthU stated,

> I'm nervous about open source. I'm not paying anybody to support it and thus I'm depending largely on goodwill and luck and skill of my own people and soliciting solutions from other people for free. That explanation looks amateurish when you offer it to a dean or to a faculty when a production system is down in my opinion.

Most of our respondents were reassured by the availability of Linux support from major systems vendors or Linux distributors. As FastFood stated, "Support from major vendors like IBM and HP would be important to us. It gives a little bit of a safety net." Three larger companies (FastFood, Biotech and Semico), cited vendor support as being important in considering open source.[6]

Major vendor support also prompted several respondents to increase their belief in the long-term viability of Linux. In the words of Semico's CIO, "If the world is moving to a Linux standard, even over a very long time frame, you don't want to be on the wrong path following a proprietary standard." This concern over standards viability is consistent with the standards literature, and we find that vendor support not only has value as a complementary asset, but is a signal of viability. Based on this finding, we frame the next proposition:

> *Proposition 3: Organizations are more likely to adopt a new technology standard if it is supported by reputable vendors who can provide necessary technical support, and whose sponsorship increases the perceived future viability of the standard.*

4.2 System-level Moderators

We find that the scope of deployment of a new system is a moderator of the impacts of switching costs and network externalities, as limited scope deployments do not impact the broader organization and do not require compatibility with the full range of an organization's applications. The timing of deployment likewise can moderate switching costs. When deployed for a new use, or when an existing technology is reaching obsolescence, switching costs can be much lower. In both cases, the likelihood of adopting a new standard is greater.

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6 In the abstract, support by software developers for the Linux platform could conceivably include any implementation that conforms to the Linux API standards. As a practical matter, support service commitments by application or systems vendors are limited to a specific subset of implementations, e.g. Red Hat or SuSE. Of course, Linux distributors provide support services only for their own particular compilation of Linux and related software — where the act of compilation defines a specific implementation.

4.2.1 Scope of deployment

Depending on the nature of the system, IT adoption decisions can be made entirely within the information systems (IS) department, or may be influenced by others inside or outside the organization. Swanson (1994) defines three types of information technology innovations. Type I innovations are restricted to the IS task and mainly affect the IS unit; Type II innovations support administration of the business and affect the broader organization; Type III innovations involve the core technology of the business and affect both the organization and its customers and other external partners. In this typology, adoption of a server platform would be a Type I innovation, whose use has little impact beyond the IS department. As Biotech's CIO said, end users "don't know, don't care" what platform is used on the server side. As such, switching costs associated with adopting a new standard are lower than in the case of Type II or III technologies, where users within and beyond the organization are affected.

Respondents also suggested that adopting a new platform was easier for single purpose systems rather than general purpose ones. We found many examples of single-purpose servers, whether running an SAP module (Semico), or a web or print server (several sites). For example, to save money E-store shifted its web servers from Unix to Lintel: whether they could run any other application was irrelevant. In the case of a single purpose system, network externalities associated with a large library of applications do not favor incumbent standards the way they do with general purpose systems such as desktop PCs or mainframe computers.

These characteristics of the scope of deployment lead to two related propositions:

> *Proposition 4: The cost to an organization of adopting a new technology standard will be lower for Type I technologies whose impact is limited to the MIS organization.*

Proposition 5: The cost to an organization of adopting a new technology standard will be lower for special-purpose information systems than general-purpose ones, and the impact of network externalities associated with a large software library is minimized.

4.2.2 Timing of deployment

While not reviewed every time a new server is purchased, our organizations faced server platform decisions fairly frequently, suggesting that firms are not locked in by previous decisions for a long period of time. Standards decisions mostly came up under two circumstances:

New uses – most adoptions of Lintel were for new applications, most commonly when Internet infrastructure was being created or expanded, cited by eight of the 11 organizations.

From the interview with Biotech's associate director:

> Q. Are most of your Linux applications ones that you switched from other platforms or are they new applications?
>
> A. I would say that since I've been here it's mostly been new applications. … We don't have a lot of time to go back through our existing systems and say "Hey, can we do this better on Linux? What are the cost benefits here?" … If we did have that time we would do it.

Hardware retirement or obsolescence – for an existing use, the current hardware may be phased out, or the cost of keeping it running becomes prohibitive. For instance, both Semico and Biotech considered Lintel on systems where the platform hardware or operating system was reaching "end of life." Others considered changes when newer hardware offered superior price/performance.

