WHY FIRMS ADOPT OPEN SOURCE PLATFORMS: A GROUNDED THEORY OF INNOVATION AND STANDARDS ADOPTION

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ABSTRACT

There is a rich stream of research that studies technology adoption by individuals and organizations (Rogers, 1962; Tornatzky and Fleischer, 1990; Cooper & Zmud, 1990). This research considers factors such as the nature of the technology, the organizational and environmental context in which adoption decisions are made, and the processes by which users adopt and implement new technologies. Research on open source software has focused mainly on the motivations of open source programmers and the organization of open source projects (Kogut & Metiu, 2001; Lerner and Tirole, 2002; Benkler, 2002). Some researchers portray open source as an extension of the earlier open systems movement (West and Dedrick, 2001). While there has been some research on open-systems software adoption by corporate MIS organizations (Chau and Tam, 1997), the issue of open source adoption has received little attention. We use a series of interviews with MIS managers to develop a grounded theory of open source platform adoption. We then place our findings within the contexts of diffusion of innovation and economics of standards theories.

Keywords: Open source; standards adoption; computing platforms; grounded theory; diffusion of innovation; economics of standards; MIS organizations.

INTRODUCTION

For technology users, standards adoption decisions have important consequences. Adopting a winning standard enables users to benefit from a sustained stream of producer investment in the technology and access to a large supply of complementary assets. For instance, users of Microsoft Windows benefit from R&D in computer hardware and software on the Windows platform, as well as access to the immense library of Windows applications. By contrast, adopters of a losing standard face the choice of having to switch to the winning standard or living with a much smaller supply of complementary assets and smaller levels of producer investment (David, 1987; Farrell and Saloner, 1985; Katz and Shapiro, 1986).

While standards theories imply that user adoption decisions are critical to standards outcomes, most researchers treat user choice as a black box, in which exogenous variables (complementary assets, first-mover advantage, vendor strategy) go in and individual standards decisions come out. Over time, the economics of positive network externalities, switching costs, and fear of being orphaned on a losing standard can change users' calculations in ways

that reinforce or weaken commitment to a standard. But because the actual decision process is a black box, standards theory does not consider the relative importance of its own variables in determining user decisions, nor how they are moderated by characteristics of adopters and the environment in which they adopt.

By contrast, diffusion of innovation (DOI) theories of innovation (e.g., Rogers, 1983; Tornatzky and Klein, 1982; Tornatzky and Fleischer, 1990; Davis, 1989) offer rich explanations of how new innovations are adopted, and how adoption decisions are affected by perceptions of the technology itself as well as the character of the adopters (individuals or organizations) and their environment. Alas, this literature looks almost exclusively at adoption of new innovations and pays little attention to the process of choosing among different standards within a given technology.

We expect that actual standards decisions will be influenced by factors posited by both literatures, as argued by Fichman and Kemerer (1993), and that a richer framework for understanding these decisions can be developed through a qualitative study of a specific standards adoption case. Linux is an especially interesting case because it has succeeded as a newcomer in competition with powerful existing standards, Unix and Windows, and because it is an open source standard not sponsored by any company or formal organization. Using a grounded theory approach, we study the Linux adoption decisions of MIS departments in order to answer the following questions:

- What are the major factors influencing the adoption of Linux by information systems departments?
- To what extent do these factors correspond to existing theories of standards adoption or innovation diffusion?
- In what ways does the open source nature of Linux influence the adoption decision?

We conclude that the major factors are cost, perceived reliability, compatibility with existing technologies in use, presence of boundary spanners in the organization, availability of complementary assets, and fear of being "orphaned" by a losing standard. The first four of these are consistent with innovation diffusion theory, while the last two correspond to standards theory.

THEORY

Diffusion of innovation theory

The theoretical foundation for most technology adoption research is found in the diffusion of innovation literature (Tornatzky and Klein, 1982; Rogers, 1983) which studies the process of technology diffusion and the factors influencing technology adoption decisions. Tornatzky and Fleischer (1982: 32) present a process view that moves from research and development to deployment, adoption, implementation and routinization. Research, development and deployment are carried out by technology developers (or producers), while adoption, implementation and routinization are carried out by technology users. Rogers (1983) focuses on the adoption process itself, classifying users according to the point in time at which they adopt, from innovators to early adopters, early majority, late majority and laggards.

A major stream in diffusion of innovation literature theorizes about the characteristics of innovations that influence whether, and at what rate, such innovations are adopted. Rogers lists five technology characteristics that influence the adoption decision: relative advantage, compatibility, complexity, trialability, and observability. In a meta-analysis of prior studies, Tornatzky and Klein (1982) concluded that three of these variables were consistently linked to

technology adoption: *compatibility, relative advantage,* and *complexity*. Compatibility with existing technologies and relative advantage over current technologies were positively related to adoption, while technological complexity was negatively related to adoption.

Organizational Adoption of Innovations

Much of the technology diffusion literature focuses on the adoption decisions of individuals, either for themselves or for their employers. But for organizations, 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" (Tornatzky and Fleischer, 1990: 133). Thus, a more robust framework is needed to study organizational adoption.

An influential framework for understanding technology adoption in an organizational context has been developed by DePietro, Wiarda and Fleischer (1990).[1] Their model defines a "context for change" consisting of three elements:

- *Technology.* The model subsumes the five innovation attributes that Rogers (1983) argues influence the likelihood of adoption. The authors also note that radical innovations increase the relative advantage but reduce the compatibility of the innovation.

- *Organization.* Adoption propensity is influenced by formal and informal intra-organizational mechanisms for communication and control. The resources and innovativeness of the organization also play a role.

- *Environment.* Consistent with Porter (1980), a firm's strategic technology decisions will depend in part on industry characteristics such as rivalry, relations with buyers and suppliers, as well as the stages of the industry life cycle (DePietro et al, 169-171). Organizational adoption of new technologies depends on having the prerequisite skills for effective deployment, so as Attewell (1992) found, the availability of external skills (such as through integrators or consultants) is essential for adoption by some organizations.

