HARVARD | BUSINESS | SCHOOL

Design Rules, Volume 2: How Technology Shapes Organizations

Chapter 14 Introducing Open Platforms and Business Ecosystems

Carliss Y. Baldwin

Working Paper 19-035

Design Rules, Volume 2: How Technology Shapes Organizations

Chapter 14 Introducing Open Platforms and Business Ecosystems

Carliss Y. Baldwin
Harvard Business School

Working Paper 19-035

Design Rules, Volume 2: How Technology Shapes Organizations

Chapter 14 Introducing Open Platforms and Business Ecosystems

By Carliss Y. Baldwin

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:

Baldwin, C. Y. (2018) "Introducing Open Platforms and Business Ecosystems," HBS Working Paper (October 2018).

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 open platforms, each with its own set of technological requirements and challenges. I first develop a taxonomy of open platform types and then provide a brief history of digitally enabled open platforms. I go on to argue that the competitive success of open platforms against closed platforms gave rise to the "vertical-to-horizontal" transition in the computer industry in the 1980s and 1990s. This transition was one of the organizational "surprises" highlighted in Chapter 1. In this case, newly competitive technology of open platforms not only shaped individual organizations but changed the structure of the entire 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 generally designed and produced both the platform and complements.

[1] Wheelwright and Clark (1992).

The last two decades of the 20th Century saw the rise of two distinct types of *open platforms and surrounding ecosystems* based on digital technologies. First, "open product" platforms spread the design and production of different components of complex modular systems over many autonomous organizations. Second, in the 1990s, the Internet and the WorldWide Web led to the creation of "open exchange" platforms—websites designed specifically to facilitate transactions and other valued exchanges of goods, services, 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 1-5 in the previous chapter. These systems exhibit a positive impact of options; positive network effects between options and users; a positive impact of risk contained within options; a positive impact of modularity; and finally complementarity between modularity and risk.

Finally, through modularity, all platform systems support the decentralization of tasks and decision-making. Sponsors of open platforms delegate key tasks to third parties while attempting to control unique and essential components of the platform.

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 platform types and then provide a brief history of digitally enabled open platforms. I go on to argue that the competitive success of open platforms against closed platforms gave rise to the "vertical-to-horizontal" transition in the computer industry in the 1980s and 1990s. 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 industry.

Platform systems have existed in various forms for centuries. However, open platform systems based on digital technology and modular architectures were a new phenomenon that exploded on the scene in the 1980s and 1990s. These systems posed new problems for strategy and organization design. Companies and communities discovered the possibilities and the pitfalls of open digital platform systems largely via trial and error. In the five chapters that follow (Chapters 15 -19), I extend the analysis of functional components, modules, and bottlenecks set forth in Chapters 6 and 7 to deal with open platform systems. In case studies of different types of open platforms, I demonstrate a general approach to understanding such systems grounded in the value structure of their technical architectures.

14.1 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 complements.

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]

This definition is fundamentally rooted in the architecture of a complex product, thus I have labeled these platforms "product platforms." Beginning in the early 1990s, definitions like this one appear in articles by Langlois and Robertson (1992); Wheelwright and Clark (1992); Church and Gandal (1992); Sanderson and Uzumeri (1995); and Bresnahan and Greenstein (1999). In most instances, the term first was first used by practitioners and then adopted by scholars.

The crucial property that defines all product 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 a product platform's creation exactly what will happen—what options will be realized—is not known with any degree of certainty. Because of its modular architecture, the platform is tolerant of that uncertainty.[3] As shown in Chapter 13, this is a very different value structure from that of a step process that requires a particular series of actions and will fail if any step is left out.[4]

Product platforms in turn can be divided into *standards-based product platforms* and *logistical product platforms*.

---

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

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

[4] At the same time, both platform systems and step processes are technologies under Brian Arthur's definition, that is, both use control over natural phenomena to serve a human purpose or fulfil a goal. Arthur (2009) p. 28.

Standards-based product platforms support the design and production of complex systems of goods and services. The platform sets standards that allow components of the system to interoperate with the platform and with each other. Microprocessor instruction sets and APIs are examples of standards-based platforms.

In a *logistical product platform*, a system integrator orchestrates the movement of products and services through a complex network of step processes. Flexible manufacturing systems, distribution systems, and transportation systems are examples of logisitical platforms.

In contrast to product platforms, *exchange platforms* are physical or virtual spaces that facilitate valuable, transient exchanges between diverse agents. Exchange platforms are also called two-sided (or N-sided) markets. As with product platforms, the value of an exchange platform is derived from the options it supports. At the time of the exchange platform's creation, it is not known what specific transfers will be desired by the participants. What *is* known is that the desired transfers will require rapid and efficient connections among participants. Exchange platforms facilitate efficient connections and transfers of information, goods and services through the medium of the platform.

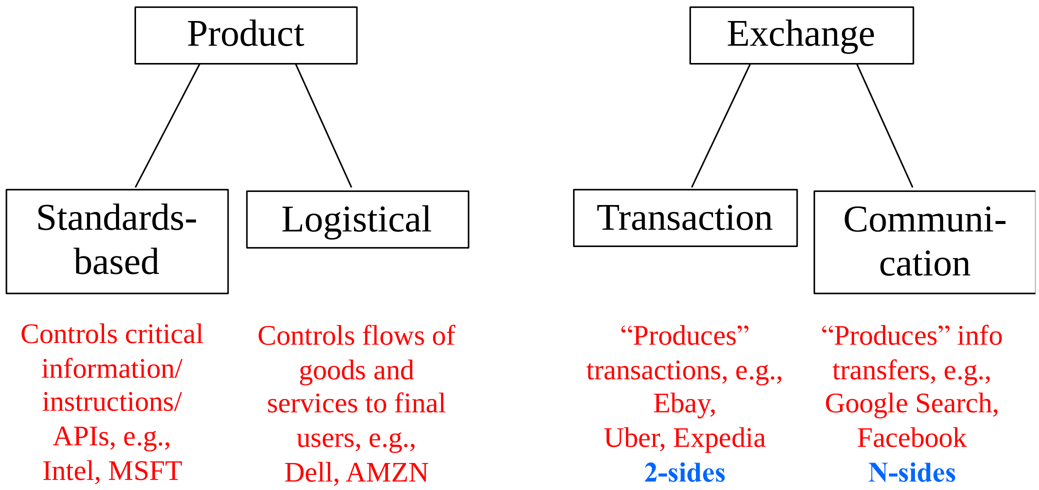
Exchange platforms can also be divided into two subtypes.

