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Design Rules, Volume 2: How Technology Shapes Organizations

Chapter 14 Introducing Open Platforms and Ecosystems

Carliss Y. Baldwin

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Harvard Business School

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Note to Readers: This is a draft of Chapter 14 of *Design Rules, Volume 2: How Technology Shapes Organizations*. It builds on prior chapters, but I believe it is possible to read this chapter on a stand-alone basis. The chapter may be cited as:

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I would be most grateful for your comments on any aspect of this chapter! Thank you in advance, Carliss.

Abstract

The purpose of this chapter is to lay the groundwork for a comprehensive theoretical investigation of open platform systems. To do this, we must first recognize that, although there is a strong family resemblance among all platform systems, there are different types of platforms, each with its own set of technological requirements and challenges. I first develop a taxonomy of open platforms and then provide a brief history of open digital platforms. I go on to argue that the success of open platforms in competition with vertically integrated firms gave rise to the "vertical-to-horizontal" transition in the computer industry between 1985 and 2000. The technology of open digital platforms not only shaped individual organizations but changed the structure of the entire computer industry.

Introduction

The very first modern systems to be identified as platforms were manufacturing systems designed to support a high level of product variety and rapid evolution in response to changing demand. For example, in the early 1990s, Steven Wheelwright and Kim Clark used the term "platform product" to describe new products that "meet the needs of a core group of customers but [are designed] for easy modification into derivatives through the addition, substitution, or removal of features."[1] These platform systems were *closed*: a single firm designed and produced both the platform and complements.

The last two decades of the 20th Century saw the rise of two distinct types of open

[1] Wheelwright and Clark (1992).

platforms and surrounding ecosystems based on digital technologies. First, in the 1980s, *open product platforms* spread the design and production of different components of complex digital systems over many autonomous organizations. Second, in the 1990s, the advent of the Internet and WorldWide Web led to the creation of *open exchange platforms*—websites designed specifically to facilitate exchanges of goods, information, and opinion.

All platforms systems, both open and closed, are similar in several ways. All are based on a fundamental modularization between the core platform and optional components. All rely on design rules—an architecture, interfaces and tests—to ensure interoperability of components. In addition, all platform systems conform to Propositions P-1 to P-5 in the previous chapter. These systems exhibit increasing value with the addition of options; positive network effects; a positive impact of risk; a positive impact of modularity; and finally complementarity between modularity and risk.

Finally, because of their modular architecture, all platform systems support the decentralization of tasks and decision-making. As a result, sponsors of open platforms can delegate many tasks to third parties while controlling unique and essential components of the platform themselves.

The purpose of this chapter is to lay the groundwork for a comprehensive theoretical investigation of open platform systems. To do this, we must first recognize that, although there is a strong family resemblance among all platform systems, there are different types of open platforms, each with its own set of technological requirements and challenges. I first develop a taxonomy of open platforms and then provide a brief history of open digital platforms. I go on to argue that the competitive success of open platforms against closed platforms in the computer industry in the 1980s and 1990s gave rise to the "vertical-to-horizontal" transition described by Andy Grove. This transition was one of the organizational "surprises" highlighted in Chapter 1. In this case, the newly competitive technology of open platforms not only shaped individual organizations but changed the structure of the entire computer industry.

14.1 Open Platforms—A Taxonomy

In Chapter 6, I defined a "platform system" as:

> … a technical system comprising a core set of essential functional elements (the platform) plus a set of optional complements. The platform and each complement are separate modules bound together by commonly recognized design rules (visible information). The platform has no value except in conjunction with one or more options.

This definition is consistent with one put forward by Annabelle Gawer and Michael Cusumano in their seminal book, *Platform Leadership*:

> A platform … company develops and sells a core product that is (1) part of a system that is itself evolving and (2) not valuable itself without complementary products or services.
>
> A fundamental condition is that the firm's product has *limited value when used alone but gains in value when used along with complements*.[2]

The crucial property that defines all platforms is that the platform creates options—the "right but not the obligation" to modify the product in response to new technology, new prices, or new demands by consumers. At the time of the platform's creation, exactly what will happen—what options will be realized—is not known with certainty. Because of its modular architecture, the platform is tolerant of uncertainty.[3] This is a very different value structure from that of an integrated step process that requires a particular series of actions and will fail if any step is left out.

Platform systems in turn may be divided into product platforms and exchange platforms. *Product platforms* provide options for the design and production of complex goods and services. Complex products and services are "built on" product platforms. In contrast, *exchange platforms* are physical or virtual spaces that facilitate valuable, transient exchanges of goods and information between autonomous agents. These platforms are used to "connect" agents briefly and then break off the connection.[4]

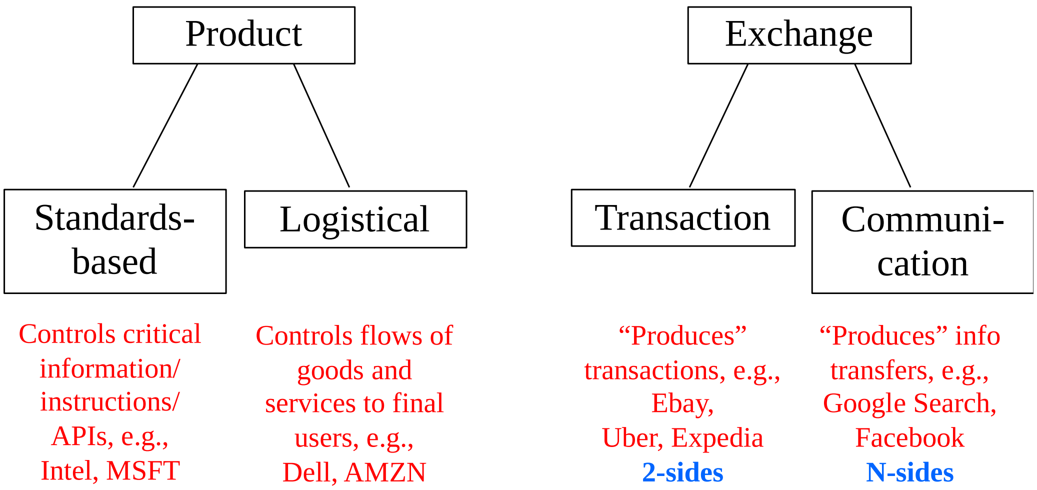
Figure 14-1 offers a visual summary of this platform taxonomy, with examples of each type. As shown in the figure, product platforms can be subdivided into standards-based platforms and logistical platforms, while exchange platforms can be subdivided into transaction and communication platforms.

