Knowledge Creation and Temporality in the Information Economy

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ABSTRACT

The linkage between knowledge creation and the time dimension has been little understood. The advent of the computer and data communication networks has accelerated knowledge creation, but with this has come a more rapid obsolescence in the things that objectify this knowledge. This acceleration of these twin processes of knowledge creation and obsolescence are illustrated by examples from the producer goods, personal computer, and Internet software industries. Moreover, the recent growth of the Internet seems to have added an extra push to this acceleration. We conclude that these temporal dynamics appeared most blatantly in the information industries, but now are affecting and infecting even formerly stable, slow-moving industries.

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Information processing and knowledge creation are critical activities for firms in any historical period. Firms must constantly create new knowledge and integrate it into their production, distribution, and marketing activities in a timely fashion. The advent of the computer and the ability to represent and communicate reality in digital form is creating new tools and objects for human creativity, while also accelerating the pace of change. The power of information processing and the possibilities it opens for rethinking traditional methods of doing business is sweeping formerly comfortably protected industries and firms in slowly evolving markets into an environment of accelerated change. Competitive advantage is being built on the ability to constantly collect new information and process it meaningfully, i.e., to digest it and create new knowledge. This new knowledge must then be transmitted throughout the firm (Imai et al 1985; Nonaka and Takeuchi 1995; Leonard-Barton 1995). The increasing role of knowledge creation combined with the dramatically growing power of information processing has overturned the traditional temporal dynamics of product innovation and introduction.

In response firms are restructuring operations to accelerate their ability to create new knowledge and embody it in new products. Each acceleration becomes generalized, because of the nature of competition, and this further accelerates the tendency. This is having profound effects on the economy leading to shorter product development cycles and the acceleration of new product introductions. The interaction between accelerating information processing and knowledge creation is no longer a novelty limited to high-technology industries, rather it is becoming the norm. The side effect of this process is that the market value of products, i.e., the embodied outcome of the knowledge creation process, is increasingly transient and the commercial life span of products is declining (Curry 1997).

Another aspect of the growing importance of the embodied knowledge is that the actual value of the purely physical constituents drops. Products are "dematerializing," as the physical materials embodied in products shrink in importance. This is most apparent in the electronics-related industries, such as personal computers, software, and data communications, but is true in a significant number of industries (Moschella 1996). Where, in the same way as power machinery in the Industrial Revolution earlier freed humans from the limits of their physical bodies, thereby enlarging the scale and scope of material production, information processing power frees the human mind from routine calculations and allows the application of calculative force to far larger problems. The result is that humans can be more active in the knowledge-based portion of the production process.[1]

Our aim is to outline some impacts these developments are having on contemporary business. The first section discusses how the main impact of knowledge and information intensiveness on the contemporary dynamics are manifested in an overall increase in the rate of change. The second section describes the impact of the changing temporal dynamics on the producers' goods industry, a critical sector because of its central role in manufacturing. The third section on the supercharged pace of change in

[1]This is not meant to say that humans need no longer be concerned with matter. As material beings, we must continue to work with the material, but it is our minds working through our hands that is the critical feature. When the mind is no longer working through the hands, i.e., mindless labor, the work is suitable for machines. For a further

the personal computer (PC) industry perhaps best illustrates the impacts of the knowledge revolution on manufacturing industries. Because of the modular nature of the PC, we can clearly explain the reason for very different rates of change in different components of a single product. The fourth section considers the quintessential knowledge creation industry, computer software. The fifth section considers the impact of the Internet on the diffusion of knowledge and information intensity to a broader field than the traditional boundaries of the firm. The concluding section discusses the implications of the increasing centrality of knowledge creation and the temporal dynamics of firms.

