**Title**

# Tools for Thought: What is New and Important about the "E-conomy"?



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## What is New and Important about the "E-conomy"

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# Contents

# EXECUTIVE SUMMARY

There are eras when advancing technology and changing business organizations transform economies and societies. Such episodes do not just amplify productivity in one leading sector. Instead they give all economic sectors powerful new "tools." Today we are living through such a shift in our economic landscape, a shift that warrants a new name: the "E-conomy." Information technologies, data communication and data processing technologies, are tools to manipulate, organize, transmit, and store information in digital form. They are tools for thought that amplify brainpower in the way the technologies of the Industrial Revolution amplified muscle power.

The story of the revolution in information technology is at once a story of technology and a story of innovations in business organization and practice. The two stories are yoked together; they pull forward together. The technology story is underpinned, and measured, by the doubling of semiconductor capability and productivity every-eighteen-months –a rate that has carried us from the room-sized vacuum-tube computers to the modern Internet – and by the complementary surge in the capacity of the communications network to transmit digital information. Changes in business organization and practice are the second driver of this transformation. The E-conomy is as much a story about changes in business organization, market structures, government regulations, and human experience as it is about new technology. While these changes are spreading across industries and countries, they are more difficult to measure. Taken together, the business innovations represent a new business ecology that includes a prominent role for venture capital, the start-up, the spinoff, and new option based ways of compensating skilled workers and entrepreneurs – innovations that have unleashed a tsunami wave of new business and new technology.

The E-conomy is generating substantial and unexpected increases in productivity that have motored our recent surge in economic growth and that have enlarged the margin for monetary policy. But the economic transformation is not about soft landings, smooth growth, permanently rising stock prices, government surpluses, and low rates of interest and inflation. It is about structural transformation and developments that carry disruption and change. The policy issues are moving rapidly from the narrowly technical through the narrowly legal into fundamental questions of how to organize our markets and society. Under the best of circumstances the risks of policy making are high.

This background briefing on the E-conomy is aimed to provide a context and a structure for policy debate by defining the stakes, the forces, the issues at play, and an agenda – not a choice of outcomes. For the past fifty years, US government policy has played a major role in enabling America to lead in developing information technology– and just as important– in creating the conditions for America to lead in the use of information technology throughout the economy. The American government largely got policy right under three important headings – headings we use to structure the agenda that follows: 1) Public investment in science and technology and in the technological-age education of people needed to realize the benefits

# WELCOME TO THE E-CONOMY

Federal Reserve Chair Alan Greenspan sees "a deep-seated [and] still developing shift in our economic landscape" caused by "an unexpected leap in technology."[1] He is only the most prominent of those who believe that the information technology revolution is transforming our economy. Central bankers are by nature and training cautious: their words move markets. Thus when a central banker announces that there is an ongoing technological leap, and attributes to it changes in macroeconomic dynamics– then it is truly time to sit up and pay attention.

This ongoing shift in our economic landscape has many names: a "post-industrial society," an "innovation economy," a "knowledge economy," a "network economy"– a "new economy."[2] We prefer a new term: the "E-conomy." The other names seem vulnerable to misinterpretation, and they possibly focus our attention in the wrong direction. For example, the economy has always been driven by innovation. The term "network economy" is too narrow. The term "new economy" is too broad: it can carry (and has carried) anything anybody wants to put into it.

The term "E-conomy" points at the fact that today's economic transformation is driven by the development and diffusion of modern electronics-based information technology. The term emphasizes that the ongoing shift is a change in structure, and not primarily a macroeconomic or cyclical phenomenon. The E-conomy is a structural shift, bringing transformation and disruption. But it is not about soft macroeconomic landings, smooth growth, permanently rising stock prices, government budget surpluses, or permanently low rates of unemployment, interest and inflation.[3]

What, then, is the E-conomy about? There are eras when advancing technology and changing organizations transform not just one production sector but the whole economy and the society on which it rests. Such moments are rare. But today we may well living in the middle of one. We are living through the rise of what will soon be the dominant source of economic development: information technology. Information technology builds tools to manipulate, organize, transmit, and store information in digital form. It amplifies brainpower in a way analogous to that in which the nineteenth century Industrial Revolution's technology of steam engines, metallurgy and giant power tools multiplied muscle power.

The nineteenth century Industrial Revolution hugely increased the scale and accuracy with which energy could be applied to production and transportation. It changed the world. Will the twenty-first century rise of the E-conomy be as important? Perhaps. But at this point no one can tell the ultimate magnitude of the changes set in motion.