These three elements (cited in subsequent research via the anagram "TOE") are posited to interact with each other and to influence technology adoption decisions (De Pietro et al, 1990: 153). In fact, the TOE framework as originally presented, and later adapted in IT adoption studies, is little more than a taxonomy for categorizing variables, and does not represent an integrated conceptual framework or a well-developed theory. On the other hand, it is a useful analytical tool for distinguishing between inherent qualities of an innovation itself and the motivations, capabilities, and broader environmental context of adopting organizations.

Adoption of Computing Platforms

There has been considerable research regarding organizational adoption of information systems, including studies of MRP (Cooper and Zmud, 1990), EDI (Iacovou, et al. 1995; Kuan and Chau, 2001; Chwelos, 2001), and e-commerce (Zhu et al, 2002). However, despite the importance of standards in the IT industry, the role of standards in adoption decisions has rarely been considered.

[1] The work of DePietro, Wiarda and Fleischer in developing the TOE framework is often cited as that of Tornatzky and Fleischer (1990), but we hereafter we credit the actual chapter authors.

One of the exception is Chau and Tam (1997), who conducted in-person surveys of organizations considering adoption of Unix-based open systems. Studying various technology, organizational and environmental factors, they found that two factors (barriers to adoption and satisfaction with existing systems) were statistically significant (and negatively correlated) to the open systems adoption decision.

Economics of standards

When considering standards adoption, such barriers to adoption have previously been classified in economics research under the category of "switching costs" — part of a much larger body of research on the economics of standards. 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 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. 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. Such benefits may be captured by subsequent consumers, or the producer of the good, or spill over to society at large.[2]

Prior organizational adoption studies have not considered the interrelationship of an architecture of computing standards to form a computer "platform." For a general-purpose computer system, such architectural standards typically encompass a processor, operating system (OS), and associated peripherals. Some have also extended the concept of a "platform" to include multiple layers of software, so that applications can be built upon a "middleware" tool such as Java or a database (Morris and Ferguson, 1993; Bresnahan and Greenstein, 1999; West and Dedrick, 2000).

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, 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).

Among the few to combine standards theory with diffusion of innovation theory were Fichman and Kemerer (1993), who analyze three cases of adoption of software development tools in the light of both theories. They employ five innovation attributes (relative advantage, complexity, compatibility, trialability and observability) from Rogers (1983) and four factors from standards theory (prior technology 'drag', investment irreversibility, sponsorship, and expections) to analyze when innovations in software development are likely to be widely adopted. They argue that innovations are most likely to become dominant technologies when they score highly on both diffusion of innovation and economics of standards criteria.

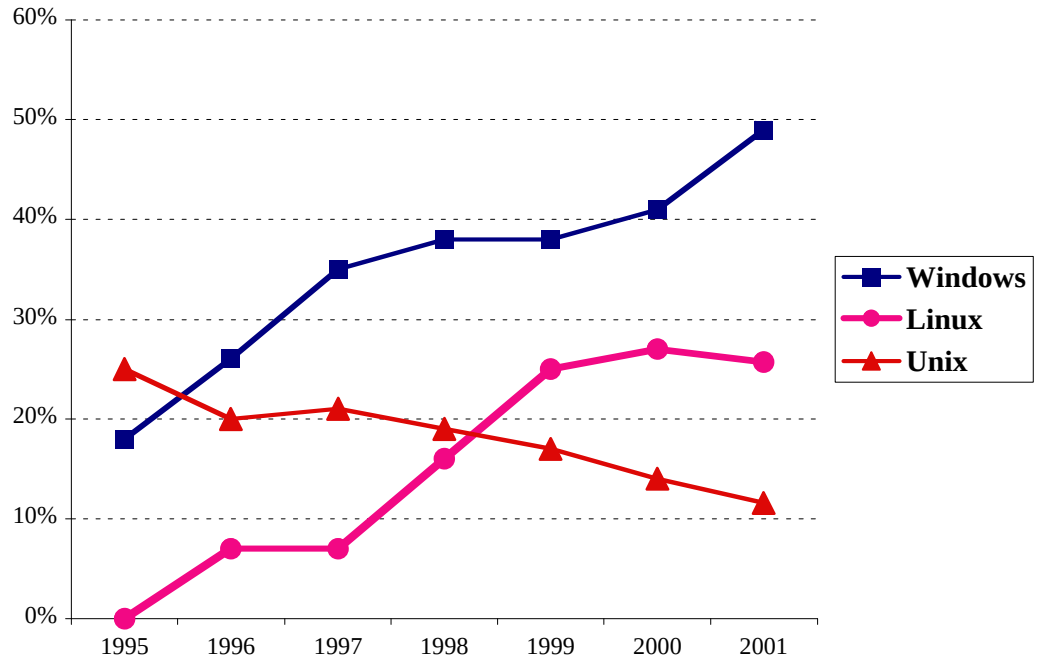
[2] Liebowitz and Margolis (1994 and 1995) argue that theories of switching costs and path dependency are not supported by empirical evidence.

Open-source Software Adoption

An interesting case of technology standards selection involves the choice between proprietary and open source software. Open source software has gained a great deal of attention recently, as applications such as Apache, Perl and Sendmail have gained widespread adoption, in particular for Internet-based applications.

The best-known open source software is Linux, a Unix-compatible operating system created in the early 1990s by Finnish programmer Linus Torvalds and developed by a large community of programmers around the world. Linux has been the fastest growing operating system in recent years, and has surpassed the various proprietary versions of Unix (e.g., Sun Solaris, HP Unix, and IBM's AIX) in the market for server operating systems (Figure 1).

