

developing with open source software

Economics of Linux Adoption in Developing Countries

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There was once a time when developing software required only three main ingredients: a user with a need, a computer, and a programmer. Once these three ingredients came together, the resulting team could largely ignore everything in the outside world except the occasional need for pizza. Later, both the sizes and goals of such teams grew considerably, but often the insular attitude remained. Needs, computers, and software developers still went into a big black box, and

sometime later, if the project was fortunate, the required software emerged as if by magic.

For most software developers, those days of splendid isolation disappeared long ago. Increasingly, software developers became dependent on their choice of external software products, which supported them but over which they had no direct control. A wrong choice could spell disaster for a project, no matter how well the actual development went.

Recent globalization of software has made this choice even more critical. Over the last

two decades, software development has gone from an esoteric discipline dominated by American and European white-collar workers to a significant new global driver of emerging national economies. This globalization can affect build-versus-buy decisions at every level of software development. Software managers and developers who ignore this expansion do so at their fiscal and productivity peril.

Linux, an open source operating system, is an interesting example of a globally available software product that has nontrivial choice and productivity implications for software projects in developing countries. Its low cost, source code availability, and range of features make it an intriguing option when developing and deploying new software using limited resources. However, software managers must examine the full range of costs and benefits in-

Software globalization affects the build-versus-buy decision process at every level and phase of software development. One of the most interesting and controversial issues is the expansion of Linux into software development efforts in developing countries.

involved in selecting Linux over proprietary options, because they can have a powerful impact on both individual developers and developing countries. A deeper and richer understanding of the facilitators and hurdles of Linux adoption in developing countries could help software developers and marketers devise appropriate strategies to accelerate its diffusion and to recognize cases where a proprietary solution might be a better choice. This article examines the positive and negative effects of adopting Linux and ways to achieve the greatest overall benefits for developing countries and their policy makers. Because Microsoft's Windows operating system, used in over 90 percent of the world's desktops, is the major proprietary system competing with Linux, we compare Linux with Windows on several dimensions.

The current status of Linux use

Open source software is often touted to be ideal for accelerating the growth of low-income countries' IT sectors, with the expectation that it will increase their propensity to innovate. Developing countries seem to have adopted Linux, the "flagship" of open source,¹ faster than developed countries, according to numerous publications. For instance, a study conducted by the United Nations Conference on Trade and Development indicated that Linux has been a significant force behind some developing countries' increased IT ascendancy in recent years.² (In this article, the term "developed countries" indicates the 30 member countries of the Organization for Economic Cooperation and Development, and "developing countries" indicates all other countries.)

Because users can purchase Linux from distributors and also freely download it from various FTP Web sites, it can be difficult to reasonably estimate developing countries' share of the Linux market. But the number of registered users at the *Linux Counter* (<http://counter.li.org>) and their countries suggest an approximate distribution of Linux users worldwide. In 2001, people living in developing countries (81 percent of the world population) accounted for 24.1 percent of Internet users but only 18.6 percent of Linux users.^{3,4} Moreover, from 1998^{5,6} to 2001, the proportion of Linux users in developing economies grew more slowly than the proportion of Internet users (see Figure 1).³⁻⁶ Thus,

