The information technology ecosystem: Structure, health, and performance

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I. OVERVIEW

A number of modern industries are organized as complex networks of firms whose integrated efforts are necessary to deliver value to end customers. The complexity of these networks, or “business ecosystems,” and the associated interdependencies among firms, make traditional antitrust market analysis difficult. The purpose of this paper is to provide a framework for how one might analyze and understand the “health” and performance of a business ecosystem. We focus on the IT ecosystem, by which we mean the network of organizations that drives the delivery of information technology products and services.

In order to assess the health of the IT ecosystem, the first half of this paper reviews three crucial IT ecosystem metrics: robustness, productivity, and innovation. The second half focuses on innovation and presents an analysis of specific product and company case examples that highlight significant new developments across IT hardware, software, and services.

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The IT ecosystem began the 21st century by entering a deep recession, exacerbated by excessive investment and business failures in the Internet, software, and telecommunications industries. At around the same time, Microsoft Corporation and the US Department of Justice entered into a Consent Decree ("Consent Decree") that resolved their multiyear antitrust dispute. Our analysis indicates that since the period of retrenchment, the IT ecosystem has regained its health, rebounding from its recession and delivering significant levels of innovation. Drawing from a variety of public and proprietary data, including market value indicators, productivity measurements, and return on invested capital metrics, we find that with respect to the three critical indicators of IT ecosystem health, robustness, productivity, and innovation, the IT ecosystem is strong in all three of the most important sectors of hardware, software, and services.

More detailed analysis of individual ecosystem domains is consistent with this overall picture and showcases striking examples of innovation, diversity, and increased competitiveness in a variety of settings. A broad set of software platforms and middleware, ranging from the Linux operating system to the Apache Web content delivery platform, continue to capture increasing market share and important market positions. Web browsers are becoming more diverse through the success of new entrants such as Firefox. Traditional software firms are showing recovering productivity numbers and, as in the case of Microsoft, introducing innovative new products. Additionally, new software-driven services like Google are exhibiting stunning growth through innovative business models. Lastly, the introduction of popular new devices, ranging from smart phones to music players, is combining hardware, software, and content solutions in innovative ways to deliver new converged experiences to customers.

II. THE IT ECOSYSTEM—ROLES AND STRUCTURES

The IT industry today consists of a rapidly evolving and massively interconnected network of organizations, technologies, products, and consumers. In contrast with the vertically integrated environment of the 1960s and 1970s, today's industry is divided into a large number of segments producing specialized components,
systems, and services. The degree of interaction among firms in the industry is truly astounding, with hundreds of organizations frequently involved in the design, production, distribution, and implementation of a single product.

This network of organizations can be compared to a biological ecosystem. Like its biological counterparts, the IT ecosystem is characterized by a large number of participants who depend on each other for their mutual effectiveness and survival. Because the performance of individual firms and the utility of individual products depends so much on the performance of other firms and products in the ecosystem, understanding the IT ecosystem requires the development of ways to characterize the collective health of the setting.

The boundary of the IT ecosystem is difficult to define. The organizations that influence the value of a single IT product or service are many and dispersed across numerous traditional industries, ranging from software application developers to venture capital firms. Some of the most important domains of the ecosystem are depicted in figure 1. A domain is a specific group of organizations in an ecosystem that shares common characteristics and solves similar problems for its customers.

For the purpose of this analysis, we restrict our focus to the "core" domains shown in figure 1. The market opportunity map of figure 1 shows the size of the market in billions of dollars to scale across the horizontal axis for some of the most important sub-sectors of IT hardware, software, and services. Figure 1 also illustrates the market share along the vertical access of the constituents of each of the sub-sectors. It is important to understand that the sectors of the IT ecosystem shown in figure 1 are not isolated from the rest of the economy, but instead interact with it in crucial ways. Among the causes of the poor health of the IT ecosystem after the economic downturn in 2001, for example, are the performance of sectors like...

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banking and telecommunications that are beyond the scope of our current analysis.\(^2\)

It is also worth noting that software, an important segment of focus in the Consent Decree, represents a very small vertical slice of the overall IT ecosystem. Even more striking is the smaller size of the operating system market, at $23 billion, compared to over $2 trillion for the broader IT industry. Despite their smaller size, operating systems and other platform domains have broad importance to many other players in the ecosystem.

Although they depend on each other, not all members of an ecosystem are the same. Perhaps most importantly, not all members of an ecosystem perform similar roles. Two critical and distinct roles are application providers and platform providers.

\(^2\) For much additional detail, see IANSITI & LEVIEN, supra note 1.
Some ecosystem participants compete by providing a product that is used directly by an end customer to solve a set of problems. This is what we define as an "application." For example, in the physical world, an application of concrete is a bridge or an office building. In the IT ecosystem, Intuit's Quicken financial management products or SAP's enterprise resource planning suite represent software applications, because their primary purpose is to be used directly by end customers.