When a server is being employed for a new use, or when current hardware is being phased out, the cost of adoption or switching is minimized. Therefore, we predict:

Proposition 6a: When a technology is deployed for a new use, switching costs are reduced or eliminated. Thus, organizations are more likely to adopt a new standard for new uses than for existing applications.

Proposition 6b: Switching costs are lowest when existing technologies are becoming obsolete or at the end of a replacement cycle. Thus, organizations are more likely to adopt a new standard when the incumbent systems are due to be replaced for other reasons.

4.3. Organizational Effects

4.3.1 Individual-level Factors

While we studied the decisions of organizations, the actual decisions were made by individuals. Not surprisingly, the interpretation of various attributes and relative advantages and disadvantages are subjectively interpreted through the biases of the existing MIS decision makers. Respondents identified similar goals including making life easier for MIS staff, reducing costs, ensuring compatibility with key applications, and having staff with skills to necessary support the platform. However, we found differences between organizations in their approaches towards meeting those goals, with a crucial split between MIS departments with IT skills predominantly in Unix or Windows.

The "Unix shops" preferred staying with a Unix variant rather than switching to Windows, arguing that Unix IT programmers and administrators could easily learn Linux, thus minimizing switching costs. An alternate (but unstated) explanation might be that staying with a Unix clone provided job security for the existing staff, and reinforced their power within the organization.

Likewise, small Windows shops such as SouthU or Beach Co. would not consider a standard that could not be supported by current staff. The skills of Windows administrators and programmers could not easily be redeployed to work on the Lintel platform, so switching to Lintel would require hiring new staff. In one case, the CIO had strong knowledge of the Wintel platform, so a switch to Lintel would dilute the value of his expertise.

In our interviews, we saw how the delegation of power influenced the evaluation of the various standards attributes and thus the ultimate adoption outcome. For example, the CIO of SouthU decided to standardize on Wintel servers across the organization, but deferred to our other informant when deciding to switch to the Apache web server for a particular application, stating his trust in the informant's expertise in this area. At Semico, the CIO stated that the person driving the server decision for the SAP module was a systems administrator, because the decision was not considered strategic. When Biotech hired a Linux expert and enthusiast as Associate Director of IT Infrastructure, that enthusiast stated

> My internal policy is for every product we deploy, I always ask, 'Can we do this on Linux?' Sometimes the answer is no, but I'll always ask the question 'What's the best OS to do this on?' And implicit in that statement is Linux is one of the choices.

4.3.2 Internal standardization

Studies of consumer standards decisions assume that individuals will select one standard for each product category. Organizational technologies such as computer servers are different in that organizations often support multiple standards adopted at different times for different functions. Organizations must decide whether to standardize their choices internally, or to support more than one standard.

In our sample, some had standardized completely or mostly on a single platform, while others supported mixed server platforms. Both those who had standardized and even some who had not recognized the tangible benefits of internal standardization, such as ease of hardware and software administration and maintenance. The CIO of E-store stated, "We run the same configuration everywhere. We try very hard to keep it standard across the board. Why create your own problems?" Another benefit was reducing the scope of skills needed. SouthU specifically avoided non-Windows platforms because it did not have, and did not want to hire, skills to support other platforms. Even at Semico, which supported multiple platforms, the CIO stated that it would be advantageous to have one ubiquitous server platform: one reason he was considering adopting Lintel was that if he did so, he eventually would need only one staffer a deep knowledge of Linux rather than maintain deep expertise on a number of platforms.

Respondents also identified disadvantages of complete standardization, such as the risk of becoming too dependent on one vendor. Biotech's CIO said that he specifically avoided standardizing on Windows in order to limit Microsoft's leverage. Internal standardization also limits an organization's ability to select technologies that are best suited for a particular task. For instance, Semico moved one module of SAP to a Lintel server while keeping the more critical database engine on an HP-UX server, thus taking advantage of the low cost of Lintel for one task while enjoying the greater perceived reliability of HP-UX and PA-RISC hardware for a more demanding task. E-store used a similar staged Lintel deployment.

We found that internal standardization reduced the likelihood of adopting a new standard. In our sample, both Beach Co. and SouthU standardized on Wintel servers and thus were not generally considering the Lintel standard. ISP was unique in that it had standardized on Linux at its inception (being a startup in the late 1990s). All the remaining sites were mixed shops either adopted or were actively evaluating Linux for some uses.