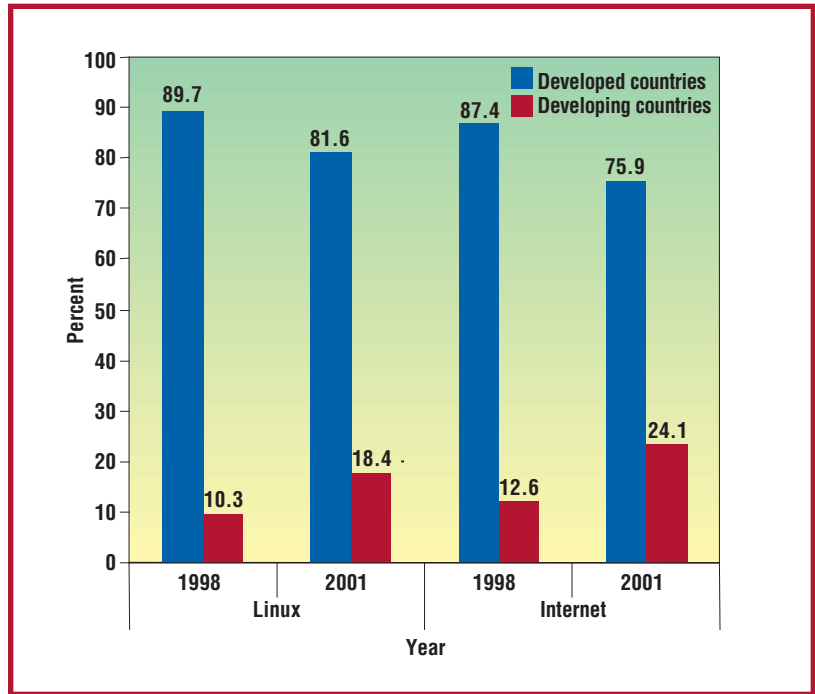


Figure 1. Percentage of Linux and Internet users from developed and developing countries.³⁻⁶

developing and developed countries seem more disparate in Linux adoption and use than in other modern information and communications technologies.

Microeconomics of Linux adoption

Software managers must examine four microeconomics issues of Linux use and selection: ownership, effective use, learning and switching to Linux, and compatibility (see Table 1). These economics evaluate the costs and benefits of Linux versus proprietary software at the level of an adopting unit.

Ownership

Ownership includes investment, maintenance, and the costs of downtime and obsolescence. These costs are a much higher proportion of income for a computer user in Burundi, which has an annual per-capita gross domestic product of US\$99, than for a user in Belgium. Open source advocates argue that Linux has a lower total cost of ownership (TCO) than its competing products. For instance, the price for Microsoft's entry-level operating system was US\$5 per computer in 1981 and \$90 in 2002. Taking \$600 as a PC's average price, Microsoft's entry-level operating system amounts to 15 percent of the PC's total cost. Although the operating system's cost decreases when manufacturers buy it in

Table 1**Macro- and microinfluences on choosing Linux in developing countries**

Factor	Positive effects	Negative effects
Microeconomics:		
Ownership	Slower obsolescence of basic infrastructure features help reduce total cost of ownership.	Lack of supports to deal with security vulnerabilities.
Effective use	Amenability to modification makes localized customization easier.	Ordinary users can't custom-configure the system. Costs of supporting custom changes can escalate dramatically over time.
Learning/switching	Switching costs might be lower compared to developed countries. Linux communities provide supportive environments for transition.	Undertaking to use the full complexity of Linux utilities and source code can lead to higher learning and switching costs.
Compatibility	Linux has high levels of compatibility and portability for old and used hardware.	Likely to be incompatible with business partners' technologies. Hardware-OS incompatibility if Linux device drivers are unavailable.
Macroeconomics:		
Enforcement of intellectual property laws	Linux IP rules encompass both aggressive sharing of basic resources and support for business growth.	Proprietary versions of Linux depend on IP laws.
National security	Linux provides an easier basis for global sharing of security infrastructure.	Microsoft's opening of codes increases Windows' relative attractiveness.

bulk, it is still likely to be a significant proportion of a PC's total cost. A cost comparison based on data from the Tech Zone (<http://thetechnozone.com>) indicates that although Mac OS X seems cheaper than Windows XP, upgrade costs over time make it twice as expensive. Likewise, according to *Internet Week's* 3 April 2000 issue, Linux is less expensive than BSD/OS.

Ironically, proprietary operating systems' higher prices often aren't a significant issue in developing countries because piracy of proprietary software is so endemic. However, the World Trade Organization's Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) requires developing countries to provide adequate legal and enforcement tools to prevent such piracy. Enforcement will be staggered, with the last mandatory compliance being 1 January 2006 for the poorest countries. Developing countries' full compliance with this agreement will thus likely strengthen the relative value proposition of Linux adoption over time.

