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An Exploratory Study into Open Source Platform Adoption

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Abstract

Research on open source software has focused mainly on the motivations of open source programmers and the organization of open source projects [17] [19]. Some researchers portray open source as an extension of the earlier open systems movement [36]. While there has been some research on open-systems software adoption by corporate MIS organizations [4] 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 contrast this to prior academic and popular reports about the adoption of open source.

1. 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 likelihood of eventually having to switch to the winning standard or living with a much smaller supply of complementary assets and smaller levels of producer investment [10] [16].

Prior research on standards competition has focused mainly on the decisions of producers of technology products such as PCs, mobile phones and consumer electronics. The emphasis has been on which standards these producers adopt for their own products, and what strategies they employ to ensure widespread adoption while maintaining the ability to appropriate some of the returns from such adoption [27] [10]. By contrast, the literature has paid little attention to identifying the factors that determine the standards adoption decisions of technology users, even though these decisions ultimately decide the outcomes of standards competitions.

Although the standards literature says little about end user adoption decisions, there is a rich stream of research that studies technology adoption and diffusion more generally. This research considers a number of factors influencing the adoption of new technologies by organizations, including the nature of the technology, the beliefs and attitudes of individual adopters, the social and political context in which adoption decisions are made, the economic factors influencing adoption, and the processes by which potential adopters evaluate, experiment, adopt, adapt and implement new technologies [24] [28] [29]. However, there has been limited research that incorporates both diffusion of innovation and economics of standards theories. An exception is Fichman and Kemerer [11].

In this paper, we use grounded theory to explore the complex adoption decisions made by organizations. Our focus is on computing platform standards as defined by operating systems and computer hardware, specifically the decision process of organizations selecting among competing server platforms.

In this study, we seek to understand why organizations adopt computing platforms based on Linux or other open source software. We document a rich set of technological, organizational and environmental factors that influence such decisions. We also extend the innovation adoption literature by showing the multidimensional nature of key innovation attributes — such as price and organizational slack — that push organizations in different directions.

2. Background

The theoretical foundation for most technology adoption research is found in the diffusion of innovation literature [28] [24] which studies the process of technology diffusion and the factors influencing technology adoption decisions. Tornatzky and Fleischer [29] 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 [24] 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 [28] concluded that three of these variables were consistently linked to technology adoption: *compatibility, relative advantage,* and *complexity*.

2.1 Organizational Adoption of Technologies

Much of the technology diffusion literature focuses on the adoption decisions of individuals. 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" [29], p.133. Thus, a more robust framework is needed to study organizational adoption.

An influential framework for understanding MIS adoption in an organizational context has been developed by DePietro, Wiarda and Fleischer [7].[1] Their model defines a "context for change" consisting of three elements:

Technology. This aspect of the model subsumes the five innovation attributes that Rogers [24] 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. A firm's strategic IS decisions will depend in part on industry characteristics such as competition, relations with buyers and suppliers, as well as the stages of the industry life cycle [7] (p.169-171). Organizational adoption of new technologies depends on having the prerequisite skills for effective deployment, so as Attewell [1] found, the availability of external skills (such as through integrators or consultants) is essential for adoption by some organizations.

These three elements are posited to interact with each other and to influence technological innovation decision making [7]. In fact, the so-called 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.

2.2 Adoption of Computing Platforms

There has been considerable research regarding organizational adoption of information systems, including studies of MRP [5], EDI [15] [18], and e-commerce [37]. However, despite the importance of standards in the IT industry, the role of standards in adoption decisions has rarely been considered.

One of the few such studies is that of Chau and Tam [4], who conducted in-person surveys of organizations considering adoption of Unix-based open systems. Using three technology, three organizational and one 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.

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 adoption and competition. Among the first to consider such costs in technology adoption was von Weizsäcker [31], who modeled how users would consider the net present value of anticipated future switching costs.

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] 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.

Katz & Shapiro [16] 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.

