

The Comingled Code

**Open Source
and Economic
Development**

JOSH LERNER AND MARK SCHANKERMAN

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To Carol and Ralph

To my mother Etta and my father Paul (Z"L), with love

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Preface and Acknowledgments

Many a book has a tangled story behind it, and this one has a particularly long and twisted one. As a result there are a lot of people to thank.

This project has sought to understand the role of open source in economic development using several approaches. Given the early stage of open source software's development and the inherent difficulty of measuring these activities, only through taking multiple approaches can we do justice to this complex phenomenon.

The first approach was a careful review of the economic principles to shed light on the open source phenomenon and its implications for economic development. We prepared an analytical framework that highlighted how economics could guide us in understanding these complex issues. To do so, we drew on a diverse array of bodies of literature, including work on growth, the nature of innovation, and the literature on incentives and innovation in open source. When economic principles point in different directions—as they sometime do—we highlighted the open questions. The analytic framework underlies the work, and broadly informs how we approach the conceptualization of the demand and the supply sides in open source, as well as how we address the key policy questions.

The second approach was the preparation of a series of case studies of the open source phenomenon. We sought to understand the complexity of the role of open source in half a dozen nations in various stages of development. Rather than focus on the entire canvas of activities in each nation, we looked at different issues raised by specific situations in a number of emerging economies. Each study was based on interviews with Harvard Business School's case writers and secondary sources. The cases we studied were:¹

1. A variety of supplemental material not included in the book is posted on-line at <http://mitpress.mit.edu/comingledcode>.

- In Brazil, a project called HackerTeen seeks to combine educating young programmers with the development of new software.
- In China, the CEO of a mobile telephone software company must decide whether to use Linux or commercial alternatives as the basis for his system.
- In France, a chief information officer must choose whether to recommend the Ministry of Finance will run on open source or proprietary software.
- In Singapore, the government considers whether to support a research initiative to promote research in open source.
- In South Africa, a vendor of software and services must decide how much effort to devote to developing expertise in open source.
- In Thailand, the government considers whether to promote a “People’s PC,” which would combine a low-cost hardware platform with open source software.

By focusing on a wide variety of actors in a diverse array of situations, we gained a rich picture of open source activity and its implications for development.

The third and final aspect of the project involved a large-scale survey of software users and developers in fifteen countries. (The developer survey alone had nearly 2,000 respondents.) The nations included many of the same ones on which we wrote cases, as well as other developing and industrialized countries, including Chile, Greece, India, Israel, Kenya, Mexico, Poland, Russia, and Turkey. We highlighted in the questionnaire not just questions about the utilization of open source software, but also about the respondents’ attitudes and perspectives on the costs and benefits of this software. We further looked separately at developers and users of different types (for users, different sizes of companies, government agencies, and ownership; for developers, different sizes, ownership, software activities, etc.).

After we had conceptualized the project, we realized that the expense was so great that it was unlikely that we could fund it using our own resources: both the surveys and case studies proved to be extremely costly to implement. We discovered that Microsoft was interested in funding academic work into open source, with the goal of promoting a less ideological discussion of the pros and cons of software choices and public policy toward this sector, as well as providing

the empirical evidence that could contribute to a more balanced and evidence-based formulation of public policy. We accepted their funding under stringent terms that ensured that the effort was characterized by intellectual independence and analytical rigor.

This work, and the conversations it engendered, led to the idea of developing this book. As always, the process of converting research into (at least what we hope is) readable prose proved to be a far more daunting task than we had initially envisioned.

First of all, we are very grateful for the contributions of Jacques Crémer of the University of Toulouse. In addition to being the co-author of chapter 6, Jacques was crucially involved in many discussions that led to the development and elaboration of the main themes and ideas of the book. His was an important contribution to the volume.

Next, our thanks must go to our long-suffering MIT Press acquiring editor, Jane Macdonald, for her patience with us. We also would like to thank David Evans, Anne Layne-Farrar, and Daniel Schwartz of LECCG for their initial encouragement and help with the project, especially in the development of the survey questionnaires. Jacques Lawarree was the project's champion at Microsoft. We also benefited from considerable financial support from Harvard Business School's Division of Research. Mark Schankerman also thanks the British Academy and the Muzzy Chair in Entrepreneurship at the University of Arizona for their financial support of this research.