Whereas prices so far haven't been of much concern to individuals using pirated proprietary software, they've contributed to the high prices of PCs that are bundled with proprietary operating systems. So, one way to bring down manufacturers' PC prices is to use Linux as the operating system. For instance, the South Korean multinational company LG

Electronics sells Linux-based desktops in India that are priced lower than brands using commercial operating systems. The company says it lowered the cost by legally saving the license cost of proprietary operating systems.

Linux traditionally has a strong reputation among developers for its ability to continue running under adverse circumstances, leading to lower costs due to less downtime. Another powerful distinguishing factor in downtime costs is the relative prevalence of malicious software. According to the Symantec Corp. in an 18 September 2003 article in the *Wall Street Journal*, more than 4,000 viruses and other malicious codes were launched against Microsoft Windows during the first eight months of 2003, compared to 11 attacks against Unix and Linux combined for the same period. Moreover, by using communications such as email, bug reports, bulletin boards, and various tracking mechanisms, Linux communities have gained a strong technical reputation for their ability to address and process most attacks and errors rapidly.⁷ On the other hand, rapid discovery of errors or attacks in Linux doesn't necessarily translate into adequate handling of the attacks at the individual user level, whereas Windows users have a wide range of online and commercial resources available to help combat virus attacks.

Although a study commissioned by Microsoft found that Windows' TCO was

cheaper by at least 10 percent in four of the five most common tasks,⁸ surveys of open source users tend to give different results. For instance, an article published by the NewsFactor Network (<http://newsfactor.com>) on 7 November 2002 quotes a survey conducted in the US, Brazil, France, Germany, Sweden, and Japan in which 40 percent of the respondents perceived Linux as having a lower TCO. Some organizations from developing countries that have adopted Linux have also reported a substantially lower TCO for Linux. For instance, Univates (a university in Lajeado, Brazil) estimates that switching to Linux saved US\$130,000 in one-time server and software procurement costs, plus an annual savings of \$70,000 on upgrades and maintenance.

Effective use

If we view open source as a form of technology transfer, developing countries' capability to employ it effectively is critical to the transfer process's overall success.⁹ For everyday data-processing applications, open source and proprietary software deploy with similar effectiveness in developing countries. However, when it comes to customization and adaptation to highly specific local technology transfer, the availability of source code provides important and obvious advantages.¹⁰

Adaptation to local languages is a good example. The most powerful adaptation advantages show up not on large language groups such as Asian character sets but on smaller groups for which there might not be sufficient market for a proprietary company to create and support a localized version. For example, the Open Source Software Translation Project in South Africa (www.translate.org.za) has produced Xhosa language packs for Linux to counter the lack of support for Windows systems.

Linux's affordability has allowed some developing countries to develop low-cost technologies that meet their unique needs. For instance, India-based Encore Software has designed a handheld Internet appliance, called Simputer, based on Linux. Simputer uses the Intel StrongARM chip (known for its low power consumption), 64 Mbytes of RAM, 32 Mbytes of flash memory, and a modem to connect to a telephone line. At a cost of less than US\$200, Simputer provides Internet and email access in local languages, microbanking,

speech recognition, and text-to-speech conversion. *Time* magazine described Simputer as among the 10 best technological innovations of 2001. India, which has two official languages (Hindi and English), 18 major languages, and 418 officially listed languages, has benefited from Simputer's low cost, efficiency, and local-language capabilities. For example, India's Karnataka state accountants use Simputers to collect and upload village data to the government servers, cutting data collection time by an estimated 80 to 90 percent. Similarly, Brazil's US\$250 Computador Popular, a Linux-based Internet appliance with no floppy or hard disk drive, features many of the attributes you'd expect in a moderately priced PC. Consumers can also buy inexpensive hard disks and other peripherals. The first shipment of Computador Populares is planned to go to schools, libraries, and health centers to provide access to the Internet.