[2] Gawer and Cusumano (2002) pp. 131, 245. Emphasis added.

[3] Baldwin and Clark (2000), p. 91.

[4] Product and exchange platforms under my definition roughly correspond to what Cusumano, Gawer, and Yoffie (2019) call "innovation" and "transaction" platforms. However, they define a platform as a "company owned business," while I define a platform system as a specific technical architecture. Many technical systems that qualify as platform systems under my definition are not businesses. One obvious example is the Internet, which is both a product and exchange platform.

Figure 14-1 A Taxonomy of Platform Systems



Standards-based platforms support the design and production of complex systems of goods and services. The sponsor of an open standards-based platform publishes design rules and standards and encourages third parties to provide optional complements, add-ons and upgrades. With this type of platform, *users* decide what to include in their systems. Examples of standards-based platforms include computer operating systems and applications, video consoles and games, as well as microprocessors and compatible hardware and software.

A *logistical platform* (sometimes called a supply chain platform) stands in contrast to a vertically integrated firm. Instead of performing all tasks needed to make the product inhouse, the platform sponsor outsources most components and activities. It does so through contracts combined with modular interfaces that separate design from fabrication, fabrication from assembly, and assembly from distribution.[5] The sponsors of open logistical platforms act as systems integrators, bringing together diverse components and orchestrating processes.[6]

The fabless-foundry model of semiconductor production, discussed in Chapter 12, is an example of an open logistical platform: fabless design firms contract with mask-makers, foundries, and assembly-and-test firms to make chips that they then sell or assemble into systems. Other open logistical platforms include the container shipping industry, discussed in Chapter 7, and the global apparel industry, where "brand" companies contract with globally dispersed designers and manufacturers to make clothes

[5] Fine (1998); Sturgeon (2002).

[6] Brusoni, Prencipe and Pavitt (2001).

sold under their labels.[7]

Throughout the 1980s and much of the 1990s, the most prominent digital platforms were product platforms, both standards-based and logistical. However, following the rise of the Internet, a different view of platforms emerged. The early 2000s, the economists, Jean-Charles Rochet and Jean Tirole wrote a pair of seminal papers on exchange platforms. Rather than focusing on complex products, Rochet and Tirole concentrated on markets and the need for match-making. The role of a platform, they said, was to facilitate transactions and exchanges. Platforms could thus be seen as two-sided, or in some cases, N-sided markets.[8] The job of the platform sponsor is to design a venue in which exchanges can take place efficiently.

Open exchange platforms can be traced far back in history—to ancient marketplaces and bazaars, to the medieval fairs at Champagne, to bourses and financial exchanges. However, digital exchange platforms became newly important in the second half of the 1990s with the commercialization of the Internet.[9] As the Internet penetrated business and social relationships, online marketplaces and communication media sprang up to facilitate transactions and messages.

Transaction platforms are places of trade, where buyers and sellers meet to exchange goods and services in return for payments in money or in kind. The platform sponsor initially focuses on one or more thin crossing points in the larger task network. It must attract qualified buyers and sellers to its venue in approximately equal numbers. Given sufficient depth in the market, the platform sponsor must ensure that matches can be found with relative ease, that transaction costs are low, and that cheating is discouraged. Ebay, Alibaba, Uber, and AirBNB are all examples of digital transaction platforms.

Communication platforms are places of information exchange. They may operate point-to-point, as in the case of traditional mail or email, or via broadcast as in the case of newspapers, radio, TV, and social media. The platform sponsor must provide a communication technology, attract suppliers of content (senders) and consumers of content (receivers), plus capture sufficient revenue to pay for the platform and the content. Google and other search engines, Facebook and other social media, Wikipedia, regular mail and email, as well as newspapers, radio, TV, and movies are all examples of communication platforms.

Each type of platform may be closed or open. In a closed platform system, the platform and related options are contained within a single enterprise with unified governance. In an open platform system, the platform and related options are spread

[7] On container shipping, see Levinson (2006). On apparel, see Berger (2005).

[8] Rochet and Tirole (2003; 2006).

[9] Greenstein (2015).

across many autonomous individuals and organizations.

On first glance, it might seem that exchange platforms are open "by definition." However, secure corporate email systems and bulletin boards are closed communication platforms. Less commonly, a company might permit employees to bid for jobs, or divisions to bid for business within a corporation. These would be closed transaction platforms.

14.2 A Brief History of Open Digital Platforms

The precursors of modern digital platforms include such things as the electrical grid, water distribution systems, the railway network and road systems going back to ancient times.[10] Before the advent of large synchronized flow systems in manufacturing, the production and distribution of goods was organized as an open logistical platform.[11] Finally, telegraph and telephone systems, stock exchanges, marketplaces and meeting places have supported the open exchange of goods and information since well before the advent of the Internet.[12]

What was new in the latter half of the 20th Century was digital technology. First, digital encoding allowed computation and communication to take place at low cost and at the speed of light. Digital systems were also easy to divide into modules. Finally, the fundamental physical entities (chips and circuits) behind the technology were subject to ongoing miniaturization and cost reduction. Under the dynamics of Moore's Law, the possibilities for new products were ever-changing. As a result, the value of modularity in both products and processes was high (see Chapter 13).

The first modular computer system was IBM System/360, introduced in the mid-1960s.[13] System/360 was meant to be a closed platform, but its popularity and the simplicity of its interfaces allowed "plug-compatible" manufacturers to attach their products to the system without IBM's permission. Thus System/360 became open despite IBM's strong resistance, expressed in lawsuits and defensive changes to contract terms and technical interfaces.[14]

The IBM PC revealed just how far openness could be taken, as well as the competitive advantages of this strategy. However, as described in the next chapter, the

[10] Frischmann (2004; 2012) defines infrastructure as a capital resource that provides opportunities (options) to many actors, and whose value lies in "downstream productive activities." He explicitly identifies infrastructure with platforms: "Essentially, infrastructure resources are enabling "platforms" on which others build" (2004, p. 957).