Transaction exchange platforms facilitate and enable transactions. They are marketplaces where buyers and sellers meet to exchange property rights for payments. Transaction platforms have two natural "sides," the buy-side and the sell-side. Examples include traditional bazaars, auctions (both online and offline), and brokers. Ebay, Alibaba, Uber and AirBNB are digital transaction platforms.

Communication exchange platforms facilitate exchanges of information, opinion, and other signals or messages. 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. Senders and receivers of messages constitute the two primary "sides" of these platforms. Quite often, however, additional agents may want to "piggy-back" on the basic messages through advertising or data collection. Examples of communication platforms include public squares, mail services, and all forms of media both online and offline.

Figure 14-1 offers a visual summary of this platform taxonomy, with examples of each type:

Figure 14-1 A Taxonomy of Platform Systems



Broadly speaking, product platforms, both standards-based and logistical, are ways of organizing the *design and production* of complex goods, services and information. Complex products and services are "built on" product platforms. Exchange platforms, in contrast, are ways of organizing *trade and transfers of information*. These platforms are used to "connect" agents briefly and then break off the connection.[5]

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 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 the corporation. These would be closed transaction platforms.

14.2 A Brief History of Open Platform Systems in the Computer Industry

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

---

[5] 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 form of technical architecture. Many technical systems that qualify as platform systems under my definition are not company-owned businesses. One obvious example is the Internet (or more precisely the Internet protocols) which is both a product and exchange platform.

times.[6] Before the advent of large synchronized flow systems in manufacturing, the production and distribution of goods was organized as an open logistical platform.[7] Finally, telegraph and telephone systems, stock exchanges, marketplaces and meeting places have supported the open exchange of goods and information from well before the advent of the Internet.[8]

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. Second, as discussed in Chapter 12, the fundamental physical entities (chips and circuits) behind the technology were subject to ongoing miniaturization and cost reduction. Under the dynamic 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).

As a matter of historical record, the evolution of open platforms in the computer industry followed a clear trajectory. Open platforms require highly modular technical architectures. The interface between platform and options must be clear and sharp and the options themselves must be encapsulated and relatively small. Early computers were not modular.

The first modular computer system was IBM System/360, introduced in the mid-1960s.[9] 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.[10]

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

---

[6] 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).

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

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

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

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

Internet in the mid-1990s, platforms dedicated to exchanges of goods, information, and opinion took center stage. For reasons discussed in Chapter 18, many sponsors of open product platforms decided to sponsor open exchange platforms as well.

14.3 Open Product Platforms

Before knowledge of how to modularize complex product systems was widely diffused, open exchange platforms were much more common than open product platforms. Open exchange platforms were based based on pre-existing thin crossing points in the task network. (Recall the example of the smiths and the cooks in Chapter 2.) In contrast, breaking apart complex products into modular systems required knowledge of underlying causal interdependencies, which could then be addressed via formal standards and design rules.

An open standards-based product platform is open to external downstream complementors. To promote this type of openness, the platform sponsor creates many modular points of entry (thin crossing points) in the technical system, 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. The platform system is thus “modular-in-use.”

Examples of standards-based product platforms include computer operating systems and applications, video consoles and games, as well as microprocessors and compatible hardware and software.

An open logistical product 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 sponsor of an open logistical platform outsources most components and many activities. It does so through contracts combined with modular interfaces that separate design from fabrication, fabrication from assembly, and assembly from distribution.[11] The sponsors of open logistical platforms act as systems integrators, bringing together diverse components and orchestrating processes.[12] A logistical platform system is thus “modular-in-production.”

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

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

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

sold under their labels.[13]

14.4 Business Ecosystems

Open product platforms, both standards-based and logistical, rely on ecosystems of providers to supply many parts and perform many of the tasks needed to arrive at a finished product. The term "ecosystem," originating in the science of ecology, has recently been adopted by managers and management scholars.[14]

Building on this prior work, I define a business ecosystem as a network of interconnected but autonomous firms whose products are more valuable when used together than separately. Business ecosystems are thus defined by complementarities among products. For an ecosystem to be sustained, the complementarities must be strong enough to warrant some degree of coordination but not so strong as to require unified governance.[15] Complementarities in a business ecosystem are frequently supermodular: investment by one type of firm makes investments by other firms more valuable.

Firms from many different industries may be part of the same ecosystem. Conversely, a single firm may participate in several ecosystems. Coordination among firms in an ecosystem may be achieved through standards, roadmaps, contracts, prices or a combination of all of these mechanisms.

Product platforms provide central points of coordination among firms in an ecosystem. Standards-based platforms coordinate rules; logistical platforms coordinate flows through production network.

Of necessity, open platforms and ecosystems satisfy the conditions of distributed supermodular complementarity (DSMC): otherwise they would collapse into or be replaced by closed systems.

14.5 Open Exchange Platforms

Throughout the 1980s and much of the 1990s, the most salient platforms *in the computer industry* were product platforms, both standards-based and logistical. However, a different view of platforms emerged in the early 2000s following seminal papers by Jean-Charles Rochet and Jean Tirole. 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

---

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

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

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

seen as two-sided, or in some cases, N-sided markets.[16]

The sponsor of an exchange platform essentially supplies matchmaking and other services related to trade or communication. According to Rochet and Tirole, the platform sponsor's key challenge is to "get both sides of the market on board."[17] For example, on a retail exchange site like eBay, buyers and sellers need to find appropriate counterparties. The job of the platform sponsor is to design a venue in which exchanges can take place efficiently.

Open exchange platforms can be traced back in history—to ancient marketplaces and bazaars, to the medieval fairs at Champagne, to bourses and financial exchanges. Open exchange platforms became even more important in the second half of the 1990s with the commercialization of the Internet.[18] As the Internet penetrated business and social relationships, online clearing houses and marketplaces sprang up to facilitate transactions in many goods. These new venues of exchange were platforms in terms of their technical architecture because their value lay solely in the options they generated. (This is also true of traditional marketplaces, fairs, and meeting places. Their value lies in the optional encounters, exchanges and transactions they make possible, not in the physical place itself.)