Knowledge Creation and the Acceleration of Change

To understand the acceleration of change, it is necessary to recognize that a products have an intellectual component and a physical component. This analytical separation permits us to think about where value is added. In the contemporary economy the relative balance between the physical value-added and the intellectual value-added is shifting inexorably toward the intellectual. Many of the fastest growing firms, such as Microsoft, Intel, Oracle, Netscape, and Cisco, are so profitable and fast-changing because their businesses are based much more upon the knowledge-intensity of their products than upon the physical content of their products. The "goods" these companies produce are largely dematerialized, in the sense, that the value of the material component is relatively minor compared to the value attributable to the knowledge embedded in the product. Now, product change can come in the knowledge components, many of which are “soft” and easily accessible (on different types of knowledge see Garud 1997).

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discussion of this see, Kenney 1996.

The physical artifact, the semiconductor, illustrates the importance of knowledge and the accelerated temporal dynamic. A semiconductor sold in 1997 will, in three years, have lost more than 50 percent of its value. Many of today's generation of semiconductors will no longer be available in the year 2001, having been replaced by improved products with much greater functionality. The speed of new product introduction means that the market demand for a particular semiconductor model is extremely transient (for an excellent discussion of this see Hutcheson and Hutcheson 1996). According to an article in Electronic News (1996: 1), "The life span of an IC made by a big player is short. There's only about 18 months to four years while a firm like Motorola ramps up production, places a circuit in a system and manufactures the circuit at volumes high enough to keep it profitable." After four years the market value of the knowledge congealed in the semiconductor had decreased dramatically. This is because a semiconductor's value is almost entirely determined by the knowledge embedded in it, both in the form of its design and the width of its circuits, i.e., its manufacture. The semiconductor rapidly becomes worthless, even though it retains full functionality and its physical attributes are the same as its replacement.

In the last two decades of the 20th Century the fastest growing industrial sectors have been the ones in which knowledge creation is most central. The Fordist period in which consumer durables manufacturing was the leading sector is giving way to an era in which the crucial economic sectors are those based upon the creation, manipulation, and transmission of information in digital form. The contrast with the key products of earlier periods could not be more striking. For example, when purchasing an automobile its physical function of transporting you is of great interest, i.e., you expect it to convey you somewhere, safely and reliably. In the case of computer software, you expect it to manipulate symbols in a virtual spreadsheet (not a physical spreadsheet), a virtual document, a virtual game, or to order a device to perform functions such as printing. Software, though requiring physical devices to operate is a separate product from those devices and as such software is a dephysicalized representation of mental effort. It is necessary to be careful with this line of reasoning because software only operates the physical machine for which it was specially designed.

The software program, the integrated circuit, or the car are the concretizations of the knowledge that human beings have developed. As concretizations, they now are removed from the knowledge creation process, so they are now stationary. When the process of change was slow this was not very significant. New developments had little impact upon existing products. However, when knowledge is being created quickly and the product is highly dematerialized, old products become obsolete very quickly.

Change in Traditional Industries

Until the last fifteen years most manufacturing firms experienced gradual change to which it was relatively easy to adjust. Change was limited to the annual model changes that usually were minor appearance changes or a slight upgrading of mechanical parts. In the last fifteen years a change that had been gestating longer finally became manifest and has contributed to a fundamental change in their locus of value creation in there industries. No longer is value largely embedded in the physical component of traditional products, increasingly the software and semiconductors had become the locus of the value-added. So, for example, in 1997 the typical automobile depends on computers, microprocessors, and embedded software to stop (ABS brakes), to control combustion and timing, to deploy airbags, and for numerous other duties. As a result, an increasing amount of the autos' total value is contained in its electronics. The capabilities of these "intelligent" components allows a transcendence of the physical limitations imposed by mechanical gears, belts, and pulleys and far more complex operations are now possible and the number of physical components also has dropped. The automobile is only an example of the increased integration of these knowledge-rich components into nearly every artifact. The increased use of electronics both in the car and in the car design and manufacturing process offers opportunities to speed the rate of evolution of the entire artifact. The acceleration is then reflected in the source of the products value-added, as the software and integrated circuitry components become an ever-larger portion of the total value.