Figure 1: Global server market share, 1995-2001



Source: International Data Corp., as reported by West & Dedrick (2001): IDC (2002)

When considering open source-based platforms, there are at least two crucial differences when compared to more traditionally proprietary platforms such as those offered by Microsoft, IBM or Sun. First, the R&D, sales and support for the proprietary solution is the responsibility of a well-defined profit-making enterprise that receives income from its products, while the open source solution uses collaborative R&D and support in cooperation with firms whose role is far less central or defined. Second, the fundamental difference of open source software is that the source code is widely disseminated to all and thus adopting organizations have the opportunity (whether valued or not) to modify the software to suit their own needs.

Most of the prior research on open source software has focused on the motivation and organization of the programmers providing the free R&D (Markus et al., 2000; Kogut & Metiu, 2001; Lerner and Tirole, 2002; O'Mahony 2003). A few have examined the role of for profit-firms to act as change agents supporting the adoption of open source products, marking this as an extension of the earlier open systems movement (West and Dedrick, 2001; West, 2003).

Comparatively little work has been done to see how the organizational adoption of open source differs from that of other technologies. An exception is Franke and von Hippel (2003), who surveyed the motivations of webmasters who had adopted the Apache open source web server application, showing that the more skilled users who modified the source code were most satisfied with their decision.

Research Design

Our study examines the adoption of platforms based on open source operating systems such as Linux and FreeBSD (hereafter "open source platforms"). The choice of a computer platform is far more complex than that for a single application package. The platform decision involves the mutually-dependent choice of both hardware (e.g. Sun Fire vs. IBM R/6000 vs. Dell PowerEdge) and operating system (Windows, proprietary Unix, Linux, FreeBSD), since not all operating systems are available with all hardware systems (Table 1). That platform decision both constrains and is constrained by the choice of application software, hardware peripherals, and related skills and services. As such, the decision to adopt a new platform has broad implications for the overall technology direction of an organization.

Table 1: Representative server platforms

	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
CPU			
Name	UltraSparc	Pentium	Pentium
Producer	Sun	Intel§	Intel§

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

METHODS

Because the organizational adoption of computer platform standards and open source software are not well understood, we have chosen to use a theory-building approach grounded in the context of rich data. This draws on established procedures for generating theory from qualitative data (Glaser and Strauss, 1967), as well as management studies that employ the inductive method to draw theory from a set of case studies (Harris and Sutton, 1986; Bourgeois and Eisenhardt, 1988; Eisenhardt, 1989). Such rich data is an accepted way of capturing the complexity of an organizational IT adoption decision (e.g. Orlikowski, 1993).

We gathered as much context as possible on a wide range of organizations through a series of depth interviews conducted from November 2002 through August 2003. Such an approach naturally complements the TOE framework, in that we can identify which technological,

organizational or environmental factors are salient for each firm's adoption decision. Finally, because non-adoption is comparatively under-studied (e.g. Rogers 1995: 100) we sought out a wide range of possible outcomes — complete adoption, partial adoption and non-adoption — for open source platforms.

The adoption decision being studied might apply to an entire organization or one of its divisions. The actual decision could be made by the MIS department acting autonomously, or in consultation with client departments or top management. 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 that by doing so we could develop a more complete picture, incorporating the view of both top management and those "in the trenches."

We sought a stratified sample of organizations, segmented by size, task, and technological orientation. Our sample is summarized in Table 2. The primary data consisted of semistructured interviews based on a common protocol. Interviews were conducted either in person or by telephone, were tape recorded and partially transcribed, and typically lasted from 45 to 90 minutes. 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.

Table 2: Characteristics of sample firms

Name	Business	Org. (unit) Size†	Primary Platform	OSS Platform Adoption	Inform-ants
FastFood	Restaurant chain	200,000	Mixed	None	1
Semico	Semiconductor design	2,500	Mixed	Limited; evaluating further use	2
ISP	Internet service provider	11	Linux	Since founding	1
NewMedia	Content provider	35	Unix	Partial transition	2
North U	Public university professional school	114,000 (325)	Mixed	Replacing Unix, but mainly Windows	2
South U	Public university professional school	114,000 (300)	Windows	Abandoned previous limited use	2
Biotech	Pharmaceuticals	1,000	Unix	Internet and database applications	2
Bio Branch	Pharmaceuticals	560 (150)	Linux	Predominant	1
E-data	Online database	2,700 (1,500)	Linux	Phasing out Unix	1
Beach Co.	Rec. equipment	80	Windows	Website only	1

† Size of parent organization (unit) in number of employees

Outcome: Server Platform Choice

In studying organizational adoption of open source standards, we chose to focus on the selection of platform standards for computer servers for two reasons.

First, at the time of our study there was a wide range of economically viable server platforms. Unlike on the desktop — where one platform has held more than 90% share since 1997, for servers there were three major categories — Unix servers using proprietary RISC-based processors, servers based on Microsoft Windows and commodity Intel-compatible commodity

hardware ("Wintel"), and those based on open source operating systems using the same commodity hardware — the most popular being Linux on Intel ("Lintel"). The platforms shown earlier in Figure 2 are representative of those used in our sample, and their patterns were generally consistent with overall industry trends for the three major platforms.

Second, the server market is one in which open source platforms have had notable success, as measured both by market share and public notice. In 1999, the number of Linux servers passed the number of Unix servers (West & Dedrick 2001) From 1999 to 2002, IDC estimated that annual shipments of new Linux servers increased from 173,000 to 598,000, while revenue from their sales increased from $749 million to $2 billion (Shankland, 2003). Coming in direct competition with Microsoft, Sun, IBM and HP, this success has captured a good deal of attention in both the trade and business press.

RESULTS

An analysis of the interviews completed shows some consistent patterns. These are summarized in Table 3, and further explained below.

In looking at organizational decisions on technology adoption, we found that a distinction needs to be made between the adoption of an "innovation" (as defined by Rogers 1995 or Wolfe et al. 1990) and the adoption of a different variant of the same fundamental technology.