[11] Chandler (1977) Chapters 1 and 2. Rosenberg and Birdzell (2008) Chapter 5.

[12] Rochet and Tirole (2003); Boudreau and Hagiu (2011).

[13] Ferguson and Morris (1993); Baldwin and Clark (2000).

[14] Baldwin and Clark (2000) pp. 388-390; DeLamarter (1986).

reverse engineering of the PC BIOS led to the entry of numerous PC-compatible clones. IBM's subsequent loss of market share and profitability demonstrates the pitfalls of openness.

Thereafter, from the 1980s through the mid-1990s, firms in the computer industry experimented with different combinations of platform openness. Following the rise of the commercial Internet in the mid-1990s,[15] platforms dedicated to exchanges of goods, information, and opinion took center stage. For reasons discussed in Chapters 19 and 20, many sponsors of open product platforms decided to sponsor open exchange platforms as well.

14.3 Business Ecosystems

Open platforms of all types rely on ecosystems of firms and individuals to supply many parts and perform many of the tasks needed to arrive at a complete product or exchange. The term "ecosystem" originated in the science of ecology,[16] but has recently been adopted by managers and management scholars.[17]

Building on this prior work, I define a (business) ecosystem as a network of autonomous firms and individuals whose products or actions are complementary.[18] For an ecosystem to be sustained, the complementarities among products and/or actions must be strong enough to require coordination but not so strong as to need unified governance.[19] Complementarities in business ecosystems are frequently supermodular: actions by one member of the ecosystem make actions by other members more valuable. (Below, I will drop the modifier "business" and speak merely of "ecosystems.")

Diverse firms and individuals may be part of the same ecosystem, and a single firm or individual may participate in several ecosystems. Coordination among members of an ecosystem may be achieved through standards, roadmaps, contracts, prices or a combination of all of these mechanisms. Standards-based platforms coordinate designs; logistical platforms coordinate flows through a production network. Exchange platforms coordinate transactions and/or messages.

Of necessity, open platforms and ecosystems satisfy the conditions of distributed

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[15] Greenstein (2015).

[16] Willis (1997).

[17] J.F. Moore (1996); Iansiti and Levien (2004); Adner and Kapoor (2010); Adner (2017); Jacobides, Cennamo and Gawer (2018).

[18] In the migration from ecology to management, the meaning of the term "ecosystem" has changed slightly. In ecology, ecosystems include "the physical-chemical-biological processes active in a space-time unit." (Lindeman (1942) quoted in Willis (1997) *op. cit.*) In management, the term refers only to interacting firms and individuals. Conditions in the material world, including technologies, are *not* part of the ecosystem. Platform sponsors are sometimes included but more often excluded from the ecosystem.

[19] Jacobides, Cennamo and Gawer (2018).

supermodular complementarity (DSMC): otherwise they would collapse into or be replaced by closed platforms or vertically integrated firms.

14.4 Platform Combinations

The same firm may sponsor several different types of platforms. For example, Apple sponsors two open standards-based platforms—one for mobile devices (iOS) and a one for computers (Mac OS). QuickTime Player is part of the MacOS, but accessing advanced audio and video functions requires QuickTime Pro, another standards-based platform.

Apple also sponsors an open logistical platform that coordinates flows of Apple hardware through a modular production network. In 2018, Apple was a fabless designer of numerous systems-on-chips (SOCs), most of which are based on the ARM RISC architecture, itself a standards-based platform. Apple contracts with semiconductor manufacturers such as Samsung and TSMC to fabricate its SOCs and with manufacturers such as Foxconn plus hundreds of component suppliers to make its devices.[20] It distributes its hardware through its own retail stores and website, but also through third-party retailers such as Walmart and Amazon, and through phone companies.[21]

Apple sponsors two digital transaction platforms, the iTunes Store, which is primarily focused on music and video, and the Apps Store, which supplies applications for Apple mobile devices. Finally, virtually all transaction platforms today support product ratings and reviews by consumers. These are open communication platforms within the transaction platforms.

Companies whose principal business is to sponsor communication platforms generally sponsor other types of platforms as well. For example, Google sponsors not only Google Search, Gmail, and YouTube (all communication platforms) but also Android and Google Maps (standards-based platforms) and Google Play (a transaction platform). Google's parent company, Alphabet, owns Google Fiber, a logistical platform that supplies high-speed Internet services in a handful of cities.[22]

We will discuss platform combinations in greater detail in Chapter 20, after looking carefully at each of the "pure" platform types. In the remainder of this chapter, we will look at evidence of the impact of open digital platforms on the structure of the computer industry.

14.5 The Impact of Open Platforms on the Structure of the Computer Industry

As discussed in Chapter 1, according to Andy Grove, CEO of Intel, the computer

[20] https://www.apple.com/supplier-responsibility/pdf/Apple-Supplier-List.pdf, viewed 9/30/18.

[21] https://www.lifewire.com/where-to-buy-iphone-1999719, viewed 9/30/18.

[22] https://www.lifewire.com/understanding-google-and-alphabet-4116085, viewed 9/30/18.

industry went through a vertical-to-horizontal transition between 1980 and 1995. This transition was one of the key "surprises" in the evolution of the industry, something no one at the time anticipated. Grove called it a "strategic inflection point … when the balance of forces shifts … from the old ways of doing business and the old ways of competing, to the new."[23] In his words:

> Even in retrospect, I can't put my finger on exactly where the inflection point took place in the computer industry. Was it in the early eighties when PCs started to emerge? Was it in the second half of the decade, when networks based on PC technology started to grow in number?
>
> [What is clear is that] by the end of the 1980s, many large vertical computer companies were in the midst of layoffs and restructuring … . [At] the same time, the new order provided an opportunity for a number of new entries to shoot into preeminence.[24]

A graphical depiction of the vertical-to-horizontal transition is shown in Figure 14-2. Grove divided a computer system into five essential functional components: (1) sales and distribution; (2) application software; (3) operating systems; (4) hardware; and (5) chips. Initially, vertically integrated computer manufacturers supplied all five components.