What's more, Linux's transparent and collaborative nature will let developing countries provide affordable technology education and skills development, which will help build local programming skills and avoid spending hard currency on foreign technologies. Additionally, the Simputer might help train students on software in countries where there are few opportunities to use a computer because of English language constraints.

There's one caveat: An individual's capability to enjoy the economics of effective use is a function of skill level. Substantial skills might be needed to custom-configure some aspects of Linux systems to suit particular needs.

Learning and switching to Linux

Linux's extreme configurability has created a major disincentive for learning and switching to it. Josh Quittner described Linux's complexity in his *Time* magazine article of 24 May 1999: "The [Linux] interface is user friendly only if the user happens to be a [computer science] PhD." Since then, Linux programmers have worked hard to make the software more user friendly, and many of its users consider Quittner's assertion an overstatement now. Compared to commercial software, however, a small-budget Linux project typically has limited support and staff knowledge and fewer usability labs, user surveys, and outside experts such as technical authors and graphic designers.

Moreover, whereas Linux-friendly commer-

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cial companies such as Red Hat, VA Software, and IBM provide complementary services and products not supplied by open source communities,¹¹ such measures are heavily oriented toward developed countries. As with other technologies, commercial distributors often find developing countries unprofitable for their markets.

However, Linux communities worldwide and collaborations among them have contributed to the economics of learning open source. They're helping educational institutions, government agencies, private businesses, and individual users worldwide to adopt Linux. Kathleen Sibley, in an article published in *Computing Canada* on 21 July 1997, compares Linux communities with the Red Cross and the United Nations. Similarly, Thomas Malone and Robert Laubacher, in a *Harvard Business Review* article published in September 1998 (pp. 144–152), view Linux communities as a “model for a new kind of business organization that could form the basis for a new kind of economy.” Linux user groups are located in many places—from Albania to Armenia—where less experienced users get installation and other help from knowledgeable and experienced users.

On the other hand, Microsoft programs in some developing countries are helping to instill Windows-centric computer habits. For instance, a significant proportion of Microsoft's US\$400 million investment in India is being spent on computer literacy programs and localization of its products. Microsoft is also contributing its software to schools and is providing training to 80,000 schoolteachers and 3.5 million students in government-run Indian schools. This acclimatization increases the relative cost of learning and switching to Linux.

Compatibility

Networked technologies such as Linux derive much of their value from compatibility. Corporate resources such as hardware, applications, and existing files and technologies used by trading partners largely influence this compatibility. There are three important issues here.

The first is compatibility between operating systems and hardware. Because of the unaffordability of new PCs and thanks to charitable donations from developed countries, a much higher proportion of developing countries' computers are used and old. The Silicon

Valley Toxics Coalition, for instance, estimates that the US will discard 500 million computers between 1997 and 2007, 80 percent of which will be shipped to developing countries. Linux tends to be smaller than the latest versions of Windows, allowing it to run even on outdated machines powered by Intel Pentium 90 and even older 486 chips. Older versions of Windows, however, are smaller and run on older machines and can still be bought and used. However, Linux device drivers might not be available in developing countries for some components, which worsens the economics of Linux ownership.

Second, Linux is experiencing a vicious circle of low penetration of both its operating system and applications. Although some applications such as Wine and VMware can be used to run Windows applications on and within Linux, many of the Linux and Windows applications don't work on each other's platforms. So, Linux can't become widely used unless its applications become popular, but its applications will become popular only if Linux is widely used. Because Linux is free, Microsoft isn't likely to gain from the demand for hybrids (for example, using Microsoft's applications and Linux operating systems), so it has little economic incentive to create them. The resulting absence of products such as Microsoft Office on Linux thus encourages desktop users to stay with Microsoft or other proprietary operating systems.

Third, Linux users are also encountering compatibility issues with business partners' standards. Trading relationships between firms is a function of their technologies' degree of “fit,” or the “technological distance.” Because of their lower bargaining power, firms from developing countries are forced to comply with the technologies used by their trading partners in advanced countries. For instance, a 1995 study found that organizations from developed countries accepted new suppliers only if they could demonstrate an electronic-data-interchange capability.¹² Similarly, pressure from American multinationals such as Wal-Mart and J.C. Penney require their foreign suppliers to transact on the Internet. The suppliers, mainly from developing Asian countries, adopted the Internet because of such pressure.