The rise of online commerce and social media mediated by the Internet caused the number of online marketplaces and meeting places to grow explosively. These developments in turn led to a new definition of platform. According to Geoffrey Parker, Marshall Van Alstyne and Sangeet Choudray:

> A *platform* is a business based on enabling value-creating interactions between external producers and consumers. The platform provides an open, participative infrastructure for these interactions and sets governance conditions for them. The platform's overarching purpose is to *consummate matches among users and facilitate the exchange of goods, services, or social currency*, thereby enabling value creation for all participants.[19]

As indicated, exchange platforms can be divided into two subtypes, transaction and communication platforms. A transaction involves the tranfer of rights and of payment preceded by transfers of information. Thus transaction platforms are perforce communication platforms. The reverse is not true: a communication platform may be transaction-free or may have transactions on its periphery. For example, when friends meet to converse in a café, the café serves as their communication platform. The friends

---

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

[17] Rochet and Tirole (2003) p. 990.

[18] Greenstein (2015).

[19] Parker, G., Van Alstyne, M. and Choudary, S.P. (2016) p. 5. Emphasis added.

need not transact with one another; their purchases of food and beverages are the price of using the café. They could meet in a public square or in a private home without transactions.

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 the mundane transaction costs related to defining, measuring and paying for goods are low, and that cheating is discouraged.

Uber, AirBNB, Alibaba, and numerous auction websites are all examples of modern digital transaction platforms. Most of these platforms outsource payment and credit to credit card companies and/or banks. The payment and credit infrastructure is a platform that supports other platforms. The ecosystem of a transaction platform includes buyers and sellers on the platform, plus suppliers of ancillary services such as payment, credit, transportation, and product reviews.

A communication platform is a place of information exchange. The exchanges may be one-to-one or one-to-many. The platform sponsor must provide a communication technology, attract suppliers of content (senders) and consumers of content (receivers), and capture sufficient revenue to pay for the platform and the content.

Communication platforms have diverse revenue-generating strategies. They may charge the senders (as with mail) or the receivers (as with subscriptions). They may charge both senders and receivers for ancillary services (as the café charges for food and drink). Or they may provide the basic service free of charge, but charge third parties for advertising and/or data extraction. Mixed revenue models, for example, subscription fees plus advertising, are common in communication platforms.

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. These platforms are alike in that their fundamental “product” is an information transfer, which can be made digital. Thus all are subject to the dynamic of Moore’s Law.

However, communications platforms differ greatly in terms of their ecosystems. (This was true even before the digital era.) The narrowest ecosystem of a communication platform consists of the senders and receivers of the primary messages. However, the ecosystem can be expanded to include suppliers of complementary services, advertisers, and data extractors.

14.6 Platforms Compared

Marketplaces and meeting places have a different underlying logic from open product platforms. The role of a product platform is to permit mixing and matching of components in a modular system—either a system of complements or a logistical network. The role of marketplaces and meeting places is to facilitate formal transactions and/or exchanges of information.

Exchange platforms, by definition, facilitate transient interactions between otherwise unrelated parties. Thus in many exchange platforms, the question of whether to integrate the platform and its users within the boundaries of a single firm does not arise. The agents do not seek semi-permanent connection, but limited communication, transaction, and matchmaking services from the platform. In such cases, there is little value in unified governance and thus distributed supermodular complementarity (DSMC) holds *a fortiori*.

The two types of open platforms—product and exchange—can be combined in different ways. Each type rests on a separable set of activities, and poses a different set of strategic challenges and risks.

The same firm may sponsor several different types of platforms. For example, Apple sponsors an open standards-based platform for mobile devices in the form of iOS and a standards-based platform for computers in the form of Mac OS. QuickTime Player comes bundled with MacOS, but accessing advanced audio and video functions requires the purchase of a license to QuickTime Pro.

Apple also sponsors an open logistical platform that coordinates flows of Apple hardware through a modular production and distribution network. In 2018, Apple is a fabless designer of numerous systems-on-chips (SOC), 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 consumer electronics manufacturers such as Foxconn plus hundreds of other suppliers of components and services to make its devices.[20] It distributes its hardware through its own retail stores and website, through third-party retailers such as Walmart and Amazon, and through phone companies.[21]

Apple sponsors two digital transaction platforms, the iTunes Store, primarily focused on music and video, and the Apps Store supplying applications for Apple mobile devices. Interestingly, as of 2018, applications for Apple computers do not pass through an Apple-sponsored transaction platform. In contrast, the Microsoft Store permits the

[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.

purchase of third-party applications for Windows computers.[22]

Finally, virtually all transaction platforms today support product ratings and reviews by consumers. These are open communication platforms within a transaction platform.

Companies whose principal business it 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 broadband and TV services in a handful of cities.[23]

The most advanced and apparently successful technology companies are sponsoring and/or experimenting with all four types of platforms. Thus if we accept Alfred Chandler's argument that the primary challenge for managers in the late 19th and early 20th Centuries was to set up administrative systems that could efficiently supervise multi-step production processes, then a new challenge for managers in the 21st Century is to coordinate multiple interacting open platforms and their surrounding ecosystems.

14.6 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 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."[24] 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.[25]

---

[22] https://www.microsoft.com/en-us/store/best-selling/apps/pc, viewed 9/30/18.

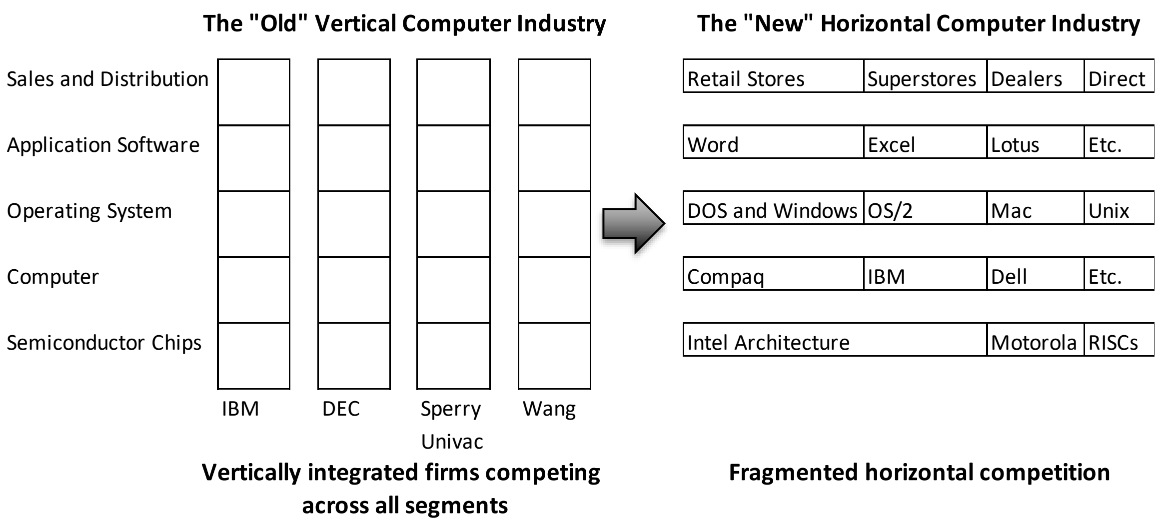
[23] https://www.lifewire.com/understanding-google-and-alphabet-4116085, viewed 9/30/18.