The effect of internal standardization was to increase the scope of deployment of a standard, as organizations would have to adopt the new standard across the board. This increases switching costs as all applications must eventually be moved to the new standard. It also increases the importance of network externalities associated with the size of the library of complementary software, as all of the organization's applications must support the new standard.

Proposition 7: A policy of internal standardization increases the scope of deployment of a new standard, hence increasing switching costs and the importance of complementary assets. Organizations that value internal standardization are thus less likely to adopt a new standard.

5. DISCUSSION

This study advances our understanding of how organizations consider and select IT standards, combing empirical data with previously disjoint research in economics of standards and MIS technology adoption to produce a moderated model of standards selection. This moderated model subsumes competing predictions about the reasons for standards (non) adoption.

5.1 Linking Organizational to Aggregate Adoption Patterns

Long-established models of *de facto* standards competition predict aggregate patterns of standards adoption, but say little about who the earliest adopters will be. As with other new technologies, there are conditions under which standards do not become widely adopted — as the diffusion of innovation literature suggests (Rogers, 1983; Moore, 1991). And both theories offer little insight as to the motivations or patterns of organizational adoption.

From our field study, we offer a model (Figure 1) that incorporates familiar constructs from *de facto* standards literature (network effects, switching costs) as well as from the diffusion of innovations (relative advantage, compatibility). But in addition to these (long accepted) main effects, we identify two important moderators that influence when, how and why organizations adopt new standards.

New platform standards start out with a twofold disadvantage – the switching costs associated with moving from a system from an old standard to a new standard, and the large library of complements (fueling indirect network effects) that have accrued to the incumbent standard. We found that organizations are most able and willing to adopt new standards when the scope of deployment is limited; such scope increases the more that the decision about an individual system standard is linked (either economically or organizationally) to other decisions and commitments both inside and outside the organization. Thus, a limited scope of deployment (such as a back office server) reduces the switching costs incurred by the firm. In parallel to this, more limited uses — such as specialized systems which serve a single purpose — allow adoption of standards which have a few key complements, even if they lack the larger library enjoyed by the incumbent standard.[7]

One key implication of this finding is the impact of intraorganizational standardization. The use of organization-wide standardized architectures (e.g., Feld and Stoddard, 2004) has been claimed to offer important efficiency and control benefits for IT managers. But such standardization inherently broadens the scope of deployment for any adoption decision, making it more difficult for such organizations to gain the information and skills necessary to evaluate and use new standardized technologies.

The timing of potential deployment also provides organizations with key windows of opportunity for considering new platform standards. One, of course, is when faced with new IT uses. For example, when the World Wide Web became popular in the mid-1990s, firms not only considered a new *de facto* standard for web server applications,[8] but also installed new computer

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7 This is an organizational-level manifestation of the aggregate observation made by Bresnahan & Greenstein (1999) that new platforms can become established if they serve new niches. Bresnahan & Greenstein consider new-to-the-world uses, while our study looks at new-to-the-organization uses.

8 Some could argue that a choice between the Apache, NCSA, Netscape or Microsoft web servers are merely choices of specific implementations of the open HTML and HTTP standards. However, during key periods of competition, each of these servers had slightly different interpretations of the standard and/or proprietary extensions. More seriously, each of these servers in turn comprised a middleware platform on which other technologies could be layered — through plug-ins, modules and other internally or externally sourced complements — as when IBM decided to base its WebSphere e-commerce system upon the Apache web server (West, 2003).

hardware and operating systems to run these web servers; here, the adoption of the Apache web server encouraged firms to adopt the Linux platform standard.

To a lesser degree, firms also have a greater likelihood to consider new standards when the existing systems are due to be replaced anyway — such as when hardware becomes obsolete or software license terms expire — since this reduces the switching costs for using new technologies. In our study, decision-makers recognized this window of opportunity and seemed inclined to widen their evaluation process to consider new standards, rather than (as in other times) be implicitly constrained by the prospect of switching costs.

Finally, the attributes of a new standardized product — whether its relative advantage, switching costs or network effects — are subjective evaluations made by one or more decision makers, not an externally verifiable objective measure. When comparing different organizations making similar standards decisions, we found (as did West, 1999) that the decision-makers differed in their interpretation of the relative advantage and switching costs relevant to their organization. Even allowing for differences in requirements, organizations with very similar needs arrived at differing conclusions (e.g. NorthU vs. SouthU). Even for the most "objective" measure — the size of the external library of complements — decision-makers differed in their interpretation of the importance of the differences in software availability, in this case when comparing Linux to the more established Unix and Windows platforms.