Software upgrading thus tends to diffuse from big to small companies and from companies in developed countries to those in develop-

ing countries. This is commonly known as the *rank effect* in industrial economics literature. When trading partners from developed countries follow the Microsoft standard, as many do, firms in developing countries are less likely to adopt Linux. In this aspect, Linux attracts governments, especially municipalities, because they are not as connected with the outside world and don't have to exchange information with customers that follow Microsoft's standards.

Macroeconomics of Linux adoption

Software managers must also examine two macroeconomic issues: enforcement of intellectual-property laws and national security (see Table 1).

Enforcement of IP laws

The WTO's TRIPS agreement has obligated developing countries to provide and ensure the adequacy of new antipiracy enforcement tools.¹³ Strengthening IP protection in developing countries arguably creates incentives for domestic innovation. Nevertheless, developing countries feel that the TRIPS agreement has created a "disproportionate burden" on them without "tangible development benefits."¹⁴

Societies in many developing countries don't support the concept of private ownership of ideas and hence don't support IP protection laws.¹⁵ Compounded by low income and proprietary software's ever-increasing costs, a high proportion of software products in developing countries are illegal copies. For instance, 96 percent of software used in China and Indonesia, 97 percent in Thailand, 95 percent in Turkey, and 99 percent in Vietnam are estimated to be illegally copied.¹⁶

Changing the prevalent social beliefs has been a costly proposition for such governments. Citizens also perceive such enforcement tools as supports to foreign software companies. For instance, Taiwan's attempt to force students using pirated versions of Microsoft Windows to pay was perceived by the students as supporting a foreign company rather than its own citizens. What's more, enforcement of IP laws also results in spending hard-earned foreign currency on software imports.

Rapid open source diffusion in developing countries will likely lower economic losses and reduce administrative costs for IP law enforcement. So, these governments have opted to promote open source by applying various

measures of institutional intervention. In Asia, for instance, almost every country has a "national" Linux and a number of high-profile open source projects. For example, under India's Indlinux.org, a vast army of programmers are working on Linux to make IT's benefits freely available. The Chinese government established the Beijing Software Industry Productivity Center to organize Linux development. Yangfan Linux, a version developed by the center, has already been installed in many government computers.

Developing countries' orientation toward IP protection and the requirement to comply with TRIPS, however, will have a differential impact on the penetration of free and proprietary versions of Linux. Whereas free versions might diffuse faster in these countries, proprietary versions of Linux depend largely on the availability and enforcement of IP laws.

National security

Policy makers around the world are realizing the increasing influence of technologies in the national-security game. The impact and distinctions between proprietary and open source development are a fascinating component of this debate and have become an important element in some countries' national-security decision making. An article published in *China Economic Times* on 12 June 2000 discusses the views of Xu Guanhua, China's vice minister of science and technology at that time, on how high technology affects national security militarily, economically, and culturally. Regarding military security, Guanhua said that developed countries have used many hi-tech arms in battle and that technology-exporting countries might have installed programs for "coercing, attacking, or sabotage" into the software they're selling into China. Some governments, such as China, perceive proprietary software's hidden protocols as threats to their national security because it's hard to know what the software is doing or whether data is being shared inappropriately. The Chinese government in particular has expressed concerns that Microsoft and the US government might spy on Chinese computer users through secret back doors in Microsoft products. Ironically, the truth or falsity of such claims is less relevant from a marketing perspective than the fear itself, which can be very damaging to sales. Microsoft has recognized

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the danger of such fears and embarked on a program of revealing source code to help alleviate such fears. However, proprietary companies will always have more difficulty balancing IP concerns with security than do open source systems with no hidden IP secrets to protect.