[24] Grove (1996) p. 33.

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

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, he said, 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 most prosperous firms did not attempt to make whole systems, but focused 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 firms in different industries coordinated by multiple standards-based and logistical platforms.

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.

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, and Cisco Systems, sponsored their own open standards-based and/or logistical platforms.

A closed product platform, by definition, corresponds to a vertically integrated firm. *Thus the vertical-to-horizontal transition in the computer industry could not have occurred except through the success of open product platforms based on modular technical architectures.*

14.6 Mapping Industry Architecture

An open product platform and ecosystem 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 in the architecture can be thought of as occupying a different "layer" in a vertical "stack" of functions.[26] Firms in the greater industry can then be associated with one or more layers in accordance with the functions their products provide.[27] 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."

Grouping products and firms by function, it is possible to construct a "layer map" of overlapping platforms and ecosystems.[28] Firms making many functional components inhouse 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.

With Michael Jacobides and Reza Dizaji, I used segment data on firm market values to construct a series of layer maps of the greater computer industry.[29] Plates 1-5 at the end of this chapter provide a series of layer maps showing the market capitalization of the largest 14 firms relative to the whole industry every five years from 1985 to 2005.

Grove's perception of a vertical-to-horizontal industry transition is borne out by the maps. In 1985, IBM, the quintessential vertically integrated computer manufacturer, accounted for more than half the market value in the industry. (See Plate 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. As Grove observed, "Going into the eighties, the old computer companies were strong, growing and vital." [30]

Between 1985 and 1990, IBM lost a great deal of its market value share, as did

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

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

[28] Fransman (2002).

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

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

Digital, National Cash Register, Sperry, Unisys, and Wang Labs. (See Plate 2.) However, the Japanese verticals, now joined by Toshiba held their own. Microsoft, which went public in 1986, occupied the #5 position in 1990, with Intel at # 6. Compaq, Novell, and Sun Microsystems, all sponsors or members of open product platforms, joined Apple on the list. Packaged software (a new layer) accounted for over 10% of the industry's market value. Notwithstanding these developments, the industry as a whole was still dominated by vertically integrated firms.

Between 1990 and 1995, the map changed dramatically. (See Plate 3.) *Horizontal layers now accounted for around three-quarters of the industry's value.* Microsoft was #1; a shrunken IBM was # 2; and Intel #3.[31] New entrants in these layers included Cisco, Oracle, First Data Corp, CA Inc. and Micron Technologies. They replaced NCR, Digital, Apple, TI, and Novell. Also notable is the increase in "white" space in the map, that is, publicly listed firms that were not in the top fourteen. Industry concentration diminished as hundreds of firms entered the industry and went public.

The industry as a whole greatly expanded in terms of total market value rising from $181 billion 1990 and $683 billion in 1995.[32] The early 1990s marked the beginning of the Internet Gold Rush, which turned into the Internet Bubble and Crash. (The Internet is both an open product platform and open exchange platform. It dwarfed all previous open platforms in terms of the scope and diversity of the options it created.)

By 2000, the verticals had disappeared. (See Plate 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 product platforms. The era of open exchange platforms lay in the future.

Thus a vertical-to-horizontal transition in industry structure did take place, beginning in the late 1980s and continuing through the 1990s. It could not have occurred in the absence of highly modular technical architectures and open product platforms, both standards-based and logistical. It was also fueled by the advent of the commercial Internet, which encouraged the creation of many online open exchange platforms. Modular architectures made open platforms feasible; open platforms with their myriad of suppliers and complementors then proved to be highly competitive against closed platforms. Over a twenty year timespan, vertically integrated firms essentially

---

[31] 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.

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

disappeared in the computer industry, and were replaced by open product platforms and related ecosystems.[33]

A further transition occurred between 2000 and 2005. (See Plate 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 product platform designed to compete with Apple's iOS, in 2007.

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.[34] 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.

14.7 Conclusion—How Technology Shapes Organizations

Why did the transition to open platform systems in the computer industry begin in the 1980s and gather steam in the 1990s? Conditions favorable to the transition developed slowly during the 1970s.

First, engineers throughout the computer industry, working in both software and hardware, became familiar with the concept of modularity and with modular architectures. Firms were motivated to create modular architectures to increase the options available to the system architect and/or users. Even within a single firm, the option value associated with modular systems was difficult to ignore. A modular architecture in turn is a necessary pre-condition for an open product platform to come into existence.

Also in the 1970s, plug-compatible peripheral computer companies formed a business ecosystem of 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 the new microcomputer sector.

Last but not least, in the 1970s, control of the rate of technical progress in

[33] 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).

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

computers shifted from computer systems makers to semiconductor firms.[35] When firms in the semiconductor industry turned Moore's Law into a self-fulfilling prophecy, systems makers lost control over rates of change in their own systems. Rates of change in semiconductor performance and prices set the pace for the rest of the industry. If a market leader did not keep pace with new semiconductor technology, other firms would happily introduce the technology in hopes of displacing the leader.

This combination of three factors—widespread knowledge about modular architectures; a growing ecosystem of firms capable of supplying modules; and consistent, rapid improvements in semiconductor performance and pricing—made it technically possible to create open product platform. Distributed supermodular complementarity—an industry comprised of firms in different functional layers—was potentially sustainable as an equilibrium in the computer industry.

If IBM System/360 was the first modular computer system, the IBM PC was the first modular product platform that was open as a matter of strategy not necessity. The history of the IBM PC aptly illustrates both advantages and pitfalls of an open product platform strategy. In the next chapter, I describe how the PC first succeeded as an open standards-based and logisitical platform, but was superseded by the Wintel standards-based platform and numerous PC clonemakers with competing logistical platforms.

[35] 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).

References

Adner, R., 2017. Ecosystem as structure: an actionable construct for strategy. *Journal of Management*, *43*(1), pp.39-58.