The current situation in the machine tool industry is illustrative. Formerly, machine tools had life expectancies measured in decades and were durable assets. Thirty years ago, machine tools were freestanding and used little or no electronics; their capabilities were embedded in metal jigs, gears, pulleys, and the skills of their operators. At the time the knowledge embedded in the machines increased at a rather slow rate. The difference between a typical lathe in 1890 and 1950 was not great. The most significant difference was that the more recent machine had an electric motor, which allowed the spindle to rotate more quickly, and used better metals for cutting.

The application of electronics to machine tools would have a dramatic impact. Microcontrollers allowed programming that permitted the extremely rapid processing of information collected by various sensors. As a result, the tool could react quickly to environmental changes – no longer was the tool limited by the human operator. Though the machine tool industry has not yet reached speed of change prevalent in the personal computer and software industries, the machine tool industry is experiencing a pervasive acceleration. The ubiquity of distributed computing power in the form of microprocessors has transformed the machining industry into an extension of the computer and software industries (Yamazaki 1995).

Microprocessors and software are ever more significant value-added components of a machine tool. For example, at Mori Seiki, one of the largest machine tool builders in the world, the value of the software and electronics in the machines increased from 20 percent of the total value in the 1980s to 30 percent in 1997 and is continuing to increase (Mori 1996). The important point here is that the software and the computer controller are the most knowledge-intensive components of a machine tool (for a discussion of knowledge in the more physical components see Kenney 1996).

The automation of machine tool operations produces enormous amounts of electronic data, which can be used in a knowledge creation process. There are opportunities for on-line computer monitoring and the fine tuning of production processes to previously unattainable levels (Zuboff 1988). In this sense, computer-controlled machine tools have two outputs: the work piece and electronic data. The data output can be analyzed locally or transmitted to anywhere in the world. To exploit this aspect of the information technologies, the Japanese machine tool builder, Mori Seiki developed a system, which communicated information from the user's machine to a computer at Mori Seiki's Technical Center for problem diagnosis or to user-designated sites for remote machine control. This means that the most knowledgeable people in the world, the tool's producers and designers, can participate in troubleshooting. Moreover, such information exchanges can make user-designer information exchanges even more intimate and immediate. There is the potential to go even further, for example, upgraded software could be downloaded to the user's machine from anywhere, even third party vendors.

Even while the merger of production machinery with the information processing ability of computers and especially microprocessors is making them more flexible and capable, it is also having another impact. The ability to program machines permits a more rapid improvement in machine performance than was possible when improvements were based on redesigning only the physical features of the machine. This means that newer models having significantly more functionality are being introduced more quickly, as the increased capability is largely embedded in the integrated circuitry and software. John McDermott, vice president of Rockwell Automation's Standard Drive Business, described the changes in the industrial motor starter business, which until the recent application of semiconductors had changed only very slowly for nearly 100 years:

> As the technology changes faster, the life cycle of our products drops . . . Both features and costs are impacted so greatly by technology that if you don't have a new product within four years, you're not competitive . . . If you have a three-year development window and four-year product life cycle, you're in tough shape (Bassack 1996: 30).

Rapid change is not confined to the traditional machining industries. For example, printed circuit board (PCB) component insertion machines can insert 300 components per minute or five components per second. The insertion head is merely a blur as it inserts components fed from a tape reel. The rapidity of improvement in insertion machines and the shrinking size of the components means that the machines also rapidly lose value (Kawai 1992). Therefore designers must constantly develop new and improved models.

The quickening tempo is highlighting the importance of time. For example, Douglas Elder, the Singapore-based managing director of Asia operations for the US semiconductor test equipment maker Teradyne, commented that price and quality were no longer the only sales features in the electronics industry, rather "the differentiating value is now cycle time . . . Many sales are now made on the basis of how soon the product can be delivered" (Bordenaro 1996). In purchasing decisions price is becoming a function of time. Late delivery, late development, or late to market are synonymous with failure.

Production equipment loses market value quickly and simultaneously as factories become more automated there is more capital at risk. Profits must be made before the equipment is superseded by a dramatically superior machine. This gives real meaning to the term "speed-based" competition. The introduction of electronics makes machines more productive, but simultaneously, because it helps accelerate technological change, the machine's productive life decreases making it a wasting asset. In many fields, the factory comes under increased pressure to operate constantly, because physical depreciation no longer bears any relationship to obsolescence.