In Table 3, we've attempted to subdivide characteristics of open source server platforms into those that are inherent to most or all open source packages (and thus characteristic of the open source "innovation") and those that are characteristic of specific open source platform standards such as Lintel, which we classify as "products". We classified the following adoption factors as tied to the open source innovation *per se:*

- willingness to take risks on a new, unproven technology
- need for organizational slack to evaluate the new technology and to self-support unsponsored technologies
- tendency of open source software to be inexpensive if not free
- inherent trialability of "free" software distributed on the Internet
- availability of external sources of support and expertise

The other factors are identified as influencing the selection of the specific platform, in this case Lintel, and are not inherent characteristics of open source software.

Platform Decision Process

While server platform decisions have important implications for the IS department, they are likely to be easier in some ways than other technology choices — because the server decision is only loosely coupled to other decisions in the organization. As such, a decision to adopt a new server platform would be classified as a Type I innovation under Swanson's (1994) taxonomy, in that it is restricted to the functional IS core.

Unlike a "desktop" adoption of Linux, the choice of the server platform had little direct impact on the day-to-day computing experience of ordinary workers. As the CIO of Biotech stated, users "don't know, don't care." If the company or division had certain application needs, switching the platform "underneath" the application would be transparent to end-users. The size of the hardware and labor investment to install a new platform made the choice of a new platform an infrequent decision.

Table 3: Factors impacting adoption of open source platforms

Context	Factor	Attribute of	Relevant theoretical concept		Im-pact *	Explanation
			DOI	Standards		
Technology	Hardware cost	Product	Relative advantage		+	Lintel runs on commodity hardware
	Software cost	Innovation	Relative advantage		+	OSS operating systems are "free"
	Reliability	Product	Relative advantage		+/-	Varying perceptions of OSS platform reliability
	Availability of 3rd party apps	Product	Compatibility	Network effects	+	Prerequisite to adoption, depends on platform popularity
	Portability of own apps	Product	Compatibility	Switching costs	+/0	Increases adoption where such apps exist
	Skills of existing IT workers	Product	Compatibility	Switching costs	+/-	Increases adoption if and only if existing skills are compatible
	Fit to task	Product	Compatibility		+/0	Increases adoption for certain tasks
	Difficulty in administra-tion	Product	Complexity		-	Perceived complexity decreases adoption
	Ease of ex-perimenting	Innovation	Trialability		+	Reduces risk
Organization	IT capital budget	Innovation	Slack		-	Large budgets allow choice of more expensive options
	IT staff time	Innovation	Slack		+	Slack required to evaluate new technologies
	Innovative-ness of IT org.	Innovation	Innovative-ness		+	More innovative firms take more risks, want to be "cutting edge"
	Worker experience with new platform	Product	Boundary spanning		+	Linux knowledge that workers bring to organization prior to adoption
Environment	Industry maturity	Innovation	Industry life cycle		-	Infant industries not committed to old ways
	Availability of skilled IT workers	Product	Support infrastructure	Network effects	+	Availability essential to adoption, more likely with popular platforms
	Availability of external support services	Innovation	Support infrastructure	Sponsorshi p	+	Support needed to run in critical environments and to reassure management
	Platform long-term viability	Product		"Angry orphan" (switching costs)	+	Organizations avoid (re)investment in technologies that may become unsupported

*Legend:
+ increases propensity for adopting open source platform
- decreases propensity for adopting open source platform
0 has no effect

Also, the wide acceptance of standard Internet communications protocols across all server platforms reduced the potential incompatibility problems of having multiple server platforms. A given application might have a path dependency — as when a company has adopted Microsoft's IIS web server and is unwilling to pay the switching costs to Apache. But in most cases, the adoption of a particular server platform for one use did not preclude the ability to choose from several available platforms for other uses. In fact, some of the organizations studied were operating both proprietary and open source server platforms for different functions.

The decision to adopt (or switch) platforms corresponded to three cases:

- new uses – of which the most common reason for adopting Linux is Internet infrastructure, used by seven of the 10 companies. Others used Linux for file or print servers, and in one case (Biotech) for databases and a scientific application.
- hardware retirement – for an existing use, the current hardware is "orphaned" (aka "end of life") or the cost of keeping it running was prohibitive (in the case of Semico).
- hardware expansion – additional capacity was being added to an existing use (as in the case of E-data)

Finally, we want to emphasize the salience of the platform decision, involving operating system, processor and the overall computer system. Studies of platform competition generally emphasize the highest level of the system architecture; this level is crucial because the application programming interfaces (APIs) control access to complementary assets such as application software (Bresnahan and Greenstein, 1999; West and Dedrick, 2000). The salience of the related issues of OS, API and application compatibility in platform was certainly evident in our sample.

At the same time, the hardware component of the platform was also important. So we saw three patterns — organizations that chose the operating system first,[3] those that chose the hardware first, and those that selected a platform based on the availability (or vendor certification) of a key third party application such as Oracle or SAP.

Technology Factors

Several characteristics of Linux were consistently mentioned as influencing the adoption decision. Consistent with Rogers (1983) and Tornatzky and Klein (1982), these included relative advantage, compatibility, complexity and trialability.

Relative advantage

The relative advantage of Linux compared to proprietary operating systems is perceived by IS departments almost entirely in terms of cost and reliability.

Cost. The cost advantage of Linux consists of two factors—hardware and software cost. For the Lintel platform, the use of commodity PC hardware gives it a cost advantage over proprietary RISC-based Unix systems, but not over Wintel servers which run on the same Intel hardware. Six of the ten companies interviewed mentioned hardware cost as an important relative advantage of Linux.

[3] For the various Unix-compatible operating systems (Solaris, HP-UX, AIX, Linux, FreeBSD), in some cases firms had an *a priori* preference among the operating systems, but in other cases the firm selected "Unix" and then selected the hardware which constrained the selection of the specific flavor within the Unix family.