In other cases, members compete by providing "platforms." A platform is a set of tools or components that provide building blocks for application providers. A platform for bridge building might include standard formulations for concrete with reliable strength and rigidity characteristics. Examples of platforms in IT include Microsoft Windows and Red Hat Linux. Windows and Linux are complemented by extensive tool sets and are used by millions of developers to more easily write end user applications.

Platform providers perform a critical role in an ecosystem—they deliver consistent and reliable components that make application providers more productive. The tools and building blocks they provide to ecosystem members make it easier to create powerful applications that in turn benefit end users. In doing so, platform providers can act as "keystones" to their ecosystems, generally enhancing innovation and productivity.\(^3\) The term keystone is drawn from biology, where a "keystone species" performs a central function that is critical to the health of the whole ecosystem.

In the IT ecosystem, the vast majority of organizations provide applications. The relatively few platform providers form crucial "hubs" in the ecosystem, in that their tools and components are typically used by many of the organizations providing applications. In this way, platform providers effectively connect many application providers to each other and to end users, defining critical common interfaces, as well as reusable components.

Operating systems are possibly the most crucial platform for the building of applications. The stability and reliability of these

\(^3\) Id.
platforms is of fundamental importance to the many participants that build upon them. Since 1999, companies in the IT sector are relying increasingly on more than one operating system to support their applications. In an analysis performed by Keystone Strategy, Inc., which included a sample of thousands of independent software vendors (ISVs), the percentage of ISVs deploying their software for more than one operating system platform (self-reported by the ISVs in a questionnaire) increased from 41% to more than 50% (see figure 2). This in turn could suggest that the value of supporting multiple platforms, such as Linux, Unix, and the Mac OS, is exceeding the cost of support, leading to a more varied and competitive ecosystem.

Further analysis indicates that operating system adoption is increasing in diversity. Linux is a well-known example of an operating system platform that has evolved into a comprehensive operating system with a growing application set. Deployment of Linux as a platform for servers continues to grow. Additionally, Linux is starting to make inroads into the desktop market.

Figure 3 shows that the percentage of ISVs supporting the Linux operating system has grown appreciably from 1999 to 2002. Support
by ISVs for an operating system is a crucial component of the success of the operating system as a platform. Without applications, the operating system provides little value to the ecosystem or its customers. Growing support by ISVs provides customers with greater opportunities and choices to take advantage of the platform's benefits.

With additional ISVs supporting the Linux operating system, customer adoption of the platform is also on the rise. The Linux operating system has traditionally provided a platform for server computing applications, as distinguished from client or personal computer applications. The worldwide shipments of PCs that run the Linux operating system has grown from 3.5% in 2001 to an estimated 5.6% in 2005—a marked gain in market share.

The IT ecosystem is evolving rapidly, and an increased number of platforms are providing alternatives to Microsoft Windows. New middleware platforms like IBM’s WebSphere and BEA Systems’ WebLogic are adding to this trend. This implies that the structure of the IT ecosystem is increasingly open and competitive, with a growing number of application providers supporting multiple platforms.
III. ECOSYSTEM HEALTH AND COMPETITIVENESS

What makes a business ecosystem healthy? In this question, we seek measures of the extent to which a business ecosystem fosters the durable growth of opportunities for its members and improves the benefits it delivers to its customers. It is not acceptable for an ecosystem simply to generate or supply new products or business models, if the entire ecosystem vanishes or collapses after the first disruptive change in the environment or if the ecosystem ceases to innovate for its customers.

To assess the health and competitiveness of business ecosystems, we use three aspects of ecosystem health inspired by our biological metaphor and expressed in terms of our ecosystem analogy: robustness, productivity, and innovation (or niche creation). We first explain and analyze these three crucial measures of business ecosystem health and competitiveness for companies in the hardware, software, and services domains in aggregate. We then include a fourth analysis of specific product and company case examples in order to highlight the particular importance of innovation in the rapidly changing IT ecosystem. From these four analyses we conclude that the IT ecosystem has rebounded from the retrenchment of the recession and gained competitiveness since the Consent Decree was entered.

A. Robustness

In order to provide durable benefits for its members and customers, a biological ecosystem needs to persist in the face of environmental changes. Therefore, a healthy business ecosystem should be robust to perturbations and disruptions. This robustness can be assessed in a variety of ways. One way is to analyze the sustainability of value in the ecosystem. The persistence or recovery of the value of the constituent firms after a major disruption can be used as an indicator of the ecosystem’s robustness.

Another approach to robustness is a measure of financial betas and firm survival rates. A healthy ecosystem will promote the survival of a

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4 Id.

5 Extensive discussions of robustness and its implications for many fields, along with a review of various definitions for the term, can be found online at the Santa Fe Institute’s robustness Website, http://discuss.santafe.edu/robustness/.
diverse set of firms, including those that populate a variety of niches, through inevitable disruptions. This diversity provides greater choice and reliability to the customers that depend on a business ecosystem.