Sam Kortum of the University of Chicago was a member of the original project team and contributed a number of ideas. Brian DeLacey, Kerry Herman, and David Kiron played key roles in developing the case studies. Ivan Maryanchuk and Liat Oren provided excellent research assistance on the empirical analysis found in chapters 4, 5, and 6, and Kathy Han and Gabriel Fotsing provided invaluable research support on other aspects of the book. Maurie SuDock helped with the manuscript preparation and cleanup. While we are grateful for all the support, it is important to note that the ideas and recommendations represent our own opinions only.

As we discuss at more length in the introduction, there remains a considerable divide between the economics and open source communities. It is our hope that this book helps bridge this gap, by discussing the economic issues around open source in an accessible but tangible way based on systematic empirical evidence. We particularly hope

that this approach leads to a less shrill (or less acrimonious) interaction between these communities, and a more informed, evidence-based public policy toward this sector.

Josh Lerner and Mark Schankerman
Boston and London
October 2009

1 Introduction

Open source software involves developers at many different locations and organizations sharing code to develop and refine computer programs that are then distributed at no or low direct cost. Over the past fifteen years open source software has experienced explosive growth around the world. The importance of open source software today can be illustrated by considering a few examples:

- The market for server software, which is used by the computers that make Web pages available to users through the Internet, has been dominated by the open source Apache project since the inception of systematic tracking by Netcraft in 1995. As of July 2009 more than half of servers employed Apache or other open source products, rather than commercial alternatives from Microsoft, Oracle, or other firms.¹
- While definitive numbers are very hard to come by, a variety of survey evidence suggests that the open source operating system called Linux has rapidly outstripped Microsoft's Windows program as the operating system most frequently embedded into products ranging from mobile phones to video recording devices.²
- Open source software is dominant in a number of other areas as well; for example, PERL and PHP are the dominant scripting languages (programming languages designed specifically for instructing one computer how to communicate with others).
- Even corporations that have traditionally resisted open source, and the stringent General Public License (GPL) in particular, have seemingly changed their approach. Most visibly Microsoft, whose executives

1. http://news.netcraft.com/archives/web_server_survey.html (accessed August 23, 2009).

2. <http://www.linuxfordevices.com/c/a/Linux-For-Devices-Articles/Snapshot-of-the-embedded-Linux-market-April-2007/> (accessed August 23, 2009).

once branded the GPL as “fundamentally undermin[ing] the independent commercial software sector,”³ released two substantial blocks of code under this license in July 2009.⁴

- Open source software is not a phenomenon that is confined to rich countries. For better or for worse, the Brazilian and many other developing nation governments are promoting the use of open source software as an alternative to proprietary products. Significant numbers of contributors to open source software, in proportion to the population, can be found in countries with per capita income as low as \$10,000.

Open source software may be poised for rapid growth in the future. The number of projects has exploded: the website SourceForge.net, which provides free services to open source software developers, has grown from a handful of projects in 2000 to well over two hundred thousand open source projects today.⁵ Many of the projects seem to have room to expand: for instance, the operating system Linux has opportunities in the market for desktop operating systems; in 2009, only one percent of the Web queries tracked by Net Applications came from machines running Linux, although that share was gradually rising.⁶ More generally, the economic downturn appears to have accelerated corporate interest in and adoption of open source solutions: for instance, IDC recently revised its projected growth in revenue from open source products through 2013 upward, to an annual rate of 22.4 percent.⁷

The growth of open source software is attracting considerable attention from the public sector as well. Government commissions and agencies have proposed—and in some cases implemented—a variety of measures to encourage open source developers, including R&D support, encouragement for open source adoption, explicit preferences in government procurement, and even mandates regarding software

3. <http://www.microsoft.com/presspass/exec/craig/05-03sharedSource.msp> (accessed August 23, 2009).