Some specifically mentioned the importance of multiple suppliers. FastFood described Linux as

> a platform neutral decision, so that if the major vendors—Sun, HP, IBM—all support Linux, I don't care what kind of servers I have, I can go with what fits my price point…We get a lot of the benefit on our desktop and laptop environment with Windows. We can go to Compaq, HP or IBM and play them off on each other and get the best prices.

The second advantage is software cost. Linux can be downloaded for free, making it cheaper than either a proprietary Unix OS or Windows.[4] Upgrades are also free, so there is no ongoing cost to stay with the latest version of Linux, unlike Unix or Windows. Perhaps surprisingly, only three of the ten companies stated that the cost of software was a significant factor in their decision whether to adopt Linux, while one (Semico) stated that the cost of software licenses was not high enough to be a factor. Only South U explicitly included the evaluation labor and human switching costs in the adoption cost, although all of our sample knew such costs existed. Of course, the evaluation and retraining costs would vary by organization, depending largely on the existing skills of its IT workers.

Reliability was another often cited factor, but one in which interviewees had more mixed views. Lintel platforms were perceived as more reliable than Wintel by six respondents, but generally considered less reliable than proprietary Unix platforms. Several organizations were unwilling to switch mission critical applications such as Oracle or SAP to Linux without convincing evidence that the Lintel platform reliability matched that of proprietary Unix systems. Two informants said they would enjoy little cost advantage from such a switch, because the Oracle license cost ($40,000 list per CPU) was the same between Lintel and RISC-based Unix servers.

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.

Technologies: Compatibility with current applications is a major concern in the adoption decision. All of the firms mentioned this issue. For most, the issue was running third party applications. For ISP, the only question was whether Linux would run Apache web server, which it did at the time of ISP's founding in 1996. For Semico, the current issue is SAP's support of Linux, which is partial at this time (some modules are certified). For FastFood, the lack of Linux support by PeopleSoft and SeeBeyond applications was a barrier to adoption. For NewMedia, the critical application is a proprietary media delivery application, and the issue was the cost and difficulty of porting that application to Linux. Biotech has adopted Linux for several applications, but has not moved to Linux for critical applications that are used for drug validation, as the relevant industry organization has yet to accept Linux as a platform for such applications.

The importance of compatibility with applications is consistent with the arguments in standards theory about the importance of complementary assets (Farrell and Saloner, 1985; Katz and Shapiro, 1986). However, in this case it is not the size of the overall pool of complementary

[4] The increasing price of some Linux distributions (specifically Red Hat Advanced Server) eliminates this cost advantage, leaving open the question as to whether customers would pay for the distribution or move to a less expensive or inherently free (e.g. Debian) distribution. The role of price could be seen in North U and South U, 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.

assets, but the availability of specific key applications, a finding more consistent with the conclusion of West (forthcoming) that for platform adoption, many users satisfice (require only a minimum number of applications) rather than always prefer the platform with the largest variety of applications.

Skills: Compatibility with current skills is another key issue, and one that involves a characteristic of the technology (its Unix roots), and the organization (the skill sets of the IT staff). Among organizations, we saw a definite polarization 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.

Three of the companies (Semico, Biotech and NewMedia) were already heavy Unix users and stated that this made the shift to Linux more manageable if not trivial A fourth (ISP) selected Linux at the time of inception, largely due to the Unix background of the top technology worker (our informant).

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 South U 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, while BeachCo was unwilling to pay the associated wages.

Task: For ISP, Linux fit the task of providing Internet service very well, as the task consists of supporting a simple set of applications such as providing POP services, serving up web pages and delivering e-mail. For Semico, the technology was considered appropriate for some tasks and not others, while for FastFood, it was not considered appropriate for any but the simpler tasks such as file or print serving For Bio Branch, Linux is compatible with the wide variety of scientific applications that are primarily developed for Unix platforms.

Trialability

The ability to try out Linux at a very low cost was frequently cited, because the software could be run on existing commodity hardware and could be downloaded for free from numerous websites. For organizational trials there was no evidence that the difference between "free" and a nominal cost had any direct impact on trialability. However, there appeared to be an indirect effect, as in several organizations a programmer first learned how to use Linux by casually trying it at home, and such programmer knowledge both reduced the perceived risk of open source adoption and steered the organization towards using Linux in their open source platform. This finding is consistent with Rogers (1983) and Eveland and Tornatzky (1990), who argue that technologies are more likely to be adopted if they can be tried and assimilated in small chunks over time.

Organizational Factors

Several organizational factors appear to influence the Linux adoption decision. These included the organization's general stance toward IT innovation, the strategic importance of IT to the business, the presence of boundary spanners in the organization, and the nature of slack resources available.

IT Innovativeness. Each of the companies had some view of itself in terms of its approach to IT innovation. Semico's CIO said his company is not an early leader, but a fast follower: "Once the tornado hits, we'll be there." ISP stated that his company was a leading edge adopter in

1996, when the whole ISP business was new and Linux was still little known in the mainstream IS world, but that the business was mature and they were no longer looking to be an innovator. This self-definition in terms of innovation orientation appears to be an important factor in terms of the timing of adoption, and also in terms of the kinds of cues that are relevant to the decision to adopt.

Centrality of IT. Another organizational factor that appears correlated to the willingness to adopt is the strategic importance of IT to the firm's business. For ISP and NewMedia, IT is at the core of the business strategy and accounts for a large share of the firm's cost structure. As such, any strategic advantage gained is more important, and a decline in IT costs have a greater impact. For Semico, IT plays an important supporting role in strategic areas such as product design and supply chain management, but IT is not a source of strategic advantage. Therefore, the adoption of Linux is being considered mainly in terms of potential cost savings in the IT function. For FastFood, IT is even less central, and the potential advantages of open source are seen as intriguing, but not anything that requires immediate action. These findings are consistent with Eveland and Tornatzky (1990), who argue that firms that are more dependent on technology for competitive advantage will be more open to new technologies and have the capability to absorb them, and Swanson's (1994) proposition that adoption of IT innovations is more likely when IT is strategic to the business.