Many analysts track the overall value and health of the IT ecosystem through market indices. For example, the Goldman Sachs Technology Composite Index (GSTI) provides a modified capitalization-weighted index based on a universe of technology-related stocks. This index covers the primary domains of the IT ecosystem by aggregating the performance of six capitalization-weighted component indices: the Hardware Index (GHA), the Semiconductor Index (GSM), the Software Index (GSO), the Services Index (GSV), the Multimedia Index (GIP), and the Internet Index (GIN).

Review of the GSTI (see figure 4) indicates that the IT ecosystem appears to be in broad recovery from the significant IT recession in 2001 and 2002. Specifically, as of March 2005, the GSTI had nearly doubled from its lows in September 2002.

**Figure 4**
Market Recovery of Technology Sector 2001–2005

\[\begin{array}{c}
\text{US Dollars} \\
\text{Mar- Sep- Mar- Sep- Mar- Sep- Mar- Sep- Mar-}
\end{array}\]

Data presented represent the performance of Goldman Sachs Technology Composite Index (GTSI) tracking fund and IGM, which closely tracks the index with the added benefit of incorporating the effects of dividends and splits into the adjusted final values. Values plotted represent adjusted values for these dividends and splits.
The IT ecosystem recovery seen in the overall value metric in figure 4 also spans all of the primary sectors addressed by the Consent Decree. If we look at each of the sectors in the index individually (see figure 5), all show recovery from their lows in late 2002. This synchronized recovery is yet another indicator that the industry is an ecosystem composed of a tightly interconnected group of firms. Despite a significant downturn and retrenchment, these analyses indicate that the IT ecosystem exhibits robustness across all segments. In a business ecosystem, robustness ensures a reliable source of valuable products for IT customers.

B. Productivity

In conservation literature on biological ecosystems, the term "productivity"—how effectively the ecosystem converts raw materials into living organisms—is a widely used measure of ecosystem health and how it benefits those who use it. This measure is a very good analog to total factor productivity analysis used routinely in economics. In biological ecosystems the set of inputs does not change significantly over time, and productivity need not

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**Figure 5**
Market Recovery of Tech Sub-sectors 2001–2005

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 SOURCE: Yahoo! Finance, GSTI Sub-Index Historical Prices.
necessarily show continuous improvement. Successful business ecosystems are strikingly different: they are constantly subject to new conditions—new technologies, new processes, new demands, and new competition. By analogy then, measures of productivity should capture not only the productivity of the ecosystem today, but also increases in productivity—improvements in the effectiveness of the business ecosystem in converting the "raw materials of value creation" into lowered costs and new products through innovation.

1. IT PRODUCTIVITY

Improvements in productivity show that an ecosystem is able to produce more with the same or less input. In the long run, real earnings in a business ecosystem are tied to productivity gains. We normally think of the IT industry as providing the engine for productivity gains across the U.S. economy. Improvements in productivity within the IT ecosystem are equally important measures of the health and competitiveness of the IT industry.

Output per hour of all persons—or labor productivity—is the most commonly used productivity measure. Labor productivity is the ratio of the output of goods and services in dollars to the labor hours devoted to the production of that output. Other productivity metrics such as multifactor productivity relate output to a combination of inputs used in the production of that output, such as labor, capital, energy, and materials. The growth in labor productivity is a particularly important measure of the health of the IT ecosystem since it provides an indication of the real earnings growth accruing to the ecosystem. Figure 6 shows labor productivity in the hardware, semiconductor, and software domains of IT.

The Bureau of Labor Statistics has no available data from 2002 to 2005 at the time of this writing for the industries plotted in figure 6. Still, we can extend the trend with another indicator of software labor productivity: revenue per employee. According to SoftwareMag.com, this metric, as applied to the top 500 companies (by revenue) in the software domain, was at $202,587 for 2001, $156,774 for 2002 and $176,909 for 2003.b

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Viewing the 2001 number in light of the prerecession activity, employee productivity saw an increase of almost 13% from 2002 to 2003.

2. IT RECOVERY AND IMPACT ON U.S. GROSS DOMESTIC PRODUCT The IT sector provides growth in real earnings of the broader U.S. economy by driving productivity gains in other industries. The IT industry also makes a significant direct contribution to U.S. economic growth. This is demonstrated by a measurement of the annual percentage changes in the real value added by various industry groups7 to the U.S. gross domestic product (GDP) (see figure 7). Real value added is the change in contribution of labor and capital to the national (real) GDP (expressed as a percentage). When the change in real value added of a domain exceeds the growth rate of the GDP, that domain is contributing more, and growing faster than, the broader economy as measured by the GDP.