Adner, Ron and Rahul Kapoor (2010) “Value Creation in Investment Ecosystems: How the Structure of Technological Interdependence Affects Firm Performance in New Technology Generations,” *Strategic Management Journal* 31:306-333.

Arthur, W. Brian (2009) *The Nature of Technology: What It Is and How It Evolve*s, New York: Free Press.

Baldwin, Carliss Y. and Kim B. Clark (2000). *Design Rules, Volume 1, The Power of Modularity*, Cambridge, MA: MIT Press.

Berger, S., 2005. *How we compete: What companies around the world are doing to make it in today's global economy*. New York: Doubleday.

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

Boudreau, Kevin J. and Andrei Hagiu (2011) "Platform Rules: Multi-Sided Platforms As Regulators," in *Platforms, Markets and Innovation*, A. Gawer, ed. (London: Edward Elgar)

Bresnahan, T.F. and Greenstein, S., 1999. Technological competition and the structure of the computer industry. *The Journal of Industrial Economics*, 47(1), pp.1-40.Gawer and Cusumano (2002)

Brusoni, Stefano, Andrea Prencipe and Keith Pavitt (2001) "Knowledge Specialization, Organizational Coupling and the Boundaries of the Firm: Why Do Firms Know More Than They Make?" *Administrative Science Quarterly*, 46(4):597-621.

Chandler, Alfred D. (1977) *The Visible Hand: The Managerial Revolution in American Business*, Cambridge, MA: Harvard University Press.

Church, J., & Gandal, N. (1992). Network effects, software provision, and standardization. *The Journal of Industrial Economics*, 85-103.

Church, J., & Gandal, N. (1993). Complementary network externalities and technological adoption. *International Journal of Industrial Organization*, 11(2), 239-260.

Colfer, L.J. and Baldwin, C.Y., 2016. The mirroring hypothesis: theory, evidence, and exceptions. *Industrial and Corporate Change*, 25(5): 709-738.

Cusumano, M.G., Gawer, A. and Yoffie, D.B. (2019) *The Business of Platforms: Strategy in the Age of Competition, Innovation and Power,* New York: Harper Business.Frischmann, B.M. (2004) An economic theory of infrastructure and commons management. *Minnesota Law Review*, 89:917-1030.

DeLamarter, R.T., (1986) *Big Blue: IBM's use and abuse of power*. New York NY: Dodd, Mead & Company.

Ferguson, Charles H. and Charles R. Morris (1993) *Computer Wars: How the West Can Win in a Post-IBM World*, New York, NY: Times Books.

Fine, Charles H. (1998). *Clockspeed: Winning Industry Control in the Age of Temporary Advantage,* Reading MA: Perseus Press.

Flamm, K. and Reiss, P.C., 1993. Semiconductor dependency and strategic trade policy. *Brookings Papers on Economic Activity. Microeconomics*, 1993(1), pp.249-333.

Fransman, Martin (2002). "Mapping the Evolving Telecoms Industry: The Uses and Shortcomings of the Layer Model," *Telecommunications Policy*, 26(9-10): 473-83.

Frischmann, B.M., 2012. *Infrastructure: The social value of shared resources*. Oxford University Press.

Greenstein, S., 2015. *How the internet became commercial: Innovation, privatization, and the birth of a new network*. Princeton University Press.

Grove, Andrew S. (1996). *Only the Paranoid Survive*, New York: Doubleday.

Iansiti, Marco and Roy Levien (2004). *The Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability*, Boston: Harvard Business

Jacobides, M. G., Baldwin, C. Y. and Dizaji, R. (2007) "From the Structure of the Value Chain to the Strategic Dynamics of Industry Sectors," *Academy of Management Symposium Presentation*, August 7.

Jacobides, M.G. and Tae, C.J., 2015. Kingpins, bottlenecks, and value dynamics along a sector. *Organization Science*, 26(3), pp.889-907

Jacobides, M.G., Cennamo, C. and Gawer, A., 2018. Towards a theory of ecosystems. *Strategic Management Journal* 39:2255-2276.

Jacobides, Michael G., Thorbjorn Knudsen and Mie Augier (2006) "Benefiting from Innovation: Value Creation, Value Appropriation and the Role of Industry Architecture," *Research Policy*, 35(8):1200-1221.

Langlois, Richard N. and Paul L. Robertson (1992). "Networks and Innovation in a Modular System: Lessons from the Microcomputer and Stereo Component Industries," *Research Policy*, 21(4): 297-313; reprinted in *Managing in the Modular Age: Architectures, Networks, and Organizations* (G. Raghu, A. Kumaraswamy, and R.N. Langlois, eds.), Blackwell, Oxford/Malden, MA.

Levinson, M. (2006). *The box: how the shipping container made the world smaller and the world economy bigger*. Princeton University Press.

Mollick, E. (2006). Establishing Moore's law. *Annals of the History of Computing, IEEE*, 28(3), 62-75.

Moore, James F. (1996). *The Death of Competition: Leadership & Strategy in the Age of Business Ecosystems*. New York: HarperBusiness

Parker, G.G., Van Alstyne, M.W. and Choudary, S.P. 2016. *Platform revolution: How networked markets are transforming the economy--and how to make them work for you*. WW Norton & Company.

Rochet, J-C and J. Tirole (2003) “Platform Competition in Two-Sided Markets,” *Journal of the European Economic Association*, 1(4):990-1029;

Rochet, J-C and J. Tirole (2006) “Two-sided Markets: A Progress Report,” *Rand Journal of Economics* 37(3):645-667.

Rosenberg, N., and Birdzell, L. E. Jr. (2008). *How the West grew rich: The economic transformation of the industrial world*. Basic Books, New York.

Sanderson, Susan and Mustafa Uzumeri (1995) "Managing product families: the case of the Sony Walkman," *Research Policy*, 24:761-782

Sturgeon, Timothy J. (2002). “Modular Production Networks: A New American Model of Industrial Organization,” *Industrial and Corporate Change*, 11(3): 451-496.

Wheelwright, S.C. and Clark, K.B., (1992) "Creating project plans to focus product development" *Harvard Business Review* (March-April): 70-82.

Yoffie, D. B. (1997) "Introduction," *Competing in the age of digital convergence*. Boston, MA: Harvard Business School Press.