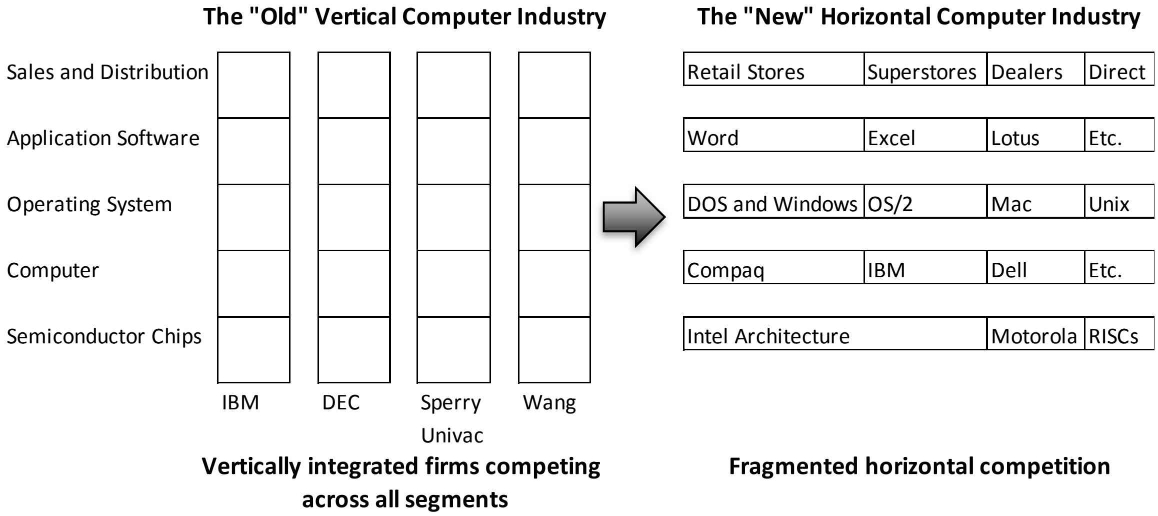
However, during the 1980s, vertically integrated computer makers ceased to grow. With the advent of personal computers, the industry fragmented. The most prosperous firms did not attempt to make whole systems, but focused instead on one component or another within the overall technical architecture. In effect, the "old" industry made up of vertically integrated firms evolved into an ecosystem of autonomous firms coordinated by multiple standards-based and logistical platforms.

In the 1980s, the IBM PC platform (discussed in the next chapter) was the largest and most visible of the open product platforms. Responding to the rapid pace of change and fierce competition in the industry, during the 1980s and 1990s, many other firms, such as Sun Microsystems, Novell, Cisco Systems, and Dell sponsored their own open standards-based and/or logistical platforms.

[23] Grove (1996) p. 33.

[24] *Ibid.* pp. 44-45.

Figure 14-2 The Vertical-to-Horizontal Transition in the Computer Industry



Source: Constructed by the author based on Grove (1996) pp. 40-42; and Yoffie (1997) pp. 18-19.

Digital exchange platforms became important with the arrival of the commercial Internet in the mid-1990s. We shall see that the vertical-to-horizontal transition was driven by product platforms: it mostly took place before digital exchange platforms came on the scene. However, after 2005, the most valuable firms in the computer industry sponsored of *both* product and exchange platforms. This continues to be true today.

14.6 Mapping Industry Architecture

Open product platforms and their ecosystems will naturally become organized according to the *specific functions* that each product or service fulfills within the overall technical architecture. As shown in Grove's diagram, each separate functional component of a computer can be thought of as occupying a different "layer" in a vertical "stack." [25]

Firms in the greater industry can then be associated with one or more layers in accordance with the functions their products provide.[26] For example, Firm A might make chips, Firm B might make storage devices, and Firm C might develop software. Each firm, along with its competitors, would appear in a different layer of the computer "stack."

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[25] Blanchette, J.F. (2011) "A Material History of Bits," *Journal of the American Society for Information Science and Technology*, 62(6):1042-1057.

[26] Providing a function can be thought of as performing a role in an industry architecture. Jacobides, Knudsen and Augier (2006).

Grouping firms by functions, it is possible to construct a "layer map" of the industry.[27] Firms making many functional components will appear in several layers, thus forming vertical columns. Firms specializing in a single functional component will appear in only one layer forming part of a horizontal band.

If open platforms and their ecosystems become more important relative to vertically integrated firms, the vertical columns will shrink and the horizontal layers will expand. If value is initially concentrated in vertically integrated firms but migrates to specialist firms, the layer map will reveal a vertical-to-horizontal transition, such as Grove described.

Michael Jacobides, Reza Dizaji and I used segment data on firm market values to construct a series of layer maps of the greater computer industry.[28] Plates 14-1 to 14-5 present maps showing the market capitalization of the largest 14 firms relative to the whole industry every five years from 1985 to 2005.

In a nutshell, Grove's impression that a vertical-to-horizontal transition took place in the 1980s or 1990s is confirmed by the maps. Let us take them one at a time.

In 1985, IBM, the quintessential vertically integrated computer manufacturer, accounted for more than half the market value in the industry. (See Plate 14-1.) Other vertically integrated computer manufacturers, including the Japanese firms, Hitachi and NEC, and U.S.-based Hewlett Packard and Digital Equipment Corporation occupied the next four places. Automatic Data Systems and Apple Computer were the only specialist firms to make the list, in positions #13 and # 14 respectively. As Grove observed, "Going into the eighties, the old computer companies were strong, growing and vital." [29]

Between 1985 and 1990, IBM lost a great deal of its market value share, as did Digital, National Cash Register, Sperry, Unisys, and Wang Labs. (See Plate 14-2.) However, the Japanese verticals, joined by Toshiba, increased their share of industry value. Specialist firms making modules occupied more places in the top 14 in 1990. Microsoft, which went public in 1986, took the #5 position, with Intel at # 6. Compaq, Novell, and Sun Microsystems, all sponsors of open product platforms, joined Automatic Data Systems and Apple on the list. For the first time, packaged software accounted for over 10% of the industry's market value. However, the industry as a whole was still dominated by vertically integrated firms.

Between 1990 and 1995, the map changed dramatically. (See Plate 14-3.) *Horizontal layers now accounted for around three-quarters of the industry's total value.*

[27] Fransman (2002).

[28] Jacobides, Baldwin and Dizaji (2007); Jacobides and Tae (2015).

[29] Grove (1996), p. 45.