National security concerns from the US and its allies in the form of a Coordinating Committee for Multilateral Export Security (COCOM) put restrictions on high-technology exports to countries such as China, which resulted in the avoidance of proprietary software in such countries. Despite the disbandment of COCOM in 1994, the US law still restricts the sale of computers that exceed specified performance limits, measured in “millions of theoretical operations per second.” Not too surprisingly, the most significant impact of such restrictions in the case of software operating systems has been to encourage rapid growth in China of Linux-based supercomputing clusters.

In general, the Chinese government sees Linux as a powerful opportunity to catch up and even pull ahead in the global technology race. Some signs of success are beginning to materialize and should be taken seriously by nations more concerned with protecting past investments than with fully exploiting the range of options made available by open source technologies. For example, in 2002 China announced a mobile version of Linux developed by Eforce, Culturecom, and Mobile Telecom.

To contribute to national security, developing countries are enacting new laws and providing guidelines to facilitate Linux development. By mid-2002, Latin American countries such as Brazil, Mexico, Argentina, and Peru had proposed bills mandating the use of open source in government organizations.

For the most part, Linux isn't being exploited as fully as possible in developing countries, and there are more impediments than unfair advantages to Linux deployment. Given that perspective, how can we encourage the effective and economically fair use of Linux?

Of the four micro and two macro issues, Linux probably fares the worst in terms of learning and switching. However, users that have touched Linux codes, which exceeded 15 million in number by 2001,¹⁷ have worked

hard to increase its user-friendliness so as to extend its reach outside technical and knowledgeable individuals and those in academic computing environments. Further improvement in its user-friendliness can help attract the critical mass of users required for broader success. Linux communities and Linux-friendly commercial companies thus should place more emphasis on improving Linux's simplicity and ease of use as opposed to more traditional quality dimensions such as accuracy, completeness, features, and structuredness.

Compatibility issues associated with business partners' technologies have the least influence on governments in developing countries, because they exchange relatively little data with more established groups and systems. However, because governments are the biggest single user of hardware and software in most developing countries,¹⁸ any decisions they make about adopting a specific operating system can have a powerful secondary compatibility effect on the OS's subsequent spread and dissemination nationwide. When they choose proprietary operating systems, the result can be an unfortunate exclusion not only of open source operating systems but also of other proprietary software systems such as Apple. Conversely, a decision to use Linux can yield a powerful incentive to use it more broadly, including in circumstances where it might not be the optimal solution. There is no easy and fully equitable resolution of this effect, but from the perspective of individual governments, it's important always to focus both on the ability to access all resources and on keeping future options open. So, exclusive statewide contracts with either proprietary or open source operating systems are seldom best for a country in the long term and should be avoided. Instead, multiple contracts that take advantage of the strong points of both open source and proprietary solutions will more likely lead to stronger long-term national positions in the global software market.

Linux communities and Linux-friendly companies can also help promote diversity and flexible options by working to make proprietary and open source operating systems more interoperable. The Chinese government has, for example, launched its own version of Wine, an open source API (application programming interface) that lets Microsoft applications run on Linux.

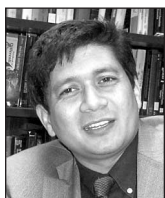
Finally, governments should explicitly support and encourage more of the kinds of low-cost, minimal-infrastructure developments demonstrated by Simputer. So far, neither the Indian information and communications technologies industry nor the Indian government has taken Simputer as seriously as the software industry has.¹⁹ This is unfortunate, because such systems could bring thousands of the poorest villages into the Computer Age. The implications of such actions could be enormous, not just for industry but also for reducing the global cycle of poverty and disillusionment that engenders many of the greatest dangers of the modern world. ☉

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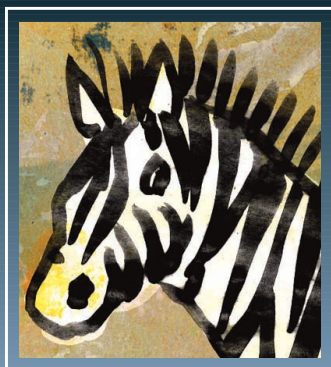
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