Boundary spanners. In several cases (ISP, Biotech, South U, Bio Branch), the presence of IT staff with previous Linux or other open source experience was a factor in the decision process. As Biotech's associate director of IT infrastructure (who had modified Linux source code in his previous job) stated, "the fact that I'm here means that Linux is at least considered when these decisions are made." Biotech's CIO agreed that this person was an advocate for Linux within the IT organization. At South U, the CIO expressed his wariness about adopting open source applications, and in fact has standardized entirely on Windows servers, yet for a key web-based application has adopted ModPerl and Apache. In explaining this decision, the CIO stated that "the primary architect for [the application], recommended that and has skills in that, and I trust him." Our interview with that developer confirmed that he had significant experience with open source software. These findings support the role of boundary spanners in innovation adoption posited by DePietro, Wiarda and Fleischer (1990: 159-160)

Slack. Informants articulated two dimensions of slack resources — financial and human — that pushed them in different directions. For firms with slack human resources and limited financial resources, a free operating system that comes with little support makes sense, if the skills exist to install and operate that system. So at their founding, both NewMedia and ISP selected Unix technologies for their Internet infrastructure: the venture-funded NewMedia bought Sun servers, while the lack of financial slack drove ISP to Linux, as its CTO explained:

> [The founding 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. Originally we thought we would going to go with Sun equipment, but because of cost etc. [we couldn't]. … And so we started right from the start with Linux.

NewMedia started with Sun's platform, but later switched some applications to FreeBSD and Linux when it desperately needed to save money, yet still had some human resources with slack time, in particular an operations person who had time to play with Linux during stretches between systems crashes. For Semico, financial pressures pushed the consideration of wider

use of Linux as the telecommunications crash of 2001 cut deeply into profits and forced retrenchment.

The relevance and impacts of slack resources in technology adoption has been a source of contention in the literature. While slack is argued to provide the room needed for experimentation, it is also argued that too much slack can reduce discipline and lead to investment in pet projects with limited economic value (Nohria and Gulati,1996). The interesting point in our findings is the fact that slack can take different forms (financial versus human resources) with different impacts.

Environmental Factors

Linux is a standard not sponsored by any one organization, implying a higher level of risk (for at least some MIS managers) than one directly controlled and sponsored by a major IT firm. As a consequence, various analysts have postulated risk would be reduced by third party sponsorship by independent distributors (e.g. Red Hat, SuSE) or hardware firms (e.g. IBM, HP) that supplied the remaining layers of open source platforms, including hardware and support services (Wagner 2000, West and Dedrick 2001).

We sought to ascertain whether third party sponsorship was important to existing and potential adopters in one of two ways.

Available technology skills and services. While users of proprietary software can turn to the vendor for technical support, there is no vendor of open source software—only a loose community of developers who are not on call when a system crashes. Three larger companies (FastFood, Biotech and Semico), cited vendor support as being important. Support from major vendors such as IBM and HP was mentioned by Fast Food as a factor that would make them more comfortable with adoption. On the other hand, for ISP and NewMedia, support from large vendors was not an important consideration. It is probably not surprising that vendor support is more important to larger organizations that are used to having the financial means to buy technology and support contracts from major IT vendors. Small firms rarely have the resources to pay for integration or maintenance services from the likes of IBM or HP, and are more likely to rely on their own skills and the free online support available from open source communities.

Legitimacy. Given how often such sponsor-driven legitimacy is mentioned in the discussion of Linux and other open source technologies, we would expect to find it frequently cited as a factor in adoption decisions — over and beyond actual support. Semico's CIO stated that "the fact that HP is committed to Linux is comforting." North U chose Dell first and then chose the Linux distribution that was fully supported by Dell.

Meanwhile, the value of commercial distributions (notably Red Hat) was also unclear. One site (North U) required support as a condition of selecting its platform. Another site (ISP) used only free downloads, while two others (Bio Branch and E-data) paid for Red Hat Advance Server on key high-end servers but mainly used the free version.

The sites without support cited the success of the open source community in providing ongoing support and updates as a major attraction of Linux. Typical was the Semico CIO, who said that with its existing proprietary operating systems, they "have to go through enormous effort to ensure patch compatibility. With Linux you get the latest patches every day." On the other hand, Semico's datacenter manager stated that they needed support from a reliable vendor such as HP, Sun, Dell or IBM if they were going to run Linux in a critical environment, as the support people from those companies could better handle problems that arise than his own staff.

In summary, we found several factors influencing Linux adoption decisions that are consistent with the diffusion of innovation literature. First, Linux was perceived to have an important *relative advantage* over competing standards in terms of cost. Second, the issue of *compatibility* with existing technologies in use was important. Third the *trialability* of Linux was considered an advantage. Beyond those technology traits, there were organizational traits that seem to influence the decision. One was the importance of *boundary spanners*. Second was the level of *complementary skills* in the organization, particularly Unix skills. In addition, consistent with the TOE framework, there were two environmental factors that affected the decision. First is the perceived *availability of Unix/Linux skills* in the external environment, either for hire in the labor market, or for contracting from IT services companies (consistent with Attewell 1992) Second is the importance of *support for Linux by major vendors* such as IBM, HP, Dell and Red Hat, not only for the services they provide, but also for the legitimacy the confer on Linux investments within the organization.