Figure 7

Figure 7 shows the annual growth rates of U.S. GDP and percentage changes in net contribution to the GDP of goods producing industries, services producing industries, and "ICT." ICT stands for information communications technology and includes the following components:

- Computer and electronic products within the durable-goods manufacturing industry group;
- Publishing industries (including software), and information and data processing services within the information group; and
- Computer systems design and related services within the professional and business services group.

The ICT bar shows that the IT industry has increased its contribution to the U.S. GDP to more than three times the other industry groups. In 2004, for instance, goods producing and service producing industries increased their real value added by 3.1% and 5.1%, respectively, whereas the ICT group increased its real value added by 14.7%.

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As measured by growth in labor productivity and contribution to the broader GDP, the productivity of the IT ecosystem is again growing across hardware, software, and services. Growing productivity indicates that the health and competitiveness of the IT ecosystem has improved and will continue to improve in coming years.

C. Innovation and niche creation

Robustness and productivity do not completely capture the health of a business ecosystem. Both in ecological and business literature, it is important that systems also exhibit variety or diversity—that they support many different species or types of organizations. Innovation, or niche creation, is the critical mechanism by which business ecosystems increase diversity over time. This diversity results in new alternatives and choices for the customers that depend on a business ecosystem. In the analysis of innovation that follows, we will first look at broad indicators of innovation across the IT ecosystem, and we will then review specific cases of very rapid innovation in products and business models that have resulted in significant growth and changes in the competitive landscape.

The return on venture capital investment is a good measure of the effectiveness of investment in innovation and niche creation. Venture capital is the primary source of funding for start-up activity in new ecosystem domains. Venture capital investment alone (or the number of new firms created) is not necessarily a good indicator in this context, because we are interested in meaningful, sustainable innovative niches. Return on venture capital investment is a much better indicator of sustainable innovation and niche creation than overall investment levels.

The return on venture capital investment in the IT sector has improved significantly from its low in 2001. Figure 8 shows the internal rate of return for venture capital investments based on the year of formation of the companies receiving investment. (Note that 2004 data, while showing a decline, actually reflects a lack of sufficient elapsed time since the formation of companies to accurately determine rate of return.) Increasing returns in venture capital will attract additional investment dollars and bode well for the future of innovation in the IT ecosystem.
Another leading indicator of the future prospects of innovation is the valuation new firms receive from investors. As returns and investment activity rise in the venture financing markets, valuations received by companies also rise—more dollars chasing the same number of good investment opportunities results in an increase in median valuations. Figure 9 shows that the median value that investors ascribe to companies receiving investments rose by more than 30% from 2003 to 2004. Rising valuations have a cascading positive effect; as entrepreneurs receive higher valuations from investors, more entrepreneurs start companies because of more readily available capital to fund their efforts.

Further evidence of a recovery in venture capital can be found in the growth of availability of new funds for investment. Investments in U.S. venture capital firms, have also risen since 2003 (see figure 10).
Investments in information technology represent the majority of venture capital investment. Over 58% of all venture capital investment flows into IT-related businesses. As a result, new IT firms will likely benefit more than other industries from the depicted backlog of venture capital monies. Within IT investments, software garners a large share of the total investment and thus an examination of new niche development in the software sector may provide valuable insight into the competitiveness of the ecosystem.

In summary, at an aggregate level it appears that venture capital, one important funding source for innovation in the IT ecosystem, is recovering from the retrenchment at the beginning of the decade. As this recovery continues, innovation will produce more valuable offerings and greater choice for IT customers. In the next section we highlight specific case examples of the magnitude of innovation's impact within the IT industry.

IV. RAPID INNOVATION IN THE IT ECOSYSTEM IN 2005

Innovation is a crucial indicator of health in a business ecosystem. The IT industry’s pace of innovation has historically produced very rapid changes in the competitive landscape as new alternatives emerge. In this section we will focus on several ecosystem domains and highlight how innovation has proliferated in recent years. We focus on the time interval since the Consent Decree was entered.

We start by looking at software platforms for Internet content delivery and Web browsing, where innovation from newcomers is changing the competitive landscape in a market where Microsoft Internet Explorer once held greater than 95% share. Next we will review combined hardware, software, and content platforms for music delivery as an illustration of the effect of rapid adoption of information technology on the broader music industry. We will then discuss multimedia players, where intense competition continues. Lastly, we will discuss the convergence of mobile devices that now
incorporate music, cameras, phone capabilities, e-mail, and Web browsing in a variety of hardware form factors. In each case, innovation continues to drive the rapid growth of new product capabilities, business models, and alternatives for consumers.

A. Platform diversity

Earlier in our analysis, we discussed the roles of the operating system platforms from Microsoft (Windows) and Redhat (Linux). In recent years, the IT ecosystem has witnessed the emergence of a variety of competitive, innovative hardware and software platforms, including middleware, such as the Apache Web server, the Firefox Web browser, and "converged" mobile device platforms for mobile wireless applications. These platforms build on the opportunity presented by the Internet to provide new choices for developers building applications and for end consumers.