4. http://www.microsoft.com/presspass/features/2009/Jul09/07-20LinuxQA.msp?rss_fdn=Toppercent20Stories (accessed August 23, 2009). It should be noted that Microsoft’s motivations for this step were hotly questioned and debated (e.g., <http://blog.seattlepi.com/microsoft/archives/174828.asp>; accessed August 23, 2009).

5. <http://sourceforge.net/apps/trac/sourceforge/wiki/Whatpercent20ispercent20SourceForge.net?> (accessed August 25, 2009).

6. <http://marketshare.hitslink.com/report.aspx?qprid=8> (accessed August 23, 2009).

7. <http://finance.yahoo.com/news/Open-Source-Software-Market-bw-400190557.html?x=0&.v=1> (accessed August 23, 2009).

choices. In 2008 the Center for Strategic and International Studies identified 275 open source public policy initiatives, 182 of which have been favorably enacted.⁸ For instance, since 2003, Singapore has offered tax breaks to companies using GNU/Linux operating systems rather than proprietary ones in order to encourage the development of the local software sector. Many European governments have enacted policies to encourage the use and purchase of open source software for government use. Governments have even mandated the development of localized open source projects, as has occurred in China. But while the efforts are concentrated in Europe and Asia, the interest in open source is truly global.

Brazil, Mexico, and South Africa are just a handful of developing nations that have launched significant open source initiatives. In part the appeal of these programs is that they are typically available for free, or at a much lower direct cost than comparable proprietary products. But these nations also argue that a wide variety of economic development benefits can follow from the development of a vibrant open source community, including the development of local industries, an improved foreign trade balance, and a reduction in intellectual property piracy.

Policy discussions around open source, though, have frequently been characterized by more heat than light. While the question at the heart of the debate—what is the impact of open source on consumers, firms, and economic growth more generally—is an economic one, the discussion is frequently framed in nearly theological tones. Advocates of open source passionately assert its benefits, while critics denigrate its role. Missing from the debate has been rigorous economic analysis and systematic microeconomic evidence, which might help sort out these competing claims.

This paucity of rigorous analysis in part reflects the strong emotions that the subject engenders. But it also reflects the difficulty of conclusively answering these questions empirically. Open source software usage is difficult to track, and the economic impacts of software utilization hard to trace definitively. Moreover there is always the chicken-and-egg problem: Did the use of a certain type of software promote the growth of a software industry in a given country, or did the rapid growth of a nation lead to it turning to a given set of software?

8. http://csis.org/files/media/csis/pubs/0807218_government_opensource_policies.pdf (accessed August 23, 2009). All citations to these programs are provided in chapter 6.

About This Book

This book seeks to address these challenging issues. Building on a series of analyses, we hope to improve our understanding of how open source and proprietary software interact and the policy issues that this raises. In particular, we try to provide an economic perspective on a debate that has been largely conducted on other terms, and a new large-scale database that can support more informed discussion.

The prior paragraph, of course, suggests a question: Why should economists have anything to say about software at all? It is true that we have spent many a happy hour programming regressions in Stata and trying to make tables come out just right in LaTeX. But we certainly do not pretend to be expert programmers, nor have we ever organized an open source project or corporate software initiative.

Rather, the answer to this question lies elsewhere. The question might well be reasonable if the book's focus was on the nature of open source and/or proprietary programs. But our focus in this book is different. In particular, we will be concentrating on understanding the broader impact of open source software. And once we move beyond the programs themselves, and to how they interact with the rest of the world, an economic perspective can be indispensable. Among the questions we will examine are these four:

- How does software differ from other technologies when it comes to promoting economic development?
- What are the motivations that drive individuals and firms to contribute to open source projects?
- How do firms using and developing software view the trade-offs between proprietary and open source projects?
- What policies can governments adapt to ensure that open source effectively competes with proprietary software and contributes to economic growth, and which steps run the danger of backfiring?

It is our belief that in each of these arenas, an economic perspective adds essential value in shedding light on these questions.