Microsoft was #1; a shrunken IBM was # 2; and Intel #3.[30] New entrants in the layers included Cisco, Oracle, First Data Corp, CA Inc. and Micron Technologies. Also notable is the increase in "white" space in the map. White space represents the value of publicly listed firms that were not in the top fourteen. The growth of white space indicates that industry concentration was declining as hundreds of new firms entered the industry.

The industry as a whole also greatly expanded during this time period rising from a total market value of $181 billion 1990 to $683 billion in 1995.[31] The early 1990s marked the beginning of the Internet Gold Rush, which turned into the Internet Bubble and Crash. (The Internet was and is both an open product platform and an open exchange platform. It dwarfed all previous open platforms in terms of the diversity of the options it created.)

By 2000, the verticals had disappeared. (See Plate 14-4.) Following a major restructuring, IBM (# 5) no longer claimed to be vertically integrated, but was focused on systems, services and software. Reflecting the importance of the Internet as a new open product platform, Cisco, which managed a logistical platform focused on Internet hardware, moved into the # 1 position. New members of the top tier included EMC, Lucent Technologies, Dell, Taiwan Semiconductor (TSMC), Juniper Networks, and STMicroelectronics. Notably, the new firms were all sponsors of open logistical platforms.

Thus a vertical-to-horizontal transition in the industry did take place, beginning in the late 1980s and continuing through the 1990s. *It could not have occurred were it not for the success of open product platforms, both standards-based and logistical.* Over a twenty year timespan, vertically integrated firms were replaced by open product platforms and related ecosystems.[32]

A further transition occurred between 2000 and 2005. (See Plate 14-5.) By 2005, the top tier of the industry included Google, Ebay, Yahoo, and a regenerated Apple. All of these companies were sponsors of open *exchange* platforms. Users went to these companies' websites to transact in goods and services and/or obtain and exchange information. Apple was also the sponsor of several open product platforms for computers and mobile devices. Google introduced Android, an open standards-based platform designed to compete with Apple's iOS, in 2007.

[30] In 1990, IBM's market capitalization was $65 billion. It dropped to $28 billion in 1992, and was $51 billion in 1995. Microsoft's market capitalization was just under $8.6 billion in 1990 and rose to $52 billion in 1995. Intel's market cap was $7.7 billion in 1990 and $47 billion in 1995.

[31] Author's calculations based on CRSP via WRDS.

[32] In our investigation of the mirroring hypothesis, Lyra Colfer and I found eight other instances in which industries split into horizontal layers after the introduction of a modular technical architecture. Thus there appears to be a robust correlation between successful modularizations and a subsequent transition to horizontally layered industry structure. Colfer and Baldwin (2016).

Notably, by 2005, the sponsors of the largest standards-based platforms—the Internet, the Worldwide Web, and telecommunications platforms, were not single firms, but standards-setting organizations.[33] Standards-setting increasingly took place in commons organizations subject to distributed governance. Relatedly, in the late 1990s and early 2000s, loose-knit communities committed to transparent, non-proprietary designs emerged as creators and stewards of open source software codebases. We will look more closely how technology shaped open source communities in Part 4 of this volume.

14.7 Conclusion—How Technology Shapes Organizations

Why did the transition to open digital platforms in the computer industry occur in the 1980s and 1990s? In fact, conditions favorable to the transition were developing slowly throughout the 1970s.

First, following the success of System/360, the first modular computer system, engineers working in both software and hardware became familiar with the concept of modularity. They learned how to create modular technical architectures via standards and design rules. Firms were motivated to create modular architectures in order to provide more options to their users. Modular architectures in turn are a necessary pre-condition for an open product platform to come into existence.

Also in the 1970s, plug-compatible peripheral computer companies became a business ecosystem comprising hundreds of firms that specialized in making modules for larger systems. In the latter part of the decade, they were joined by a new group of firms making modular hardware and software for very small personal computers.

Last but not least, in the 1970s, control of the rate of technical change shifted from computer systems makers to semiconductor firms.[34] Burned by the success of Japanese firms in the 64K DRAM generation, the U.S. semiconductor industry turned Moore's Law into a self-fulfilling prophecy. Thereafter, rates of change in semiconductor performance and prices set the pace for the rest of the industry. If a systems maker like IBM did not use the latest semiconductor chips, its competitors would happily introduce the them in hopes of displacing the leader.

This combination of factors—widespread knowledge about modular architectures; a growing ecosystem of firms capable of supplying modules; and consistent, rapid

[33] Governments are also involved in setting telecommunications standards.

[34] As described in Chapter 12, in late 1970s, U.S. firms fell badly behind when they failed to keep up with Japanese firms in the transition to 64K DRAM chips. Following that episode, U.S. firms as a group became committed to the performance gains and price declines made explicit by Moore's Law and later codified in the National Semiconductor Roadmap. Given the advantages accruing to first movers, no semiconductor firm could afford to go slower than the "scheduled" pace. Flamm and Reiss (1993); Mollick (2006).

improvements in semiconductor performance and pricing—made it technically possible and competitively advantageous to create open product platforms. Distributed supermodular complementarity—an industry comprised of complementary firms in different functional layers—became sustainable as an equilibrium.

The IBM PC was the first modular computer platform that was open as a matter of strategy, not necessity. The history of the IBM PC illustrates both the advantages and pitfalls of the strategy. In the next chapter, I describe how the PC first succeeded as an open platform, but then failed in competition with numerous PC clonemakers. Intel and Microsoft then replaced IBM has the sponsors of the platform. The mixed success of IBM and the strategies used by Intel and Microsoft to protect their positions are the focus of the next three chapters.