Before we look at competitive platforms, it is also important to note that innovation is also coming from established platform market leaders. This is significant because this is a sign of a healthy ecosystem. For example, in the PC operating system market, Microsoft is planning to launch the latest version of its operating system, Windows Vista, in 2006. Windows Vista includes innovations for both end users and ISVs.

For end users, Windows Vista focuses on improvements in operating system fundamentals such as security, deployment, manageability and performance. Some of the specific innovations include anti-malware features, network access protection, and an improved user interface. For example, "virtual folders" are a new information search concept that Microsoft is introducing with Windows Vista. A virtual folder is essentially a saved search that is automatically run when a user opens a folder. A user could, for example, create a virtual folder for "stock trades." When opened, the folder would reveal all documents that contain the words "stock trades."

Additionally, with the launch of Windows Vista, Microsoft is also releasing a new application program interface (API) called WinFX. The purpose of WinFX is to make application development easier for ISVs and allow them to tap into the new features of Windows Vista. Past
launches of new operating systems have resulted in significant effects in
the ecosystem, a pattern that should be repeated with Windows Vista.

1. THE GROWTH OF NEW MIDDLEWARE PLATFORMS  The Internet has
seen the emergence of several other Keystone platforms in critical
middleware domains. This diversity has increased the number of
options open to software developers and users alike. Two of the most
important of these platforms, among a diverse array of offerings, are
Apache and Firefox.

(a) Web server platforms: Apache  The Apache HTTP Web server is
one of the earliest open source software developments in Internet
history. Developed by a group of volunteer programmers and based
on the National Center for Supercomputing Applications (NCSA)
Subsequent new versions of Apache maintained by the open source
Apache Foundation now form the most popular Web server. Apache
supports Microsoft’s Windows OS in addition to Linux and all UNIX-
like operating systems. The success of the Apache Web server can be
seen by the dominant proportion of websites that rely on it, as shown
in figure 11.

Figure 11

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Active Websites (Millions)</th>
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<tbody>
<tr>
<td>Jan-01</td>
<td>4</td>
</tr>
<tr>
<td>Jan-02</td>
<td>6</td>
</tr>
<tr>
<td>Jan-03</td>
<td>8</td>
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<tr>
<td>Jan-04</td>
<td>10</td>
</tr>
<tr>
<td>Jan-05</td>
<td>12</td>
</tr>
</tbody>
</table>

- Apache
- Microsoft
- Other

SOURCE: Netcraft Web Server Survey.
One of the purposes of the Consent Decree was to foster opportunities for the growth of middleware platforms. The Apache Web server plays a crucial role in the delivery of the user interface of many new applications that rely on the Internet for their distribution and HTML for their primary user interface. Apache’s sustained success over the past five years, as a platform for the delivery of applications, highlights how innovation has created vibrant competition in a critical platform area of the IT ecosystem.

(b) Web browser platforms: Firefox The Consent Decree also focused on competition in the Web browser domain. In this domain Netscape and AOL have revitalized their offerings. Most importantly, new organizations like Opera and the Mozilla Corporation (Firefox) have made rapid inroads. Today’s browser market comprises many players, both incumbents and newcomers. The new alternatives and revitalized offerings have a very respectable foothold of nearly 16% market share in a market where Microsoft’s Internet Explorer once held 95% of the market.10 Market share here refers to usage share, which is the percentage of visitors using a particular browser to visit a group of Websites.11

Microsoft, Netscape, and AOL have been in the browser market since the middle of the 1990s and have participated in direct and indirect competition for market share ever since. The activity in this category seems to center on product and feature evolution, with all three companies working on releasing newer versions of their browsers with improved emphasis on features such as ease of use, security, and privacy.

Even more striking is the discovery that the majority of the share gains since the Consent Decree have come from newcomers. The Mozilla Corporation, which maintains and releases the open source Firefox browser, and Opera Software are among the most prominent newcomers. Figure 12 shows that Firefox now holds more than a 10% share.

The success of these newcomers in Web browsing is based on innovative features and exemplifies the competitiveness of many

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middleware markets. For example, the Opera Web browser from Opera Software in Norway has been developed for a broad range of hardware including smart phones, personal digital assistants and interactive television. It includes unique competitive features such as voice-activated commands. As a result, Opera has gained significant traction in the mobile computing world—mobile phones using the Opera platform include Nokia's 6600 Smartphone, Sony-Ericsson's P900, and Motorola's A920. Opera has also gained popularity in the U.K. and China mobile computing markets. Innovation has led to

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15 Lucy Sherriff, *Opera and Orange Seek Phone Browsing Perfection*, The Register (Feb. 16, 2005), http://www.theregister.co.uk/2005/02/16/opera_orange_browser.
end user adoption, and Opera’s usage share went from 0.40% in 2002 around the time of the Consent Decree to 1.03% in early 2005.\textsuperscript{16}

Similarly, the adoption of Firefox grows out of its innovative features. Firefox is a cross-platform Web browser released by the open source based Mozilla Corporation. Firefox 1.0 saw 25 million downloads in its first 99 days and 50 million downloads in its first six months.\textsuperscript{17} It has also built a rapid adoption rate, rising in usage share since its release (see figure 13).