Plate 1 Distribution of Computer Industry Market Capitalization by Layer 1985

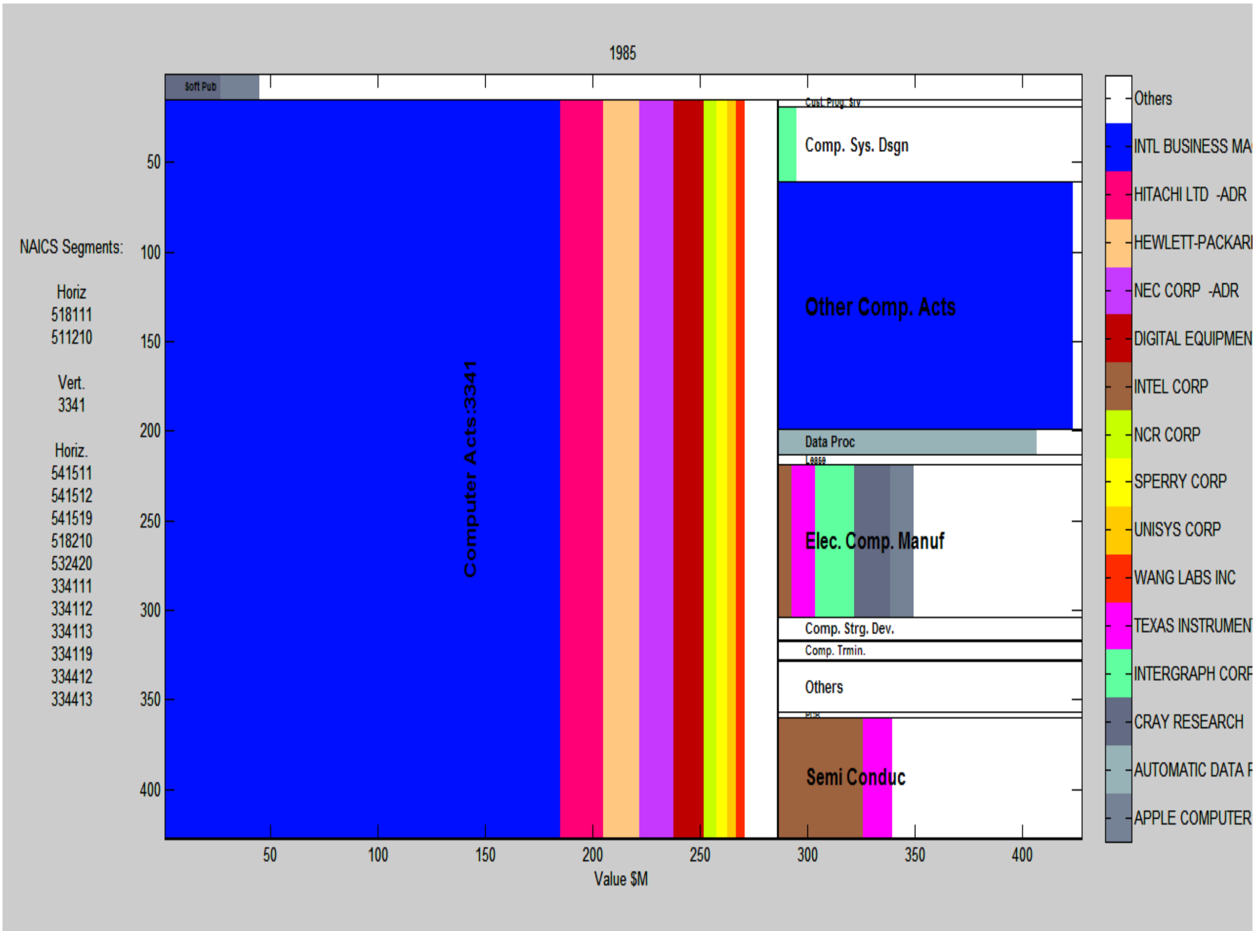


Plate 2 Distribution of Computer Industry Market Capitalization by Layer 1990