In periods of slower change, depreciation and obsolescence had a relatively tight linkage, simplifying management decision-making about timing the replacement of capital goods. Now, the previous stable linkage is broken and intensifying competition forces all companies to accelerate the introduction of new capital equipment.

Vertical integration is precarious, even the most powerful firms experience significant losses when they misjudge the pace of change. For companies in the fastest changing industries, subcontracting activities, such as production, are ever more attractive as change and obsolescence combine to make the purchase of production equipment more risky. The business press is replete with examples of large companies writing down losses because of sourcing and inventory miscalculations. The result is managers in even the traditional industries are forced to actively manage time. Moreover, the greater pressure in the productive sphere is matched by an environment in which markets often emerge and either disappear or experience explosive growth over very short periods.

Personal Computers

The personal computer industry is a fascinating example because the strategies PC firms pursue are inherently related both to the opportunities and the difficulties brought about by extremely rapid change.[2] An important reason that the PC changes so rapidly is that it is a highly modular system in which various producers devote their efforts to continually improving their particular component (Langlois 1992). Due to this modularity it is possible to see quite plainly the components that are rapidly changing and those that are less rapidly evolving. The components that have changed the least, such as the case, the mouse, and the keyboard have also experienced minimal price erosion.

[2]The personal computer is the quintessential product of the Information Age. The power of the PC is its neutrality--it can host many different functions. The PC can be an entertainment vehicle, a controller for machine tools, an information storage device, a switchboard router, a television receiver, a word processor, a spreadsheet, a telecommunications device and/or a database manager. It is not imprinted in necessarily deterministic ways. It is a universal receptacle, into which human creativity can pour the

They are also the ones in which there is also tremendous price competition, and little value-added or profit. Finally, in these sectors there is little new knowledge being created.

The various components that make up a PC can be mixed and matched in an enormous variety of technical or brand combinations. The result is that the PC's evolution is driven by change in each of its major components, memory, microprocessor, and storage. Each of these is evolving extremely rapidly. Moreover, as one component improves it quickly pressures other components to change, thereby feeding a constantly reinforcing cycle of improvement (Hughes 1983).

Rapid component innovation and permits the capture of rents by firms producing leading-edge key components, especially when they have some proprietary advantage. An illustration of firm response to speed of adoption problems is Intel. Intel's strategy has been to innovate as rapidly as possible, largely through simultaneous development of several microprocessor generations (Grove 1996), while trying to maintain its control of the microprocessor standard. Intel’s marketing approach is similar to Microsoft and involves large-scale consumer mass marketing campaigns and strategies designed to accelerate adoption of technology updates by the PC systems and component producers. Intel's current strategy is a response to slow adoption of its 486 and Pentium chips, both by end-consumers and the systems production and marketing channels. Just as consumers exhibited the tendency to question whether they really needed to buy the latest Intel processor, many components and systems producers were reluctant to undertake the expense involved in shifting production to the newest chip as quickly as Intel wanted,

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software concretizations of various ideas.

especially since sales of products based on the previous generation were still strong. Slow adoption is a problem for Intel, because of the constant tendency for price to erode due to the entry of competitors that do not need to innovate – they need merely reproduce Intel's specifications.

One strategy has been to enter mainboard production as a way to push its newest chips to market. The objective is to force other mainboard manufacturers to adopt the newest chips. This meant Intel could introduce mainboards with its newest chips ensuring that the other mainboard manufacturers would also have to introduce Intel's most advanced microprocessor to remain rather competitive. This also allowed Intel to actively develop and promote system design standards (like the PCI bus) optimized for Intel's microprocessors. Moreover, large-scale investment in mass production capacity enables Intel to expand their market and regularly lower prices to deter competition. Intel's efforts in this direction have been quite successful; the 80486 processor, first released in 1989, took 4 1/2 years to reach 25 percent market share. It took only 1 1/2 years for Intel's Pentium processor, released in March of 1993, to reach 25 percent market share (Thryft 1995).