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Plate 1 Distribution of Computer Industry Market Capitalization by Layer 1985

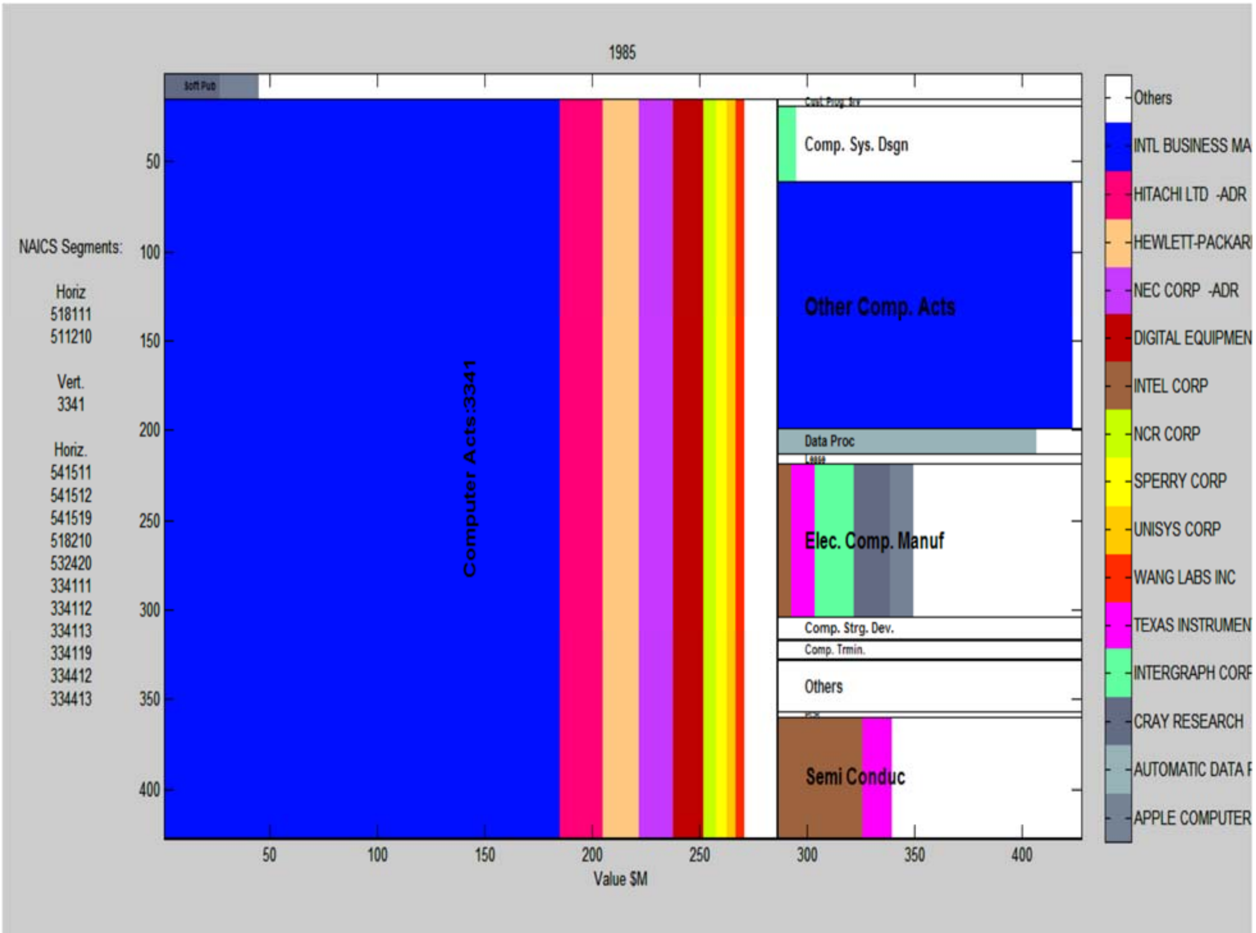


Plate 2 Distribution of Computer Industry Market Capitalization by Layer 1990