In particular, we highlight several crucial insights that the application of an economic framework to the world of open source suggests:

- Traditional economic frameworks that prescribe that the market will solve the optimal allocation of activity do not apply very well to the software industry.

- Open source and proprietary software share many common elements, as well as differences, that economic analyses can illustrate.
- Based on studies completed to date, it is hard to draw unambiguous conclusions as to the superiority of open source versus proprietary software.
- There is not a strong foundation for the claim that the government should favor open source or proprietary software when purchasing for its own purposes.
- While governments in developing countries may have strong rationales for encouraging the development of a software industry in general, the desirability of encouraging open source is more circumscribed, and economic analysis help identify the conditions under which such support may be justified.

Ultimately, it is our hope that this book stimulates more conversations between the open source and economics communities. Each side, it seems, has much that can be learned from the other. Despite (perhaps because of) the extensive research that we have undertaken in this area, we are keenly aware of the limitations that economists have faced when studying the open source realm and the way in which a keener understanding of the technical and social aspects of open source communities could be valuable. At the same time we strongly believe, and hope to have shown in this book, that many of the conceptual and methodological tools in the economics “tool kit” can be valuable additions to many in the programming community interested in more rigorous, systematic studies of this important sector of the economy.

A Road Map to the Book

To give a sense of where we are going with the book, we will provide a brief overview of chapters 2 through 7.

An Initial Look at Software and Growth

The second chapter has an ambitious mandate. To help set the stage for an understanding of open source software, we begin by explaining why software is important from an economic perspective.

Traditionally economists studying economic growth focused on how physical capital accumulates over time. As the economy grows and people take some of their earnings and invest it in extra machines

and facilities, there is greater output and hence economic growth. Later theories applied a similar principle to the accumulation of “human capital,” where savings are used to accumulate more knowledge: some of labor time is used not directly for production but for schooling and training.

In recent years, however, there has been a dramatic change in the economists’ perspective, growing out of the realization that we had “Hamlet without the prince.” The “new growth theory” puts technological innovation at the center of the growth process: the ways that inputs (e.g., people and machines) are translated into outputs, both products and services. The special thing about an innovation is that it can be shared: everyone can use it at the same time (whereas a worker or a machine cannot be everywhere at once). Unlike a physical piece of equipment, the use of a recipe for a better mosquito repellent in one country or by one individual does not hinder its use in other countries or by other individuals. Economists call this the nonrivalry property of information. But one must also ensure that individuals and firms have incentives to invent better recipes. They might not have incentives to do so if the new knowledge they generate is immediately and freely made available to everyone who wants to use it.

Where does computer software, and open source software in particular, fit within this framework of growth theory? In many respects it is like other technologies: it allows people to produce more with the same amount of materials. Indeed software’s reach extends far beyond the software industry. Much of the innovation in software sprang from firms in other industries that have embodied software into products and processes.

The same conundrum described in the new growth theory is present in traditional proprietary software. On the one hand, since a software program, once developed, can be distributed very cheaply via the Internet, it is socially wasteful for some firms and countries to use inferior software. And indeed software use (at least as evidenced by available evidence on diffusion of Internet and computers) and software production (measured using software patenting in the United States and by open source contributions) both vary with the level of development: many national information technology industries appear stuck at a lower level of development (these disparities appear to be much greater on the production side). On the other hand, as before, we need to worry about the incentives to develop better software.

Where does open source software fit within this framework? If the open source model of software development could deliver state-of-

the-art and easy-to-use products for all applications, it would solve the conundrum of the new growth theory as it applies to software. On the one hand, it would make the best recipes available everywhere at essentially zero cost, hence taking full advantage of the nonrivalry property. On the other hand, the incentive problem would be solved by the fact that programmers (either as individuals or as firms) contribute voluntarily to the software development. This analysis suggests why open source is potentially so revolutionary, and the critical importance in understanding its economic development impact.