Among the few to combine standards theory with diffusion of innovation theory were Fichman and Kemerer [11], 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 [24] and four factors from standards theory (prior technology 'drag', investment irreversibility, sponsorship, and expectations) 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.

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 [21] [3] [35].

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 [35]. 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 [33].

2.3 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 package 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. In fact, its success has driven major IT vendors such as IBM, HP, Oracle and Dell to support Linux with various computer systems, to develop Linux versions of major software applications, and to make venture investments in Linux startups. Although less popular than Linux, the BSD family of open source operating systems (NetBSD, FreeBSD, OpenBSD) have a small but loyal following among computer science professionals [36].

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; 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 [20] [17] [19]. 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 [34] [36].

Comparatively little work has been done to see how the organizational adoption of open source differs from that of other technologies. Franke and von Hippel [12] 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.

3. Research Design

Our study (currently underway) 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 of 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. 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. Thus, we

focus on one question: What are the major factors influencing the adoption of open source platforms by information systems departments?

Because the organizational adoption of platform standards and open source software is 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 [14], as well as management studies that employ the inductive method to draw theory from a set of case studies [8]. Such rich data is accepted way of capturing the complexity of an organizational adoption decision [23].

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. During our field research, we intend to conduct interviews in at least eight organizations, comprised of at least one large and one small organization in the following categories: high-technology services, high-technology manufacturing, low-tech services and government/education. Our sample (thus far) is summarized in Table 1.

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 lasted from 45 to 90 minutes. Basic organizational data was collected via questionnaire, with background data for public companies compiled from standard sources such as Compustat or Hoovers. As needed, follow-up questions were asked by phone or e-mail.

4. Analysis

Although our data collection is still in progress, a preliminary analysis of the interviews completed thus far shows some consistent patterns. These are explained below.

4.1 Server Platform Choices

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").

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 sold passed the number of Unix servers [36]. 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 [25]. 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.

4.2 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 [26] 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. If the company or division had certain application needs (such as the Apache web server or an Oracle database), switching the platform "underneath" the application would be transparent to end-users. Thus, it appeared that (when compared to more tightly coupled technologies), power and politics played a less important role in the server platform adoption decisions — simplifying the data collection and improving the internal validity of the data for each site.

Also, the wide acceptance of standard Internet communications protocols across all server platforms reduced (although did not completely eliminate) 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, more than one of the organizations studied were operating both proprietary and open source server platforms for different functions.

The size of the hardware and labor investment to install a new platform made the choice of a new platform an infrequent decision, and thus one that brought a significant amount of search cost to choose a "best" alternative. At the same time, the decision-makers gave evidence of decision shortcuts that appeared to vary between organizations. In particular, the short cuts and path dependencies seemed crucial in accounting for choices *between* open source platforms using commodity hardware (e.g. Intel hardware running Red Hat Linux or FreeBSD), which were nearly identical in price, performance and the availability of server applications.

Thus, from among the four innovation adoption decision processes described by Tornatzky & Fleischer [29] (p.181-82) — rational, bounded rational, political and garbage can — the server decision process most closely conformed to a bounded rational optimization process.

Finally, we want to emphasize the salience of the overall platform decision, involving operating system, processor and the overall computer system. Customarily, studies of platform competition have emphasized 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 [3] [35]. 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 salient. So we saw three patterns — organizations that chose the operating system first,[2] those that chose the hardware first, and those that selected an operating system on the basis of API compatibility with a critical application (i.e., whether a key enterprise application was certified to run on a particular operating system).

4.3 Technology Factors

Several characteristics of Linux were consistently mentioned as influencing the adoption decision. Consistent with Rogers [24] and Tornatzky and Klein [28], 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 primarily in terms of cost and reliability. Notably absent was the view that users value the ability to see and manipulate the source code, an attribute often cited as a major advantage of open source software.