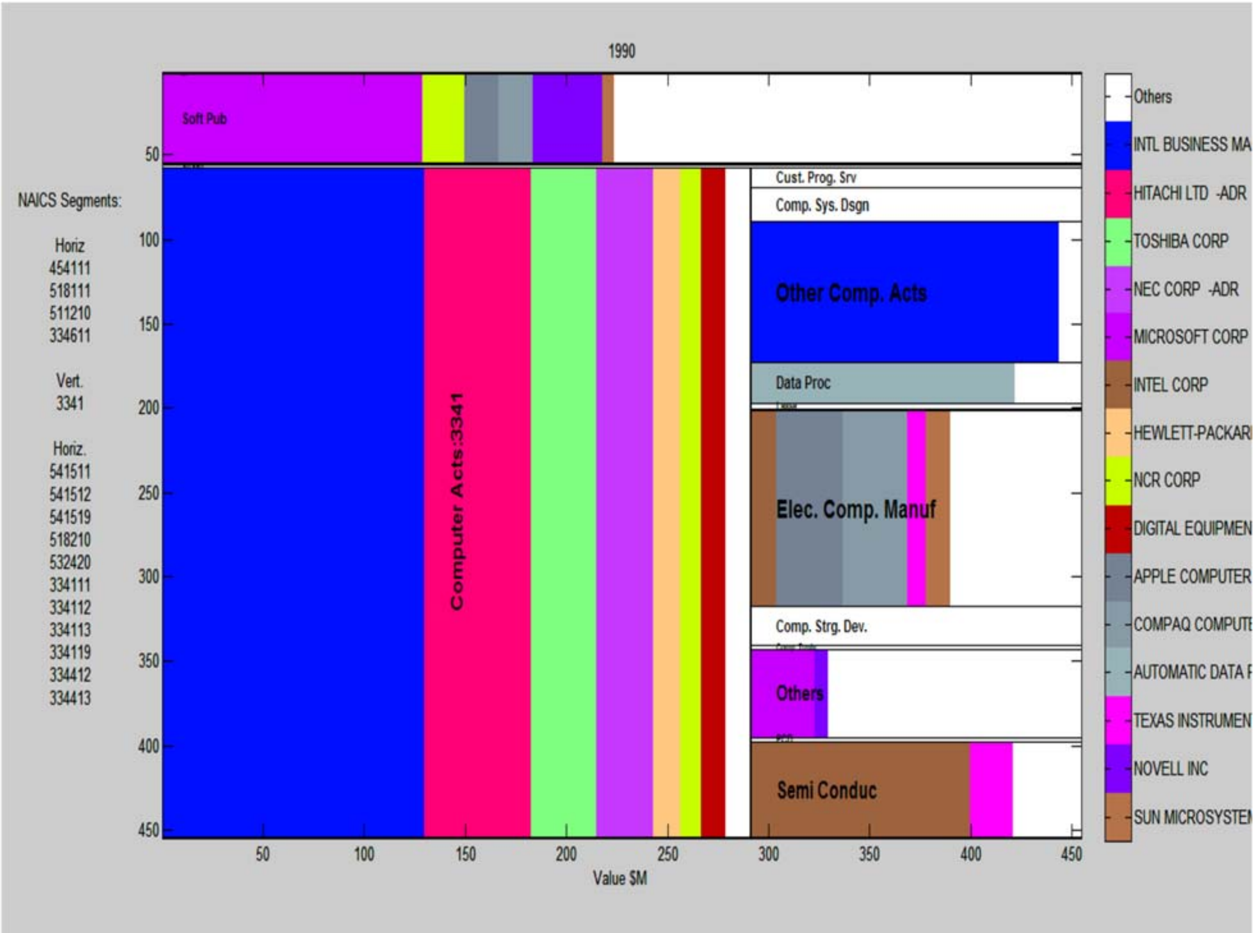


Plate 3   Distribution of Computer Industry Market Capitalization by Layer 1995

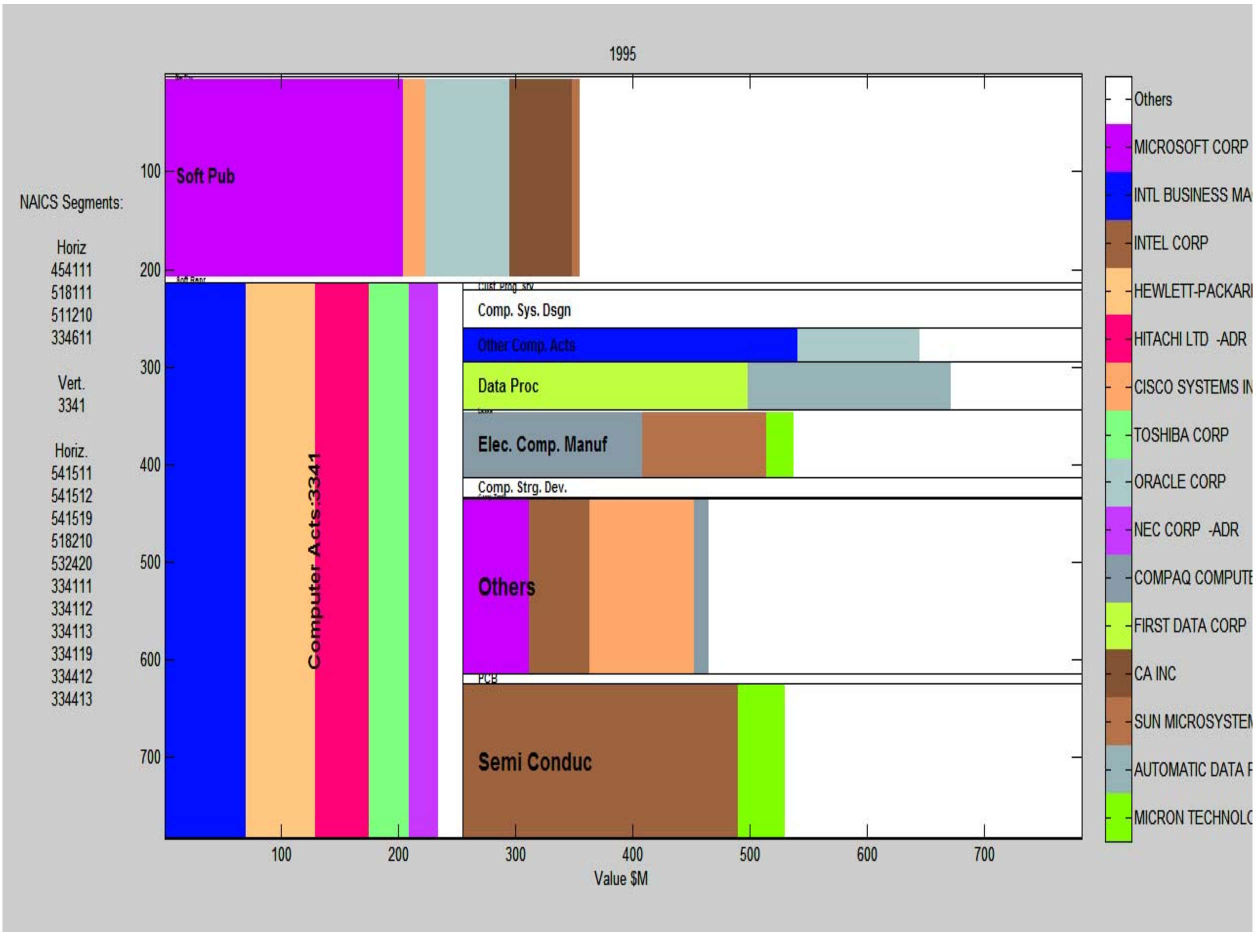


Plate 4 Distribution of Computer Industry Market Capitalization by Layer 2000