Lessons from History

To understand open source software, it is useful to understand where it has come from. In chapter 3 we explore the origins and evolution of this sector. We highlight how there have been three distinct eras of open source development:

- During the 1960s and 1970s many of the key features of computer operating systems and the Internet were developed in academic settings such as Berkeley and MIT, as well as in central corporate research facilities where researchers had a great deal of autonomy, such as Bell Labs and Xerox's Palo Alto Research Center. The sharing by programmers in different organizations of the source code for computer operating systems and for widely used transmission protocols was commonplace. These cooperative software development projects were undertaken on a highly informal basis.
- In response to the threats of litigation engendered by this lack of clear rules, efforts to formalize the ground rules behind the cooperative software development process emerged. These efforts ushered in the second era. The critical institution during this period was the Free Software Foundation, begun by Richard Stallman of the MIT Artificial Intelligence Laboratory in 1983. The foundation sought to develop and disseminate a wide variety of software at no cost. The Free Software Foundation introduced a formal licensing procedure, called a General Public License, for a computer operating system called GNU. This procedure ensured that all derivatives of the program would also be disseminated at low or no cost.
- The widespread diffusion of Internet access in the early 1990s led to the third era that saw a dramatic acceleration of open source activity. Because it became easier for developers at very distant physical locations to collaborate on the development of projects at low cost, the volume of contributions and diversity of contributors expanded sharply,

and numerous new open source projects emerged. Other innovations in recent years have been the proliferation of alternative approaches to licensing cooperatively developed software and (not unrelatedly) the emergence of corporate contributors.

The history of open source software detailed in this chapter also anticipates many of the themes that will emerge later in the book. In particular, as we review the institutional features during and research insights about the evolution of open source, five critical themes have emerged. These are:

- The pace of change in the open source community. The industry today is very different from that even a few years ago, whether we examine the number and mixture, the actors involved, and the processes followed within the groups.
- The way in which the seemingly esoteric issues of open source licenses, with their detailed delineation of rights and responsibilities of the key parties, profoundly affect the nature of these projects.
- The increasingly important role of corporations and corporate contributors. While press accounts frequently highlight the image of open source programs being driven by graduate students and moonlighting computer administrators, for-profit firms have played an important and growing role in open source development. Frequently these activities are done alongside the development of proprietary software.
- The extent to which users of open source programs are concerned about the costs of moving across programs and from one version of a program to another. These worries often are important drivers of users' willingness to adopt open source programs.
- The increasingly important role of the public sector in influencing both the development and adoption of open source software, whether through subsidies, procurement decisions, or other means.

Who Develops Open Source Software?

In chapter 4 we return to the hypothesis we highlighted in the second chapter: that the great appeal, and potential importance, of open source lies in the fact that it might represent a solution to *the* fundamental challenge to promoting innovation. In particular, open source software might be able to solve the tension between the need to provide firms and individuals with the incentive to innovate and the desirability of encouraging widespread use of cutting-edge technologies.

By making the software available to anyone at essentially zero cost, open source projects ensure that cutting-edge projects will be widely diffused. And the incentive problem may not be there, as the voluntary contributors are rewarded in other ways. On top of that, spillovers of knowledge would be enhanced by the fact that the source code is available for many to build upon.

We examine this hypothesis in this chapter by looking closely at the development and marketing of software by firms. This investigation is made possible by the new and unique survey of software companies we conducted, covering nearly two thousand firms in fifteen countries.

Three key insights are highlighted in the chapter. Most surprisingly, firms extensively blend the development of open source and proprietary product, rather than specializing in one or the other. It is commonplace to see the same firm developing both open source and proprietary programs, or else making the same program available under both a traditional proprietary and open source licenses. We observe this comingling of open source and proprietary software development by firms in all of the countries we survey. In all likelihood this mixing by software firms suggests that there are substantial cost synergies, whether in product development or marketing, between open source and proprietary software.

Software companies diversify between open source and proprietary software in other dimensions as well. For instance, companies will frequently combine support services with product development: clearly, the insights from product development can translate into its installation. We find that larger firms are far more likely diversify along these lines than smaller ones, presumably because they can exploit cost synergies more readily without sacrificing economies of scale.