DISCUSSION

Implications for Standards Research

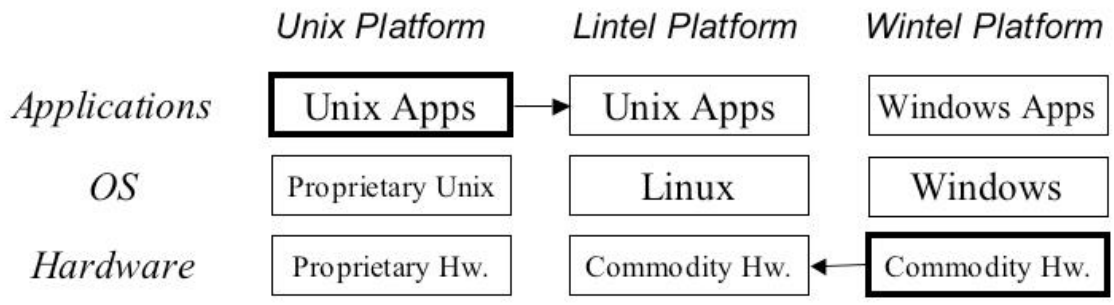
Our findings provide empirical support for both standards and diffusion of innovation theories in explaining Linux adoption decisions by corporate IT departments.

Economics of standards

Economic research holds that a key barrier to the adoption of a new standard is the barrier to entry created by existing standards through complementary assets. Specifically, the installed base of users give an established standard an advantage through positive network effects and switching costs.

As a new server platform in the 1990s, Lintel was able to build a large base of complementary assets in a relatively short time. Our data suggests that the key reason for this rapid adoption of Linux for servers has been its ability to leverage the supply of complementary assets from both of its major rivals (Figure 2).

Figure 2: Reuse of complementary assets between Windows, Linux and Unix platforms



In evaluating the Lintel platform, our respondents overwhelmingly cited the ability to use the wide range of commodity hardware — microprocessors, systems, peripherals — developed for the Wintel platform. Such hardware enjoys global economies of scale and is available from a large number of competing suppliers, while Intel and PC vendors encouraged its adaptation for use with the Linux operating system (Dedrick & Kraemer 1998; West & Dedrick 2001).

The other major attraction of the platform was the wide availability of software, most originally developed for earlier Unix-compatible systems. Systems vendors such as Sun attracted

software developers through direct appeals as well as cross-platform API standards to provide a larger market for potential software developers (Garud & Kumaraswamy, 1993). The success of Unix-based systems created a wide range of what Teece (1986) classifies as co-specialized complementary assets — not just packaged software, but custom software, documentation, training and skilled workers. The conscious choices of Richard Stallman and Linus Torvalds to "clone" pieces of Unix enabled Linux to bootstrap adoption using the Unix-specialized assets.

As our sample demonstrated, these decisions meant lower Linux-related switching costs for Unix shops than Windows shops, but those switching costs acted differently for different types of software. For custom (in-house) software, a slightly different Unix would require an investment in converting the software to Linux APIs — an investment that our respondents recouped due to lower hardware costs. For open source applications, the large (by this point) user base meant that the conversion had already been done by earlier Linux users. For applications from commercial software developers, conversion by the developer was easier for Unix to Linux (versus, say, Unix to Windows XP), but whether such software was converted was under the developer (not the user's) sole control.

Finally, Linux adopters were not worried about the risk of being "angry orphans". In fact, Linux had so successfully co-opted most of the Unix-specific assets that several interviewees predicted Linux might be the only Unix-based platform to survive.[5]

Standards adoption is not always innovation adoption

While the DOI and economics of standards research have been applied independently (Fichman and Kemerer, 1993 being a rare exception), they can play a potentially complementary role. But any attempt to study adoption of technology standards needs to make an important distinction in defining the dependent variable.

The limited MIS literature on organizational adoption of standards has tended to treat the adoption of any new standard as an innovation adoption. However, the adoption of a particular standard is not always an "innovation" in the sense of Rogers (1983) or Eveland & Tornatsky (1990). The distinction between innovation and standards adoption is more than semantic. Rogers (1995: 11) defines "an innovation is an idea, practice or object that is perceived as new by an individual or other unit of adoption" and adoption as "a decision to make full use of an innovation as the best course of action available" (p. 21). In the Rogers framework, early adopters differ from late adopters based on their personal (or organizational) traits, whereas for standards subject to indirect network effects the perceived value of a standard increases for everyone only if its increasing popularity attracts a better supply of complementary assets (such as software).

In the computer industry, different types of platforms may not reflect innovation but competing flavors within the same type. Greenstein (1993) studied government agencies that had adopted mainframe computers, but then switched between platform standards. The relational database innovation studied by Fichman and Kemerer (1993) has enjoyed widespread adoption since their study, but the battle between competing proprietary database standards (with incompatible file formats and APIs) continues to this day. Similarly, in Chau and Tam's (1997) study of open systems adoption, high perceived performance for multivendor standards would be a characteristic of the open systems innovation, but many of their barriers to adoption are

[5] During our study period, the *SCO v. IBM* lawsuit was filed attempting to prevent Linux from supplanting Unix. While respondents mentioned it, due to skepticism about the eventual outcome we did not find that it changed the attitudes of existing adopters.

measures of switching costs from an existing (mainframe-based) platform to a Unix-based platform.

Thus we believe that for many technologies, researchers will be produce a more accurate picture of IT innovation adoption if they separate the two constructs — the innovation adoption decision and the issues associated with switching between standards.

Insights into Open Source Adoption

"Free Speech" vs. "Free Beer"

What have we found thus far explaining the adoption of an open source platform such as Linux as compared to proprietary platforms? No one claimed that Linux offers any important performance advantages over other forms of Unix, which is not surprising since Linux is little more than a variation on a mature technology. Instead, the most important driver of adoption was cost — both of hardware and software.

The organizations we studied focused on open source platforms that used commodity, Intel-compatible PC hardware.[6] Such hardware had always been available for "Wintel" servers, and thus the "Lintel" solution did not provide a hardware advantage for existing Microsoft shops. However, for Unix shops, the hardware substituted for expensive proprietary RISC-based servers, allowing firms to reduce capital equipment costs for their information systems.