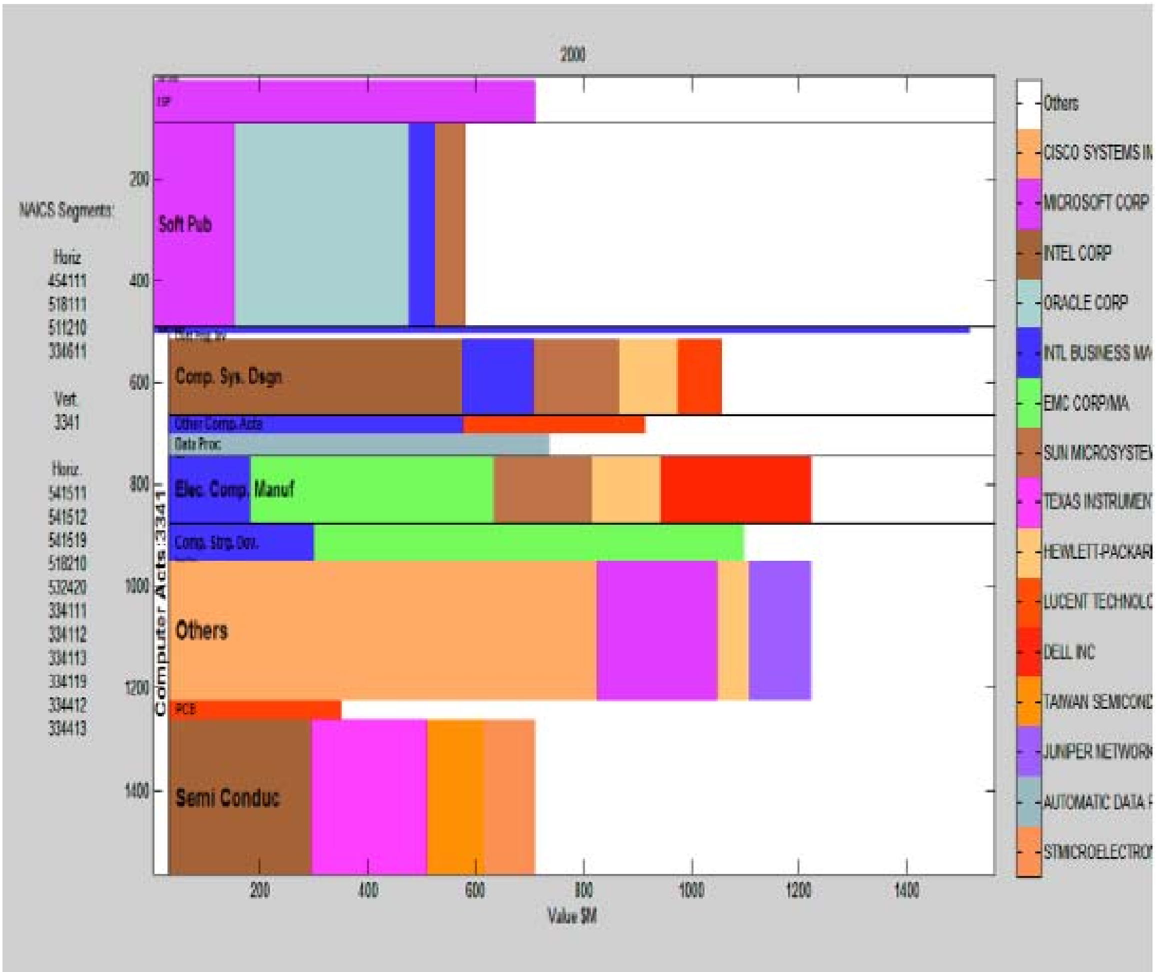
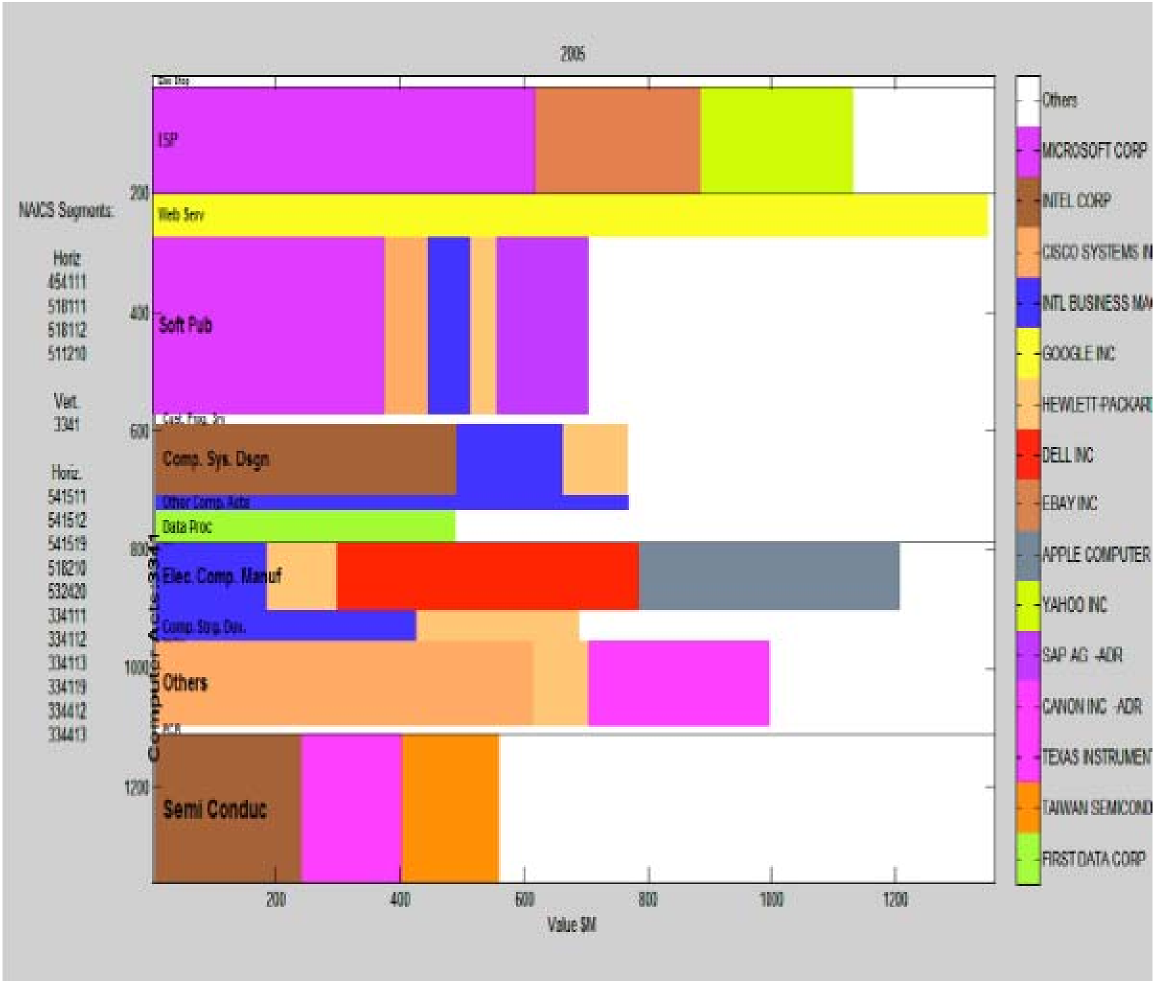


Plate 5   Distribution of Computer Industry Market Capitalization by Layer 2005



Appendix to Chapter 14—Construction of the Layer Maps