Firefox adoption is driven by competitive features prevalent in Netscape’s offerings, while also introducing many new features. For example, by avoiding built-in support for technologies such as Active X, VBScript or Browser Helper Objects (BHOs),\textsuperscript{18} Firefox is often preferred by users who are concerned about security and privacy.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{firefox USAGE SHARE.png}
\caption{Increasing Usage Share (percentage of users viewing a group of sites through the browser) of the Firefox Browser.}
\end{figure}

\textbf{Figure 13}

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Increasing Usage Share (percentage of users viewing a group of sites through the browser) of the Firefox Browser

\begin{footnotesize}
\begin{itemize}
\item\textsuperscript{16} http://www.onestat.com/html/aboutus_pressbox37.html. (Onestat.com provides usage share statistics based on worldwide usage.)
\item\textsuperscript{17} Randall Stross, \textit{The Fox Is in Microsoft’s Henhouse (and Salivating)}, N. Y. Times, Dec. 19, 2004, Sunday Business at 5.
\item\textsuperscript{18} Matthew D. Sarrel, \textit{Firefox 1.0.3}, PC MAG.COM, May 16, 2005, http://www.pcmag.com/article2/0,1759,1815952,00.asp.
\end{itemize}
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perceived as being more secure than Internet Explorer, although Firefox recently suffered a significant security vulnerability.

Innovations of Firefox have also driven end user adoption, for example, its user interface, rendering engine, and RSS (Rich Site Summary, or Really Simple Syndication) reader. Simplicity in the user interface is emphasized by the use of tabbed browsing, thereby reducing the clutter of windowing. Firefox also innovated in its ability to render Websites extremely quickly using rendering capabilities based on the cascading style sheets standard. These features are driving competition with Microsoft, inducing it to introduce Internet Explorer 7 more quickly than initially planned. (Internet Explorer 7 is expected to support tabbed browsing, integrated Web searching, RSS, and anti-phishing technology.)

Beyond driving the pace of new feature introduction for consumers, the successful market penetration of the Firefox browser may enable Firefox to become another Keystone platform for the developers of “add-ins.” Most add-ins target the Internet Explorer platform today because of IE’s large installed base. With add-ins, Firefox effectively becomes a platform alternative for Internet content providers (ICPs). This is another example of how rapidly competition can emerge in the IT ecosystem. In fact, Firefox and alternative Web browsers have become so accepted by mainstream developers, a key domain addressed in the Consent Decree, that those Websites that do not support alternative browsers arelabelled as defective.

2. NEW INTEGRATED PLATFORMS The pattern of competition and innovation found in the software domains of the IT ecosystem is repeated in its hardware domains. Case examples of platforms in music, multimedia, and converged handheld devices show that innovation is driving competition between vendors and rapid adoption of new products by end customers.


(a) **Music platforms: iPod and iTunes** The digital music industry referred to henceforth includes both hardware and software constituents, e.g., MP3 players and music download software. Rapid growth of online music has been at the center of attention in this industry. It has promulgated interesting network effects involving portable music players, peer-to-peer service providers and recording companies. At the forefront of this online music movement were highly publicized companies such as Napster, Kazaa and Audiogalaxy. Technological innovation by these and other companies in the online music domain was met with stiff resistance by the incumbents, but the innovations continued and eventually were embraced by the very same incumbents. Figure 14 provides evidence of the rapid adoption of new music technologies.

The traditional music industry’s turnaround in incorporating the Internet is evident in services such as Sony’s Connect, Universal Music Group’s music downloads through retailers like Best Buy and Circuit City, and the popular Apple iTunes. These are interesting examples of how innovation is thriving and influencing a whole ecosystem of well-established members beyond the IT industry.

*Figure 14*

Internet and Satellite Subscriber Growth in the Music Industry 2002–2005 (est.)

![Graph showing growth in Internet and Satellite subscribers from 2002 to 2005.](image)

*Source: Parks Associates, Industry Reports.*
Apple is an example of a company that has innovated by introducing an alternative business model in music services. Its integrated offering consists of both hardware and software platforms in the form of the iPod device and the iTunes service. Figure 15 shows that since the time of the Consent Decree, the Apple iPod has experienced very rapid growth for a hardware platform.