Rapid price decreases are driven by the change characteristics of information intensive industries. The environment of constant price declines creates a situation in which rapid throughput all phases of production – design, component sourcing, assembly, and distribution--is necessary for firm survival, especially for firms operating on the thin profit margins which are the norm for most parts of the PC value chain.

The industrial structure and spatial location of production has adapted to these torrid rates of change. The constantly dropping value of components production/

distribution logistics demands that elapsed times be compressed as much as possible. The emerging global system means that final PC assembly is geographically dispersed so that the final product can be brought to market much more quickly and changes in configuration can be made both in response to changes in components, and prices and local demand. Sourcing decisions for components vary; less perishable components can be purchased from inexpensive and possibly distant sources, while those experiencing severe price erosion such as microprocessors, DRAMs, and hard disk drives are purchased from sources in close proximity that can deliver quickly. For example, Acer Computer, the largest Taiwan-based PC manufacturer, describes its system as a fast-food franchise operation where the goal is to get the freshest technology into the hands of the consumer as quickly as possible (Shih 1996). Or, put differently, Acer cannot afford to let its components rot on the shelf.

The economies of time dramatically affect locational imperatives for firms in the PC industry. Michael Dell described the situation his company faces:

> The equipment to build the machines is relatively indiscriminant. It doesn't care where it sits and time to market is really important. Labor is not a really important factor in the production of motherboards, particularly in high-end machines. If you're talking about low-end machines, which we don't participate in, you might have to build them in Taiwan to get the cost ratio. But then you have the question of, if you put it on a boat for 30 days and have the devaluation of materials, it's going to be much worse than if you built it close to the market (Dell 1996).

Direct marketing (mail order) producers such as Dell Computer and Gateway 2000 have some of the highest profit margins on sales largely because their quasi-custom production process gives them a very rapid component turnover. Moreover, the customer pays for the computer at time of order, while delivery is two to four weeks later, by which time the most expensive components have already lost up to and perhaps more than 5 percent of their value.

The rapidity of change and the corresponding devaluation of their product mean that the transience of value has become a central concern for PC industry managers. This acceleration of change is illustrated by the fact that the average life of a PC model is approximately three months after which its price is dramatically reduced to remove it from the retailer's inventory. Compaq Computer, which overtook IBM as the leading PC company in the late 1980s when it beat IBM on the transition to the Intel 386 microprocessor, in 1997 announced its intention to shift its production for corporate customers to a built-to-order approach similar to the direct marketers (Ramstad 1997). In the case of Compaq being the first to market a new chip is no longer sufficient, as Dell found a new way to manage time.

The PC industry is the quintessential example of a product that is enmeshed in an almost incessant flood of changes. While some critical components, such as memory, CPU and hard disk drive are evolving at breakneck speed, others such as the highly physical computer display monitor is far more stable price-wise. This may be changing as relatively slowly evolving desktop monitors, based on vacuum tube technology, are being replaced by the flat panel displays, based on silicon, currently found in notebook computers. Price are dropping much more quickly for flat panels than for tubes. Thus, a formerly more slowly evolving PC component, the display, is being drawn into the more rapid pace of other components.

The extreme pace of change in PCs is not purely technology driven. For both leaders and challengers technological improvement provides the ultimate weapon in their competitive struggles, that is, they compete on the speed of change. The core of firm strategies has been to innovate as rapidly as possible, largely through simultaneous development of several generations.

Both component firms and PC assemblers deliberately accelerate the pace of change, in the hopes that competitors cannot maintain the pace. In effect, all the firms are trying to manage time in this whirlwind of change. Even seemingly secure monopolies such as Microsoft and Intel are vulnerable to the pace and, even more, vulnerable when the consumer does not keep up the pace. Some companies are now advocating the network computer as a response to the complication of the current PC. It is hoped that it can provide a way to deliver constant software upgrades. It might dramatically decrease the need for Microsoft's operating systems and Intel's microprocessors. The speed of change in the network computer model would be removed from the desktop and be concentrated at the host.