While as the two previous points suggest, open source and proprietary software are similar in many respects and are extensively comingled, they differ substantially when it comes to exports. While software firms of all kinds are likely to export products, firms that concentrate on the development of proprietary software are both more likely to export and are more intensive exporters than their open source-focused peers. This pattern may well change over time, but for now appears to be quite robust.

This empirical evidence suggests that the initial hypothesis formulated in chapter 2 was too optimistic. The same fundamental tension that is at the heart of innovation policy—how to encourage the

development of new knowledge without sacrificing the social gains that can occur from the widespread diffusion of cutting-edge technologies—also characterizes the software industry. And given the extensive similarity between, and cohabitation of, open source and proprietary software, these challenges are likely to apply to open source as well as proprietary software. Sad to say, open source software offers no free lunch, no easy way to solve the innovation paradox.

Who Uses Open Source Software?

We then turn in chapter 5 to understanding who uses open source software and how they make the decision between open code and proprietary software. Once again, we undertake a unique survey, covering more than two thousand users in fifteen countries. The data provides many new insights into the structure of demand for software, and in particular how it relates to a number of user characteristics and to their perceptions of the various costs involved in adopting software.

The analysis suggests four main insights:

- Open source and proprietary software present users with differing costs. Not surprisingly, proprietary software presents users with a considerably higher upfront cost. However, the other costs associated with adopting any piece of software—the costs of switching (learning), interoperability (compatibility of different programs), and support services—are greater for users of open source software. These patterns are observed across a wide variety of countries, from the most to the least developed.
- Software users vary substantially. This variation is seen not just in the users' software needs, but also in how they evaluate costs. As a result of these different preferences and requirements, two users could make very different choices between open source and proprietary software.
- Mixing is commonplace. Across countries and all types of users, open source and proprietary software are frequently comingled. Mixing is more frequently practiced in settings where economic principles would suggest it should be, such as the greater prevalence among cost-constrained (small) firms.

Thus in many respects the insights regarding the survey of users and developers are quite complementary. Despite the substantial differences between the two families of software, open source and proprietary code do not live in two totally different worlds. Rather, there are

extensive interactions. The same firms that market proprietary code are also likely to contribute to or sell open source code as product. Users are likely to be employing both open and proprietary software. Our detailed survey data on software development and usage have allowed us to document the extensive cohabitation between the open source and proprietary software worlds.

The Policy Challenge

As the discussion of the two prior chapters suggest, policy makers face a substantial challenge when it comes to setting policies for encouraging software development and diffusion. On the one hand, software has the potential to impact economic growth in a positive and substantial manner. And open source has properties that are likely to be particularly attractive, as we have discussed.

But as our survey has highlighted, many software developer firms sell proprietary software while contributing to open source development, and software users extensively mix and match the two types of software. The problem is not an either/or one—to choose between one form of software and the other—but rather to develop a policy framework that ensures that developers and users mix in an efficient manner, and one that contributes to innovation in both forms of software. How can a government develop a framework that facilitates the competitive interactions between open source and proprietary software in a manner that boosts efficiency and innovation?

In the sixth chapter we turn to the question of how public policy can address this question. We use economic reasoning to evaluate the key arguments for why the government should support open source software. We complement this analysis with our data from the fifteen-nation survey, which provides evidence on what kinds of regulatory and incentives schemes are available to users and developers.

We argue that government's role in procurement is fundamentally different from a corporate buyer. Because of the relative size and visibility of government purchases in many economies, the public sector can play a leadership role with its purchases that many others may not. Moreover the government must consider what is good for the economy as a whole (what economists call social welfare), rather than simply minimizing its own costs. These observations do not mean that the government should in every case design its procurement policies to play a leadership role: the proper decision depends very much on the

specific context, and we identify leading cases where this may be warranted. When such a role is not needed, the purchasing decision should be based on an evaluation of the total cost of ownership, similar to that which a corporate buyer would make.