(b) Multimedia platforms: Real, Media Player, and QuickTime  PC-based multimedia platforms have been a popular addition to the PC users’ experience and a fertile ground for competition. These platforms provide individuals with a method of playing audio and video files on their PCs. The 15 most popular multimedia software platforms have been downloaded more than 1.25 billion times.\textsuperscript{22}

According to Nielsen/NetRatings in 2002, RealNetworks led in penetration of at-home users, 60% of whom have downloaded the Real player to their PCs. RealNetworks was followed by Microsoft's

\footnotesize{\textsuperscript{22}  Keystone Strategy, Inc.}
Windows Media Player at 53% penetration and Apple’s QuickTime at 28% penetration.\textsuperscript{23}

This diversity has encouraged innovation and competition. Apple incorporated MPEG-4 into the version six release of its QuickTime multimedia player. MPEG-4 offers significant advantages over the common MPEG-2 video format. It can deliver similar image quality at half the required bit-rate (required bandwidth) of MPEG-2 streams. According to Philip Schiller, Apple’s Senior Vice President of Worldwide Product Marketing, “QuickTime 6 [took] off like a rocket, with over 25 million downloads in 100 days.”\textsuperscript{24}

Innovation in this area is not limited to improvements in multimedia players alone. Innovations in multimedia content distribution are also occurring. For example, capabilities present in the popular open RSS standard make it possible to distribute multimedia files created in any format. Individuals can easily use RSS both to distribute multimedia (audio and video files) to a wide audience and to subscribe to downloads of these files from multiple sources. Subscribers can time-shift their use of these files and download them to multiple platforms such as the iPod. Within the audio file area, this has led to the development of what is called Podcasting (which takes its name from the ability to download files to an iPod player for time-shifted, mobile usage). Numerous firms have emerged to develop business models around the categorization and distribution of Podcasting feeds. Additionally, Apple has incorporated support for Podcasting into its popular iTunes software.

As a result, the music industry is seeing increased diversity in new and innovative products, services and business models despite resistance from incumbents. The enormous popularity of new alternatives with consumers has resulted in a large number of competitors entering the market behind Apple’s success. This will continue to provide end consumers with new, exciting alternatives.


(c) Multi-purpose platforms: converged mobile devices  Beyond the music and media industries, rapid IT innovation and competition are influencing the telecommunications industry as well. Over the past two years, there has been strong growth in converged mobile devices as a subset of the overall growth of mobile phones. These devices in part replicate the feature functionality of personal digital assistants (PDAs) and personal computers.

A large portion of the mobile phone hardware sold now incorporates features and functionality traditionally delegated to more powerful PCs or PDAs. As shown in figure 16, these converged mobile devices have grown fivefold in unit sales over the two years from 2003 to 2005.

Converged devices offer to mobile users many of the applications once limited to personal computer users. Software applications on converged mobile devices include e-mail access, electronic

Figure 16

entertainment, e-commerce, PDA functionality, and digital photography. To address the growing demand for these devices, a diverse set of software platforms has emerged. These platforms include Symbian, Palm, and Microsoft at the operating system level, with Symbian leading the way as shown in figure 17.

Additionally, a large number of application developers and independent service providers have emerged to supply services to these converged mobile device users via Internet connections. For example, Yahoo’s Flickr allows camera phone users to upload photos to online albums. Subscribers to various wireless data services are growing extremely rapidly, as is shown in figure 18.

The rapid growth of wireless data services and the rapid adoption of alternative hardware platforms are creating many new alternatives for consumers. This rapid rate of innovation and adoption since the retrenchment in 2002, in a completely new domain, provides further evidence of the health and competitiveness of the IT ecosystem.
Figure 18
Wireless Data Subscribers by Application (North America)
2002–2005 (est.)


B. Innovative new business models

Innovation is generally discussed in the context of products or technologies. However, since the Consent Decree, new business models have emerged that have transformed traditional industries such as auctions, financial payments, retail merchandise, advertising, and enterprise software. These new business models have also created completely different solutions for consumers as well as a host of very successful new competitors providing those solutions. To explore this, we discuss the growth of Google and Salesforce.com.

1. GOOGLE: PERFORMANCE-BASED ADVERTISING    Google began with a simple value proposition: to provide relevant online search results. Its success in this goal has led the company to become one of the Internet’s most popular search engines. Today, approximately 46% of all Internet searches are accomplished through Google (see figure 19).

A critical part of Google’s business performance has been the success of its search-based advertising system. This service makes it possible for advertisers to select specific search terms on which to
advertiser. This specificity enables advertisers to reach potential customers that are looking for information and products related to their own offerings in a very targeted and efficient manner. Additionally, Google charges advertisers only when a customer clicks on their advertisement. This performance-based aspect of Google's method is a substantial improvement over impression-based methodologies, where advertisers pay a fee based on the number of times their advertisement is viewed by a customer regardless of whether the customer clicks on the advertisement (impression-based advertising through banners has been increasingly replaced by performance-based methods).