The personal computer illustrates the speed of change in one of the central products of the new economy. The accelerated change is concentrated in the components that are the most technology and engineering intensive. Moreover, these are also the components that become obsolete and need to be replaced when a new machine is purchased.

Speed and Software

Software is a particularly interesting product, because of its dephysicalized nature. This means that it is relatively easy to change even though there are concrete concerns that changes in one part of the program do not clash with those in another part of the program. In other words with software you can change the program without having to design an entirely new computer, i.e., the material component. With the physical aspect removed from a product, it is possible to dramatically speed-up new product development.

Software is, in the physical sense, an unusual product in that it experiences no wear. Most other products, recorded music and books, are "used up" very slowly. In contrast, software should operate forever -- but its value is time sensitive. This contrasts with machines that have a discrete life expectancy in the sense of how many production cycles can be performed before they wear out. In other words, a machine has physical constraints. In contrast, software has virtually none. Software, therefore, is timeless. However, in the marketplace it has only a short life-expectancy before it is replaced by an upgrade with greater functionality, or at least improvements and new features.

With no physical constraints except the specifications for the machine on which it operates, software can be rewritten quickly. This allows for an astonishing speed of change. For example, Microsoft operates on a one-year cycle for minor upgrades and a two-year cycle for major feature and architectural changes. Moreover, the entire operating systems is scheduled for major changes on a three to four-year cycle (Cusumano and Selby 1995:191). Even faster is semiconductor design software, which is usually on a six-month major upgrade cycle.

The unit price of software applications has also decreased dramatically – while simultaneously the production cost, devoted mostly to labor, has increased as a function of the ever increasing size of many software programs. For example, word processing was first available in the 1970s as part of a dedicated system of software and hardware at a cost of about $7,000 to $10,000 per machine. The actual processing was done by a mainframe or minicomputer that cost in excess of $100,000. In the mid 1980s a superior word processing system was available for approximately $500 on a PC costing approximately $5,000. In the late 1990s word processing was included in a suite of productivity applications priced anywhere from about $100 to $250 and operating on a personal computer costing approximately $1,000. One observer believes the next step is that "the word processor is likely to become a feature in the operating system with almost no explicit economic value" (Macnamee 1996: 76).

While costs have decreased, the size of most software programs has increased dramatically. The original DOS operating system fit on one 365 kilobyte floppy disk. Windows 95, in contrast, requires 16 high-density (1.2 megabyte) floppy disks. According to David N. Cutler, the manager responsible for building Windows NT, the program is so large and complex (six million lines of code) that "no one mind can comprehend it all" (quoted in Zachary 1994:3). Part of this is due to the tendency to integrate previously separate functions into the operating system, but it is also the result of increased functionality, robustness (less tendency to crash), more complex code, and, very importantly, backward compatibility to previous versions. In standard applications software such as word processing and spreadsheets, technical gains seem to come at ever greater cost. For example, for the most recent version of Microsoft Word hundreds of employees fanned out to watch the way people use word processing programs and used this information to create greater functionality in the upgrade. In other words, ever more resources need to be invested to achieve marginal gains.

In software the physical aspect has been reduced to a minimum and may even be reduced further, if, as is likely, software delivery over the Internet becomes more common. It may no longer be necessary to purchase a CD ROM (the physical embodiment or earner of the software) in a store; the software could be downloaded directly from the Internet. Much software is already distributed by Internet; the problem is not the technology of delivery, but rather securing payment. This is one goal of the current impetus to develop an information appliance, or as it is now termed, the network computer. Instead of an appliance dedicated to a single function such as a toaster connected to a power delivery network, the information appliance would be connected to an information and software delivery network. The office user or home consumer can then be linked directly to the accelerated change so prevalent in the electronics industry. Software upgrades need only be placed on centralized host computers, and thus upgrading would become a routine process invisible to most direct users. Moreover, software licensing could be done on an incremental basis, with the user paying only for the specific components actually used.