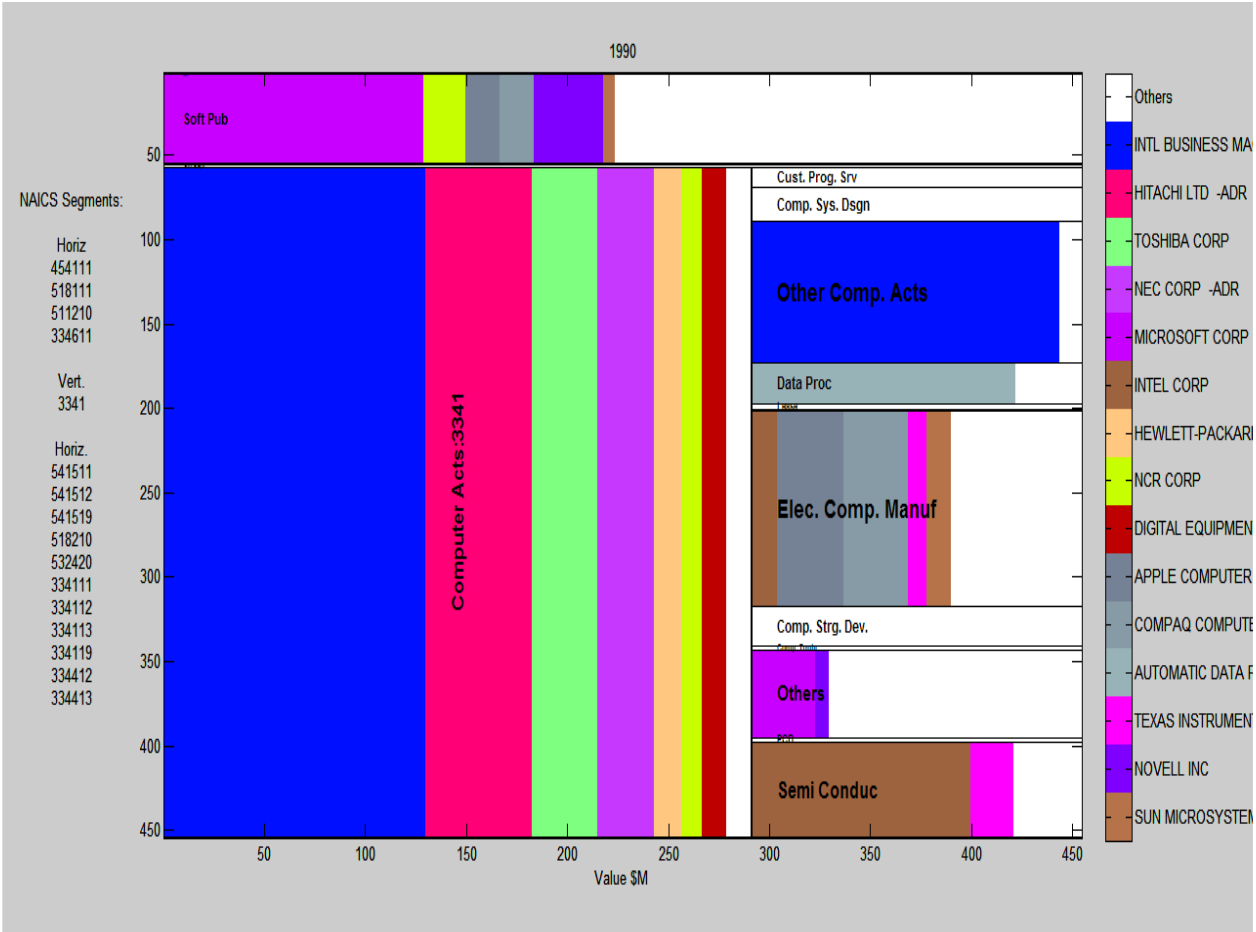


Plate 3 Distribution of Computer Industry Market Capitalization by Layer 1995

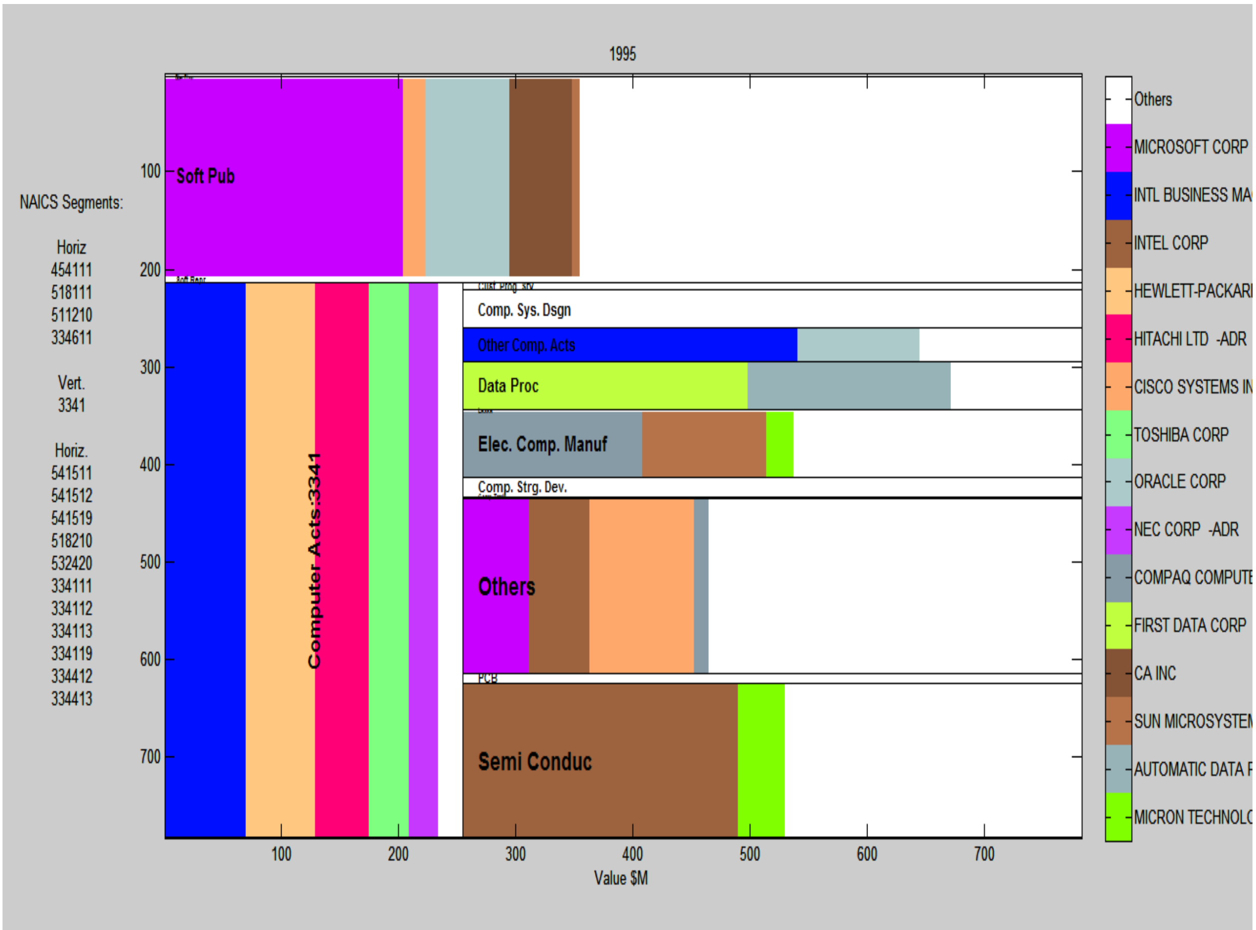


Plate 4 Distribution of Computer Industry Market Capitalization by Layer 2000