5.2 Limitations and Future Research

In addition to our findings being particularistic to a given standards decision, our research design also limits our conclusions beyond the specific sample. While multiple qualitative case studies can build theory in emergent areas that is grounded in empirical data, such theory always runs the risk of being idiosyncratic and not generalizable to the entire population, and thus should be tested using other methods (Eisenhardt, 1989). There is also the risk of attempting to generalize from one particular standards contest — whether VCRs or server platforms — to another, as the dynamics and history of standards contests clearly differ from case to case (cf. Grindley 1995).

The moderating effects of deployment timing and scope — as well as the corresponding implications for theory and practice — call for further research to establish their generalizability. For example, in looking at 30 years of computer industry platform competition, Bresnahan and Greenstein (1999) identified the importance of new uses for reducing the barriers protecting the existing platform. But they also concluded that each new platform eventually achieved "indirect entry," as its domain gradually overlapped that of the incumbent.

Their study specifically looked at general purpose computer systems. We contend that "special-purpose" computer systems are different — and thus may always retain a niche in the intraorganizational standardization decision. At the intraorganizational level, strong internal standardization would reduce likelihood of considering special-purpose systems, while at an interorganizational level, general purpose computer systems (such as those studied by Bresnhanan and Greenstein) have strongly benefited from economies of scale and scope. Thus, it remains an empirical question as to how frequently such limited scope opportunities occur, how long the opportunity remains, and whether they inevitably lead to competition with established, general-purpose technologies.

There is also the unanswered question of generalizing to other layers of a standards architecture (in the sense of West and Dedrick, 2000). Our findings suggest that strong internal platform standardization rules out platform experimentation, and is thus a risk to the standardization prescriptions of Feld and Stoddard (2004). Their normative advice focuses on the benefits of experimentation above the platform layer, while assuming that the need to change platforms arises rarely at best. So how often do significant new platform opportunities arise?

And while the platform definition here (as in Bresnahan and Greeinstein, 1999) is narrowly defined as a processor and an operating system, does the process of limited scope deployment also apply to deeper platforms, such as a computer system plus middleware? Does it apply to other non-platform standards decisions - such as peer to peer networking protocols. or application file formats? These remain open empirical questions.

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TABLES AND FIGURES

	Proprietary		Open source
Platform	Sun	"Wintel"*	"Lintel"*
System			
Name	Sun Fire	*PC-compatible*	*PC-compatible*
Producer	Sun	*commodity†*	*commodity†*
Operating System			
Name	Solaris	Windows 2000	Linux/BSD
Producer	Sun	Microsoft	*open source*
APIs	Unix	Windows	Unix-derived
CPU			
Name	UltraSparc	Pentium	Pentium
Producer	Sun	Intel§	Intel§

* "Wintel" = Windows/Intel; "Lintel" = Linux/Intel
† Available from both branded (Dell, HP, Gateway) and unbranded suppliers
§ Available from competing suppliers

Table 1: Representative server platforms

Name	Business	Org. (unit) Size†	Primary Platform	Lintel Adoption	Informants
Beach Co.	Rec. equipment	80	Windows	Website only	1
Bio Branch	Pharmaceuticals	560 (150)	Linux	Predominant	1
Biotech	Pharmaceuticals	1,000	Unix	Internet and database applications	2
Dataco	Online data retrieval	2,700 (1,500)	Linux	Phasing out Unix	1
E-store	E-commerce	7,500	Unix	Shifting from Unix to Linux	1
FastFood	Restaurant chain	200,000	Mixed	None	1
FinCo	Financial services	130,000	Mixed	Partial adoption	1
NatLab	Government research lab	(8,000)	Unix	Phasing out Unix	2
ISP	Internet service provider	11	Linux	Since founding	1
NewMedia	Content provider	35	Unix	Partial transition	2
NorthU	Public university professional school	114,000 (325)	Mixed	Replacing Unix with Linux, while keeping Windows	3
Semico	Semiconductor design	2,500	Mixed	Limited; evaluating further use	2
SouthU	Public university professional school	114,000 (300)	Windows	Abandoned previous limited use	2
Travel Service	Travel-related reservations	6,000	Mainframe	Partial adoption	1

Total: 14 companies, 21 informants
† Size of parent organization (unit) in number of employees