Direct distribution of software would also help overcome the software industry's own speed of adoption problem. Like Intel and other hardware innovators, software producers like Microsoft must also overcome consumer resistance to updated technology. There is no inherent logic, outside of relatively minor compatibility issues, which necessarily dictates the shift to a new software version. Take the migration from Windows 3.1 to Windows 95 for example. For many applications, Windows 3.1 is still a perfectly adequate operating system. Moreover, if users do not adopt the newest OS, they are unlikely to purchase the new applications.

Software is one of the critical products of the information society. It never deteriorates from usage and yet has a short useful life. Moreover, it is entirely a creation of the mind. It has almost no manufacturing or reproduction costs and can be changed quickly.

The Internet, Knowledge, and Speed

The Internet forms the core of a significant new economic space in the continuing movement of the global economy from a physical basis to a knowledge creation and information processing basis. It is simultaneously contributing to an important new acceleration in the pace of change in the information industries. The vast mass of information, images, and opinions on the Internet is accessible to any computer owner with even a relatively low-cost connection. It is an interactive communication medium through which the user can freely "travel." By accessing the Internet, information, which would have taken much time and physical travel to find, is now almost instantly available. Much of these materials are not for sale, they are provided for free. As only one example, many major companies put their press releases directly onto their Internet servers so that anyone can access them. This allows an interested individual with a computer to have access nearly simultaneously with professional analysts.

Given the relative immaturity of the Internet, it is hard to draw any firm conclusions about its future, but some tentative observations are possible. Even though no one can be sure what the system will look like when it is mature, businesses such as stock trading, bookstores, airlines, and PC firms have already gone on-line. Virtual stores are being created with virtual inventories far larger than any physically existing store and in which a customer can rapidly pinpoint the exact product desired by using specially tailored database query software. These products are drop-shipped from their production point anywhere in the world using the various courier services that are now also on-line to provide customers with constantly updated information about their shipments. The Internet eases many market entry barriers because of the minimal startup costs. This dramatically accelerates the realization of an idea and allows successful ventures to grow exponentially.

The dematerialization that the Internet represents is extremely powerful. It is no longer necessary to disseminate information in the physical medium of paper, floppy disks, or CDs. It can now be communicated through electronic impulses and/or beams of light (fiber optics). This availability accelerates information flow and communication that can facilitate new knowledge creation.

In keeping with this acceleration Internet software firms have developed a new business model. The companies with the most used Internet software, Netscape (Navigator) and Microsoft (Explorer) initially provided their software free to users in an effort to capture market and "mind" share (Lewis 1996: 70). The "search engine" companies, such as Yahoo!, Lycos, and DEC's Alta Vista also provide free access to their software and databases. Companies give software away, because of the need to quickly establish a market presence, capture market share, and create demand for their other higher-value products such as upgrades, extensions, and add-ons. If a free software product becomes a standard or is popular the free users can become customers for forthcoming upgrades or spin-off products. This business model is possible because as the chairman and founder of Netscape, Jim Clark (1995: 70) said:

The Internet is low cost. We proved that by using the Internet to distribute our first product, and we were able to build a customer base of 10 million users in just about nine months. Our only expense was the engineering cost of making the program . . . So we see this potential for low cost distribution of any kind of intellectual property -- whether software, or pictures, or movies, or compact disks, or anything that can be represented as bits.

Once again, the product is dematerialized therefore, distribution costs drop dramatically in inverse proportion to the speed and ease of distribution. John McAfee, a producer of antiviral software, is one of the pioneers of distributing software gratis over the Internet. McAfee has said "If you give software away and assist people as well, you're almost bound to make money" (Leon 1997). After McAfee's companies get five million users, they then shift their marketing mode and start charging for upgrades, add-ons, and new updates. Since computers and networks are constantly evolving, the customers actually evolve with the software in the form of upgrades. The tempo of the users merges with that of the software developers. This occurs because the software soon becomes obsolete. The market created by this model can be enormous. In the case of McAfee's antiviral product, the venture capital firm Summit Partners invested $5 million in his first company, an investment that eventually earned them $100 million. The Internet gives companies, such as Netscape, a route to users that circumvents more expensive paths.