When it comes to regulation, we argue that governments should encourage vigorous competition between open and proprietary software. This does not mean, it should be noted, a hands off, or *laissez faire*, approach. Rather, it means, first and foremost, taking the necessary steps to ensure that commercial firms do not abuse the networks they may have developed to disadvantage open source. Encouraging truly open standards, to allow the most competition possible between forms of software, is also important. Yet ensuring that private firms have real economic incentives to innovate is also critical. This conclusion is borne out in our survey of users and developers, which found a strongly voiced preference for a regulatory regime that allows them complete freedom to choose between open source and proprietary software, rather than one that either requires or favors one or the other.

Regarding the plethora of other policies relating to encouraging software development, whether open source or proprietary, clear economic prescriptions are few and far between. The strongest case can be built for the government playing a lead role in providing information to consumers about the features of different types of software, as well as demonstration projects of various types. While one cannot make definitive statements on the basis of existing economic analysis, the case for direct subsidies for open source appears to be weaker.

There are, of course, many other policy choices that will need to be addressed when shaping an information technology policy. Governments need to decide whether to finance local information technology firms (or their financiers), whether to subsidize users of advanced technologies, how much to invest in education of information technology professionals, and how to design an intellectual property regime that is appropriate for software, which does not fit neatly into traditional categories. Especially in developing countries, governments need to do all this with limited human and financial resources. On all these issues, much more research is needed to assist decision makers with the difficult choices they have to make. We hope that some of the energy that has, in recent years, been directed at the rather polarized debate between open source and proprietary software will be redirected more constructively toward these issues.

Lessons

We end in chapter 7 with a series of recommendations for the various key audiences, drawn from the discussions and analyses in the book. For government officials, we emphasize four lessons:

1. The danger of making choices: given the trade-offs between different technologies, and the frequent miscues that public efforts to “pick winners” have encountered, it is far better to let competition take its course than mandate a solution.
2. The many reasons for encouraging competition between open and proprietary software: as we highlight throughout the book, there are many trade-offs that mean that different users in different situations could come to diametrically opposed answers when choosing between software types. Recommending that governments should encourage competition, however, is not the same thing as arguing that they should not be involved in regulating the software industry.
3. The need for a different calculus when governments make decisions about software procurement as opposed to private entities: when funding the development of software, whether for their own use or as a more general R&D effort, government officials should use similar criteria as corporate users—but also take into account the likely benefits to society of adopting a leadership position.
4. Shared standards—technologies that facilitate communication with and from the users of public services, as well as with their suppliers—are essential, and they can be implemented both in proprietary and open source software.

We also highlight six implications for corporate managers:

1. There is no “right” answer in the choice between open source and proprietary software: different firms will make different choices, reflecting their circumstances.
2. Think carefully when making this choice: the “received wisdom” regarding the costs and benefits to corporations can be misleading here.
3. The appropriate mixture between open and proprietary software will vary with the firms’ circumstances: for instance, firm size and market segment can lead to very different choices.
4. The local circumstances also matter: the choice between open and proprietary software will vary with the stage of development of the nation in which the firm is based.

5. Consumers have very different needs when it comes to software products: this suggests the desirability of offering both proprietary and open products.

6. Mixing between both classes of software, both among users and developers: mixing is the general rule across many different classes of firms operating in a wide variety of nations.

Finally, we end with a few suggestions for the research community, in the hopes of encouraging more work which combines economic frameworks with an understanding of the open source phenomenon:

1. Beware of simply “transporting” economic frameworks from elsewhere into the software arena, particularly when it comes to open source.

2. Much more research is needed to assist policy makers with the difficult choices they have to make with promoting the development of information technology sector, and open source in particular.

3. Researchers into the open source phenomenon must focus more on the dynamics of choices within software-producing and using firms—too much of the focus has been on the individual developer, rather than the complex setting in which firms operate.

4. The experience with “technology sharing” that the open source and proprietary software industries have grappled with over the past few decades has important implications for other industries.

It is our hope that the analysis in our book will have accomplished two things. First, we have tried to show the power of intellectual cross-fertilization—the way that economic ideas can be useful in shedding light on these important technological questions. Second, we have tried to be candid in highlighting how much we *do not know* about economic development and open source, and the substantial opportunities that await researchers who will explore these issues in the years to come.

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Note: All Web files were accessed on September 21, 2009.

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