--*Cost.* The cost advantage of Linux consists of two factors—hardware and software cost. Linux runs on Intel-based servers which benefit from the economies of scale of the global PC industry and are available from a large number of competing suppliers. This gives Linux a cost advantage over Unix systems that are linked to proprietary RISC hardware which is more expensive and available from only one or a few vendors. On the other hand, Linux has no hardware cost advantage over Microsoft Windows servers, which run on the same Intel hardware. All of the companies interviewed mentioned hardware cost as an important relative advantage of Linux.

Two 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 Windows or the proprietary versions of Unix. Upgrades are also free, so there is no ongoing cost to stay with the latest version of Linux, unlike Unix or Windows. Two of the five organizations stated that the cost of software was a significant factor in the choice of Linux, while one (Semico) stated that the cost of software licenses was not high enough to be a factor. Only StateU 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 the second most-often cited factor. One interviewee stated that Linux is "up to speed" in terms of reliability for most tasks such as SAP applications, but was concerned that it still lacked the reliability to run mission critical applications such as an Oracle database currently running on a proprietary system. On the other hand, he was even more concerned about running Windows for a database

[2] 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.

server because of security problems such as viruses. Another interviewee (Fast Food) felt that Linux was reliable enough for non-critical applications such as a file server or print server, but not yet ready to handle critical applications.

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 for 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.

The importance of compatibility with applications is consistent with the arguments in standards theory about the importance of complementary assets [10] [16]. However, in this case it is not the size of the overall pool of complementary assets, but the availability of specific key applications, a finding more consistent with the conclusion of West [34] 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 [30] terms, the transition to Linux is incremental for Unix shops where skills are easily transferable, but discontinuous for Microsoft shops that lack such skills.

Two of the companies (Semico and NewMedia) were already heavy Unix users and stated that this made the shift to Linux more manageable if not trivial (Semico's CIO said his staff needed time to adapt to the minor incompatibilities between the command interface of Linux and their existing Unix). A third (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, but is predominantly a Microsoft shop with Windows skills: the interviewee predicted this would be an obstacle to widespread adoption of Linux. He also cited the availability of administration tools for Windows. Both FastFood and StateU felt that it would be more difficult to find system or network administrators with the necessary skill to handle the more complex requirements of a Unix or Linux environment.

--*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. All of these are handled on the server side and the technology choice has no direct impact on customers. For NewMedia, the task is more complicated, as the company's custom software includes media delivery, content editing, web- and multimedia advertising as well as off-the-shelf online payments. 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.

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, in at several organizations a programmer first learned how to use Linux by casually trying it at home, and that 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 [24] and Eveland and Tornatzky [9], who argue that technologies are more likely to be adopted if they can be tried and assimilated in small chunks over time.

4.4 Organizational Factors

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

IT Innovativeness. Each of the companies had some view of itself in terms of it 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." This suggests that the decision to adopt involves closely monitoring technology trends

and moving quickly when a new technology begins to gain widespread adoption. The FastFood interviewee likewise referred to his company as a fast follower, although his definition of "fast" appeared slower than Semico's. 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. 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 [9], 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 [26] proposition that adoption of IT innovations is more likely when IT is strategic to the business.

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: however, the venture-funded NewMedia, with plenty of slack financial resources, 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 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, as profits disappeared and the company laid off 20% of the work force, financial pressures pushed the consideration of wider use of Linux.

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 [26]. The interesting point in our findings is the fact that slack can take different forms (financial versus human resources) with different impacts.

4.5 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 [32] [36]. We tried to find out 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. Two larger companies (FastFood and Semico), cited it 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 an beyond actual support. Semico's CIO stated that "the fact that HP is committed to Linux is comforting."

Meanwhile, the value of commercial distributions (such as Red Hat) was also unclear, as the one firm (ISP) that regularly used such distributions never paid for them. Instead, Semico cited the reliability of the Linux community in posting regular patches as a reason to consider adoption. The CIO stated 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."

5. Discussion

5.1 Findings

Overall, what have we found thus far explaining the adoption of an open source platform such as Linux? 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.[3] Such hardware had always been available for "Wintel" servers, and thus the "Lintel" (or FreeBSD) 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." [13]

For server platforms, we did not see a case where the liberty to view or modify the server OS was valued by firms. 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.