In some cases, consumers actually participate in the knowledge creation process by using a new product and communicating the results back to the company. Netscape and other companies can pre-release unfinished versions of their software over the Internet, giving consumers the opportunity to become a "beta" testers, finding and reporting bugs and commenting on changes and new features. This diminishes some of the burdens of in-house testing and decreases the distance between software creators the leading customers. This creates a new information feedback loop. Moreover, integrating a subset of customers directly into the product development process not only speeds the testing process, but also accelerates the creation of a market for the finished product.

Given this ecology, product evolution in Internet software is extremely rapid (Hafner and Lyon 1996; Reid 1997). The leading personal computer software company, Microsoft, only saw the potential and danger of the Internet in early 1994, though after that it moved very quickly to exploit the new opportunity and overtake the leader, Netscape. Microsoft's strategy was to rapidly improve its Internet browser and give it away – an excellent method of gaining market share. By the end of 1997, Microsoft was rapidly taking market share from Netscape and a "browser war" raged.

What is most interesting is that the Internet economic space opened so quickly and provided so many possibly transformative opportunities. Previously stable and even stagnant activities such as book selling, travel agency, and telephone ticketing were threatened with change. Airlines have established websites allowing customers to reserve flights and purchase tickets. The cost of selling a hairline ticket through the Internet costs only one dollar, whereas telephone ticketing costs eight dollars per ticket. These are compelling economics for an airline. Similar economics prevail for a wide variety of products and this threatens the role of intermediary distributors. Newspapers may be the next frontier for transformation by the Internet as various entertainment oriented "lifestyle guides," such as Microsoft's Sidewalk sites, move into market space dominated by local newspapers. Once these operations become well established there is fear among newspaper publishers that they will then begin publishing classified advertising, an area which lends itself well to the database information management capabilities of computers, and one that is a crucial source of advertising revenue for newspapers (Hickey 1997). This could effect the temporal dynamics casual buying and selling in that ads could be posted the moment they're received, a sale could be negociated in real time or through e-mail, and the ad could be removed once the item is sold, eliminating unecessary responses to defunct ads.

It is still quite early in the development of the Internet and related data communications, so the possibilities of new medium are only beginning to be explored. Old activities such as making phone calls, sending mail, and ordering goods and services are already migrating to this nearly instantaneous environment. And, as important, for this paper, many activities formerly relatively sedate industries are now being accelerated to computer and Internet time. By using the Internet local businesses can go global and experience dramatic growth or local businesses can be outflanked by competitors from anywhere on earth and expensive rapid decline.

Discussion

This essay has reflected upon the interaction between the increased emphasis on knowledge-creation in organizations, information processing, and temporal acceleration. The removal of routine mental activity such as arithmetic calculation from human beings and its transfer to computers will be seen as of equal significance as the removal of the tool from the workers hand and its transference to the machine in the First Industrial Revolution. This freed the human mind for involvement in higher order creative tasks. Rather than devaluing the productions of the human mind, it appears that value in the twenty-first century will become even more dependent upon the creations of the human mind mediated by computers and data communication and processing.

As knowledge creation became a focal point of our thinking about economic activity, managers faced an environment with two attributes: increased emphasis on knowledge creation and a transience of existing products and knowledge. The acceleration of new knowledge creation sped up the devaluation of the concrete results of knowledge creation, the products. In electronics and computer networking knowledge creation was rapid and the pace of change was dramatic. For managers understanding and operating at the industry's speed will be the difference between success and extremely rapid failure.

In even the most material-intensive industries, the pace of change accelerated. In the high-technology fields, even industry leaders such as Intel and Microsoft have every reason to be paranoid as the pace of change engulfs all firms (Grove 1996). Stable industries will be destabilized by changes often coming from outside their current business areas and often by firms used to a more rapid pace of change. Creating new mental models for thinking about how their firm must change is being recognized as the most important management task. In other words managing knowledge will become even more critical.

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