Google is in the process of expanding its performance-based advertising service to other search areas. For example, the launch of Google Maps in 2005 will increasingly allow the company to extend performance-based advertising to local businesses and travel-related businesses, such as airlines and hotels. Google Maps provides the company with a way to tap into the multibillion dollar yellow pages market. To enhance the attractiveness of Google Maps, Google has added satellite views and opened the software as a service to modifications and enhancements by individuals and partners.
The cumulative result of these rapid, sustainable, and successful innovations at Google has been robust revenue and profit growth (see figure 20). The successful adoption of Google’s suite of services highlights the growing importance of software companies delivering services such as search-over-the-Internet as an alternative to traditional packaged software. As a result of Google’s extremely profitable business model, it is a very credible contender for delivering novel solutions in many software application areas in the future.

2. SALESFORCE.COM: CORPORATE APPLICATIONS AS A SERVICE
Salesforce.com provides another example in which innovation in business model using the Internet has changed the competitive landscape of software vendors and increased the accessibility of software technologies to end customers. While Salesforce.com provides Customer Relationship Management (CRM) software, its software-as-a-service model is based on providing outsourced customer data storage and software management to clients. Task automation, analysis tools, and sales lead management are just some of the hosted services Salesforce.com offers.
Since its inception in 1999, Salesforce.com has provided various versions of its software and services to large and small organizations worldwide. Salesforce.com has expanded from a simple application to an entire Web platform, now enabling customization and collaboration between clients and customers.

Salesforce.com has effectively leveraged the ubiquity of the Internet and declining network bandwidth prices to make a business out of selling software as an online service. Its innovation lies in the fact that many of an organization's routine procedures need not in fact be developed and maintained in-house. As such, Salesforce.com found a business opportunity to provide these as services in a more cost effective, on-demand manner (see figure 21).

Salesforce.com's business innovation provides customers with an alternative to purchasing more traditional software applications that run on in-house servers and personal computers. This innovation extends the availability of business software applications to more customers because the complexity of these applications might otherwise exceed the management capabilities of smaller businesses.

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**Figure 21**
Salesforce.com Annual Revenue and Net Income 2001–2005

Salesforce.com thus provides another example of innovation resulting in greater value for customers and increased competition with the IT ecosystem.

In summary, there has been very substantial innovation across a diverse set of market segments in both products, such as Web browsers, music hardware and software, multimedia players, and converged mobile computing devices, and business models, such as those of Google and Salesforce.com. These trends illustrate how the IT ecosystem, since the entry of the Consent Decree, is witnessing extensive experimentation and innovation. New business models incorporating the advantages of selling software as a service are gaining particular prominence, which is redirecting the focus of competition away from client applications toward Internet-based applications. Additionally, there has also been continued innovation from established market leaders. All of these factors indicate a robust IT ecosystem.

V. CONCLUSION

This paper has introduced a framework for analyzing the health of a complex business ecosystem. The analysis was carried out for the IT ecosystem, which in mid-2005 showed positive signs of health.

After the events of 2001 and 2002, we see signs of recovery across the sector. The ecosystem appears robust, with overall levels of firm value and growth prospects improving across the board. The ecosystem is regaining in productivity, not just in the hardware domains, but also across software specialties. Perhaps most critically, the ecosystem is showing strong signs of innovation, with a recovery in the levels of and returns to venture capital investment.

When we look more deeply at the domains that were the subject of the 2002 Consent Decree, we see these overall trends illustrated by numerous examples of increased competitiveness, innovation, and business model evolution. We see new software platforms such as Linux, Apache, and Firefox enjoying strong growth and adoption, and new device platforms in areas such as music and converged wireless products being offered by a diverse set of competitors. We
also see innovation in business models from a new generation of Internet content and service providers, including Google and Salesforce.com.

The resilience of the IT ecosystem and its impressive level of innovation is a function of the large diversity of organizations that populate it and of the platforms that connect these to each other and improve the performance of the whole. New and old application providers are continuing to rely on the ecosystem's top platforms as a foundation, offered by companies like Microsoft, Red Hat, and Apple. Tens of thousands of companies and millions of developers are benefiting from new platform functionality. The tools and technological components offered by these Keystones are thus a critical ingredient in the innovative efforts of the broad community of companies in the ecosystem, ranging from Google to small start-ups founded this year, and should be safeguarded and preserved by antitrust actions and policy.

In conclusion, the ecosystem appears to be working well and recovering from the financial excesses of the late 1990s. The particular domains targeted by the 2002 Consent Decree have shown strong levels of innovativeness and growth, with new competitors repeatedly challenging the more established companies, and the more established companies continuing to innovate and introduce new products. Software and hardware platforms are witnessing significant innovation and evolution, which is in turn fueling innovation in a broad variety of applications and business models.