What about the freedom provided by "free" software? The movement's founder, Richard Stallman, has always maintained that source code control is the central benefit:

> "Free software" is a matter of liberty, not price. To understand the concept, you should think of "free" as in "free speech," not as in "free beer." (Free Software Foundation, 2000)

For server platforms, we saw little evidence that the ability to modify the Linux source code was valued. To the contrary, both Semico and FastFood specifically said that they would not want their IT people getting involved with modifying Linux source code. As FastFood's Director of Enterprise Architecture stated:

> We wouldn't want anybody mucking with that; it's something we would discourage. Maybe some other organization would do that, but that's definitely not us.

Two organizations mentioned rare occasions where the Linux source code documented variations in APIs among Unix family platforms — helpful for porting from proprietary Unix to Linux. This might either be a strength of open source or merely a work-around to one of its weaknesses, the lack of formal documentation.

We recognize that our findings are at odds with prior research on the value of open source. Former Red Hat CEO Bob Young said that when they asked customers about adoption motivations in the late 1990s,

> "The answer never was because it was cheaper, or because it was faster, or because it was cleaner. The answer was always for the serious users [that] for

[6] While we have a small sample, both secondary research and our interviews with various I.T. firms lead us to believe that this finding is representative of the larger pattern of server adoption, i.e. that open source servers are primarily "Lintel" machines.

> the very first time they had control over the technologies they were using." (Speech, MIT Sloan School, June 19, 2003).

However, we believe that by studying the phenomenon four years later, we are seeing a more mature market that (like other mature markets) more highly values cost. Also our sample suggests that the most cost-sensitive organizations might be Red Hat users (via free download) but not Red Hat customers.

Similarly, other studies (e.g. Franke and von Hippel 2003) have identified users who value the ability to modify source code. Based on our respondents — who did not modify the operating system but in some cases modified open source applications — we believe again that these are a matter of how complete and rapidly changing the implementation is. For an immature product such as a web server in the mid-1990s (or, for that matter, any product needing rapid updates to patch security holes as in the Franke and von Hippel study), sophisticated users value the ability to finish or extend the incomplete work of the program author. But Linux's success as a 10-year-old clone of a 30-year-old operating system meant that users not only did not want to modify the code, but in many cases they waited long periods to update to freely available newer versions.

Linux users totaled roughly 5 to 15 million by various estimates as of 2000 (Linux International, 2001), whereas the company that has hosted the Linux kernel repository since 2002 estimated that there are about 2,500 developers of the Linux kernel (www.bitkeeper.com).[7] Even at the most optimistic assumptions and ignoring growth from 2000-2003, this is a 2,000:1 ratio of users to modifiers, meaning that very few adopters are actually modifying the code.

So in considering industry maturation, the nuanced source code attitudes of our respondents and some common sense ratios, we would suggest adoption by source code modifiers is primarily a factor for "innovators" (the first 2.5%) in the Rogers (1983) typology, but as the software gets more mature and more popular, the subsequent adopters are mostly free riding on the work of the open source community rather than fighting for free speech. In fact, the CIO of Biotech made the connection explicitly, saying "We want to be free riders."

Other Adoption Motivations

Total Cost of Ownership. Some of our informants noted that the open source platform freed them from sizable annual fees for OS usage and upgrades. However, there were other costs. Speaking for others in our sample, South U's web applications programmer noted that while "free beer" triumphed over "free speech", open source software was not exactly free:

> It's "free" — licensed free, but it's not free to use. You guys have heard the saying, "free as in beer"? It's not free as in beer… You have to have the people there to maintain it and develop it and foster it and all those things, and that costs money. And that costs *more* money than the actual licenses for the software.

While the relative advantage of Linux was clearly defined in terms of cost, the willingness and ability of organizations to adopt this lower cost technology depended on a range of factors consistent with some of the key predictions of diffusion of innovation theory. These include

[7] A few such as Richard Stallman suggest that an operating system consists of a kernel plus associated tools. The reality is that most tools (such as Stallman's own *gcc* compiler) are applications which can run on multiple operating systems, and thus are more akin to complementary assets than attributes of any specific operating system *per se.*

compatibility with current technologies and skills, organizational resources and tasks, and the availability of external technological resources.

Path Dependency. The complex adoption stories of our informants illustrate the linkage between switching costs and path-dependent technology adoption trajectories of Arthur (1989). When they made their initial server adoption decision, some chose Windows, some chose Unix and a few chose mainframes. The Linux option was far more attractive for the Unix shops — not for the reason normally cited in standards research (an investment in application software) — but because of investments made in hiring and training skilled IT workers. Among Unix users, we saw evidence of a nascent "tipping" effect toward Linux, as they increasingly see Linux as the likely long-term winner. This perception may influence Unix shops to adopt Linux, to avoid the possibility of being orphaned — a problem Semico faced as one of its current technology platforms was being cancelled. Linux support from powerful technology vendors for Linux may be fueling such a perception, as well as providing more direct benefits to adopters.

Limitations

The use of multiple qualitative case studies provides a rich opportunity for building 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 (Eisenhardt, 1989). There is also the risk of attempting to generalize from a still-emergent process: the adoption of open source — both by business end-users and proprietary hardware companies — is still comparatively recent phenomenon.

We are particularly wary at this time of generalizing from open source operating systems to open source applications, for two reasons.

First, as noted earlier, Linux is more mature than most open source applications, and thus the benefits of source code access are lower.

Secondly, open source operating systems are re-implementations of Unix, at one time the most widely adopted platform for Internet computing (cf. Dibona et al 1999). Thus it is not surprising that Linux and other Unix clones have proven popular for Internet servers, because (as ISP noted) that was the Internet's core OS. West and Dedrick (2001) identified Linux as among several software packages (along with Apache, Sendmail, and Perl) that both helped support Internet infrastructure and were dependent upon it for their virtual collaborative development. One might expect that standards decisions not related to Internet servers would lack such an exemplary fit to task, and thus the perceived compatibility of Linux (or other open source package) could easily differ from that identified in our study.

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