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

The complex adoption stories of our informants illustrate the linkage between switching costs and path-dependent technology adoption trajectories posited by Arthur [2]. When they made their initial server adoption decision, some chose Windows, some chose Unix and a few chose IBM 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 see Linux as the likely long-term winner. This perception may influence Unix shops to adopt Linux, to avoid the possibility of becoming "angry orphans" [6] — a problem Semico faced as one of its current technology

[3] 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.

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.

6. References

1. Attewell, Paul, "Technology Diffusion and Organizational Learning — The Case Of Business Computing," *Organization Science* 3, 1 (Feb. 1992): 1-19.
2. Arthur, W. Brian, "Competing Technologies, Increasing Returns, and Lock-In by Historical Events," *Economic Journal,* 99, 394 (Mar 1989): 116-131.
3. Bresnahan, Timothy F. and Shane Greenstein, "Technological competition and the structure of the computer industry," *Journal of Industrial Economics* 47, 1 (Mar 1999): 1-40.
4. Chau, Patrick Y K; Tam, Kar Yan, "Factors affecting the adoption of open systems: An exploratory study," *MIS Quarterly* 21, 1 (March 1997): 1-24.
5. Cooper, Randolph B.; Zmud, Robert W., "Information Technology Implementation Research: A Technological Diffusion Approach," *Management Science* 36, 2 (Feb 1990): 123-139.
6. David, Paul A., "Some new standards for the economics of standardization in the information age," in Partha Dasgupta and Paul Stoneman, eds., *Economic policy and technological performance,* Cambridge: Cambridge University Press, 1987.
7. Depietro, Rocco, Edith Wiarda and Mitschell Fleischer, "The Context for Change: Organization, Technology and Environment," in Tornatzky, Louis G. and Mitchell Fleischer, *The processes of technological innovation.* Lexington, Mass.: Lexington Books, 1990, pp. 151-175.
8. Eisenhardt, Kathleen M., "Building Theories from Case Study Research," *Academy of Management Review* 14, 4 (Oct. 1989): 532-550.
9. Eveland, J.D. and Louis G. Tornatzky, "The Deployment of Technology," in Tornatzky, Louis G. and Mitchell Fleischer, *The processes of technological innovation.* Lexington, Mass.: Lexington Books, 1990, pp. 117-147.
10. Farrell, Joseph and Garth Saloner, "Coordination Through Committees and Markets," *Rand Journal of Economics* 19, 2 (Summer 1988): 235-252.
11. Fichman, Robert G., Chris F. Kemerer, "Adoption of Software Engineering Process Innovations: The Case of Object Orientation," *Sloan Management Review* 34, 2 (Winter 1993): 7-22.
12. Franke, Nikolaus, von Hippel, Eric, "Satisfying Heterogeneous User Needs via Innovation Toolkits: The Case of Apache Security Software," *Research Policy* 32 (2003).
13. Free Software Foundation, "What is Free Software?", May 2000, URL: http://www.gnu.org/philosophy/free-sw.html
14. Glaser, B. and A. Strauss, 1967, *The Discovery of Grounded Theory: Strategies of Qualitative Research*. London: Wiedenfeld and Nicholson.
15. Iacovou, Charalambos L., Izak Benbasat, Albert S. Dexter, "Electronic Data Interchange and Small Organizations: Adoption and Impact of Technology," *MIS Quarterly* 19, 4 (Dec. 1995): 465-485.
16. Katz, Michael L. and Carl Shapiro, "Network Externalities, Competition, and Compatibility," *American Economic Review* 75, 3 (June 1985): 424-440.
17. Kogut, Bruce and Anca Metiu, "Open-source software development and distributed innovation," *Oxford Review of Economic Policy* 17, 2 (Summer 2001): 248-264.
18. Kuan, Kevin K.Y and Patrick Y.K. Chau, "A Perception-Based Model for EDI Adoption in Small Business Using a Technology-Organization-Environment Framework," *Information and Management* 38, 8 (Sept. 2001): 507-521.
19. Lerner, Josh and Jean Tirole, "Some Simple Economics of Open Source," *Journal of Industrial Economics,* 52, 2 (June 2002): pp. 197-234.
20. Markus, M. Lynne, Manville, Brook, Agres, Carole E., "What Makes A Virtual Organization Work?" *Sloan Management Review* 42, 1 (Fall 2000): 13-26.
21. Morris, Charles R. and Charles H. Ferguson, "How Architecture Wins Technology Wars," *Harvard Business Review* 71, 2 (March/April 1993): 86-96.
22. Nohria, Nitin and Ranjay Gulati, "Is Slack Good or Bad for Innovation?" *Academy of Management Journal* 39, 5 (Oct. 1996): 1245-1264.
23. Orlikowski, Wanda J., "CASE Tools as Organizational Change: Investigating Incremental and Radical Changes in Systems Development," *MIS Quarterly* 17, 3 (Sept. 1993): 309-340.
24. Rogers, Everett M., *Diffusion of innovations,* 3rd ed., New York: Free Press, 1983.
25. Shankland, Stephen, "IDC: Servers to Make Mild Recovery," CNET News.com, May 23, 2003, URL: http://news.com.com/2100-1010_3-1009814.html
26. Swanson, E. Burton, "Information Systems Innovation Among Organizations," *Management Science* 40, 9 (Sept. 1994): 1069-1092.
27. Teece, David, "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy," *Research Policy* 15, 6 (Dec. 1986): 285-305.
28. Tornatsky, Louis G. & Katherine J. Klein, "Innovation Characteristics and Innovation Adoption Implementation," *IEEE Transactions on Engineering Management* 29, 1 (Feb. 1982): 28-45.
29. Tornatzky, Louis G. and Mitchell Fleischer, *The processes of technological innovation.* Lexington, Mass.: Lexington Books, 1990.
30. Tushman, Michael L. and David Nadler, "Organizing for innovation," *California Management Review* 28, 3 (Spring 1986): 74-92.
31. von Weizsäcker, C. Christian, "The Costs of Substitution," *Econometrica* 52, 5 (Sept. 1984): 1085-1116.
32. Wagner, Mitch, "The Credibility Factor — Giants Get Linux Religion," *InternetWeek* (Feb 7, 2000): 1.
33. West, Joel, "How Open is Open Enough? Melding Proprietary and Open Source Platform Strategies," *Research Policy* 32 (2003).