Table 2: Characteristics of sample firms

Construct	Definition
Relative advantage	The degree that the new standard has an advantage relative to the incumbent standard(s) in use, as perceived by users. These include cost, performance, reliability and fit to particular tasks. The relative advantage is measured in terms of performing a particular task or set of tasks, and may be perceived quite differently by different individuals or organizations.
Switching costs	The costs that would have to be borne to switch to a new standard. These include new training for users and for IT staff, buying new software licenses for packaged applications, porting custom applications to a new platform, and changing work processes to accommodate the requirements of a new standard.
Internal standardization	The extent to which the organization attempts to use the same platform standard for all uses throughout an organization.
Network effects	The relative advantage of the incumbent standard over the new standard, as results from the number of others using each standard, and the availability of external complements for each standard. This value is based users' perceptions of both current conditions and expectations of future network size and availability of complements.
Decision maker preferences	The extent to which the preferences, biases and interests of the decision make
Timing of deployment	The degree to which the timing of deploying a new system reduces switching costs, either because there is no existing system or because the existing system no longer has value.
Scope of deployment	The extent to which a technology deployment impacts the organization and interacts with complements. This includes four variables: Technology type (I, II or III); general versus special purpose use; new use versus switching; and degree of internal standardization.
Standard adoption	The likelihood that the new standard will be adopted for a given task

Table 3: Construct definitions for causal model

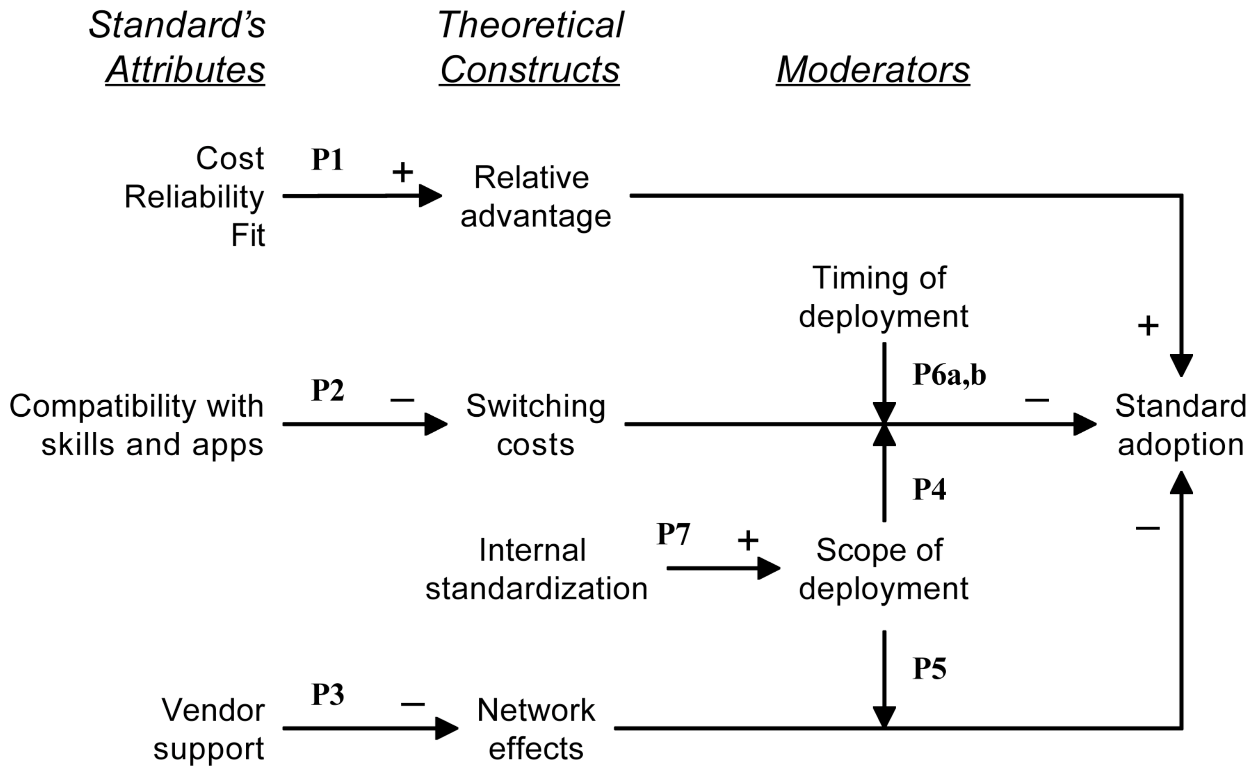

Figure 1: Moderated model for organizational adoption of a new standard

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