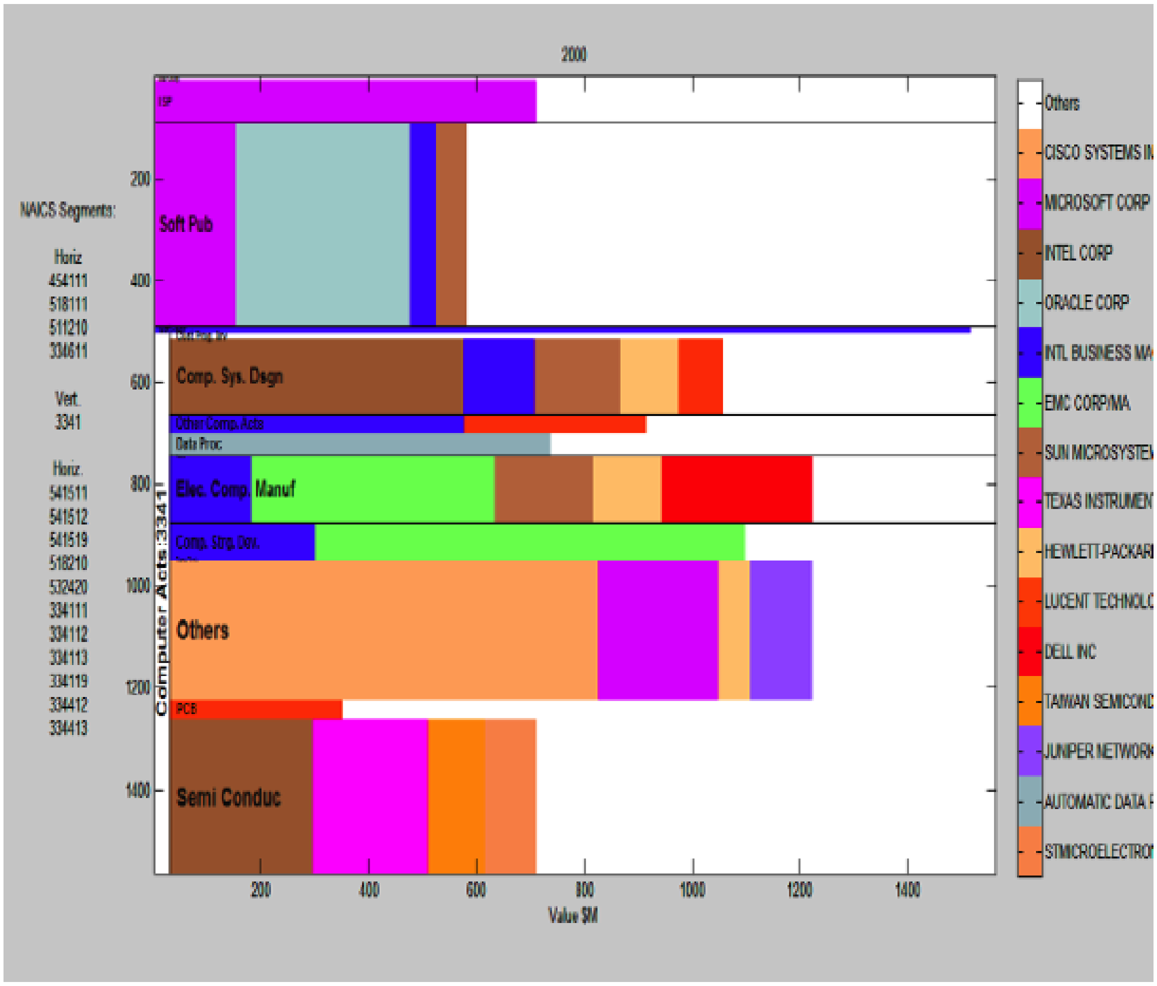
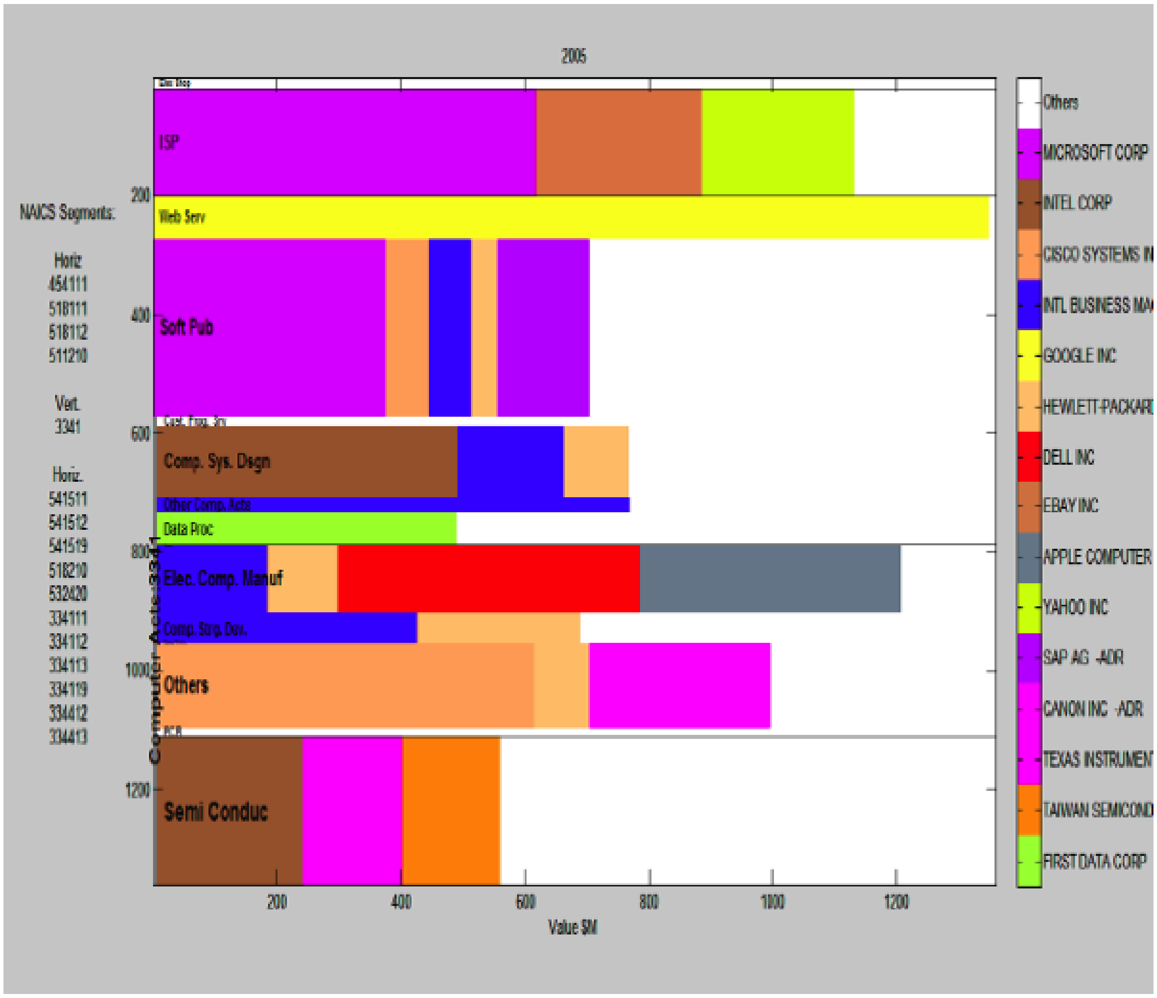


Plate 5 Distribution of Computer Industry Market Capitalization by Layer 2005



Appendix to Chapter 14—Construction of the Layer Maps