34. West, Joel, "The fall of a Silicon Valley icon: Was Apple really Betamax redux?" In Richard Bettis (Editor), *Strategy in Transition* New York: Wiley, forthcoming.
35. West, Joel and Dedrick, Jason, "Innovation and Control in Standards Architectures: The Rise and Fall of Japan's PC-98," *Information Systems Research* 11, 2 (June 2000): 197-216.
36. West, Joel, and Jason Dedrick, "Open Source Standardization: The Rise of Linux in the Network Era," *Knowledge, Technology & Policy* 14, 2 (Summer 2001): 88-112.
37. Zhu, Kevin, Kenneth L. Kraemer and Sean Xu, "A Cross-Country Study of Electronic Business Adoption Using the Technology-Organization-Environment Framework," *Proceedings of the 23rd International Conference on Information System* (Dec. 2002): 337-348.

Name (# of informants)	Business	Org. Size†	Primary Platform	OSS Platform Adoption
FastFood (1)	Restaurant chain	244,000	Mixed	None
Semico (2)	Semiconductor design	2,500	Mixed	Limited; evaluating further use
ISP (1)	Internet service provider	11	Linux	Since founding
NewMedia (2)	Content provider	35	Unix	Partial transition
StateU (1)	Public university	114,000	Windows	Abandoned

† Size of parent organization in number of employees

Table 1: Characteristics of sample firms