Information technology builds the most all-purpose tools ever, tools for thought. The capabilities created to process and distribute digital data multiply the scale and speed with which thought and information can be applied. And thought and information can be applied to almost everything, almost everywhere. Computer chips, lasers, broadband Internet, and software are the key components of the technology that drives the E-conomy.

The technological explosion of the invention of the semiconductor and subsequent productivity gains in making semiconductors has produced and will produce a stunning advance in information-processing power. In rough orders of magnitude, by 2010 computers will have ten million times the processing power of computers in 1975.[4] The market price of computing power has fallen more than ten thousand-fold in a single generation,[5] with the result that the installed base of information processing power has increased at least a million-fold since the end of the era of electro-mechanical calculators in the 1950s.[6]

The extraordinary build-out of the communications networks that link computers together is almost as remarkable as the explosion in computing power. The result has been that the E-conomy has emerged faster, diffused more rapidly and more widely throughout the economy than previous technological revolutions.[7]

But the E-conomy is about more than just better technology. It is about where and how these new technological tools, these tools for thought, are used by industries, organizations, and people to transform what they do and how they do it and to do wholly new things.[8]

## An Economic Transformation, Not Just a Leading Sector

Productivity growth and technological change in the core sectors of the information-processing revolution have been immense. But how wide and deep will the effects be? Skeptics can see this productivity explosion as just another example of a "leading sector"[9]— an explosion of invention and innovation that revolutionizes productivity in a narrow slice of the economy. There have been many such leading sectors in the past— air transport in the 1960s, television in the 1950s, automobiles in the 1920s, organic chemicals in the 1890s, railroads in the 1870s, and so on. Yet they did not change the standard dynamic of economic growth; they defined it.[10] Thus a skeptic might ask why one should pay especial attention to the emergence of yet another leading sector.

But what we are experiencing is not just a decade-long boom as technology opens up new possibilities in a leading sector of economic growth; we are experiencing something deeper and broader. Semiconductors, computers, and communications *do* constitute a large leading sector, but that that is not the whole story. Some technological changes do not just amplify productivity in one sector but give all economic sectors new "tools." They open new possibilities for economic organization across the board. They change what can be done and how it can be done across a very wide range of industries. And they require changes in ideas about property and control— in the way that the government regulates the economy— in order for these new possibilities to be realized.

The electric motor can serve as an example of such a transformative tool. It made possible, among other things, the assembly line. No longer did factory floors have to be arranged in order to make sure that each machine was connected to the network of belts and shafts that transferred energy from the central steam engine. Instead factory floors could be arranged to make the flow of work simple, easy, and automatic. Henry Ford called that reconfigured system by a special name: "mass production."[11]

Our current technological revolution is making tools for thought. The information technology tools being forged today will be used to calculate, sort, search, and organize. They can affect every economic activity in which organization, information processing, or communication is important– in short, every single economic activity. These tools for thought are making possible new uses, lots of them, some with hard-to-see and – some with easy-to-see benefits. Think of micro surgery (which saves days in hospitals, and spectacularly reduces pain and suffering);[12] of new ways to search for pharmaceuticals; of hyper-efficient retailing (which saves American consumers enough money to bring into question government statistics on US economic and income growth);[13] of remote monitoring of medical equipment like pacemakers; of cheap wireless communication that improve the productivity of repair and service workers, deliveries, real estate agents as well as family life; of farmers able to substantially increase yields while cutting back on polluting insecticides and fertilizers; and of students in small schools in Indiana– or India– who gain access to information that just the other day was available only to those with access to major research institutions.

The transition to an E-conomy rests on the emergence of distinctly new forms of business organization and work. It is shaped by new strategies for developing and deploying innovation. Large companies in a broad range of sectors have aggressively and successfully pursued innovation to defend and expand their market positions. However, often--and more often in recent years– radical technological developments and applications from semiconductors through the personal computer and the web browser were developed and commercialized by start-ups, not by established organizations.

In the last quarter of the twentieth century the U.S. high-technology economy has been composed of an extraordinarily effective blend of public investment in information technology infrastructure, large company innovation, and entrepreneurial disruption. That entrepreneurial disruption has been critical to the sudden development and diffusion of new technologies and applications. Entrepreneurial companies have spotted new opportunities. They have taken big risks to develop new applications of information technology. They have recruited innovative people willing to share those risks in anticipation of potential rewards.

Such a successful blend has required open competition in big user industries– such as finance, air travel, and pharmaceutical development– which experiment with new technologies to gain competitive advantage, and thereby launch large-scale use and production of the technologies. And it has required established companies that are both compelled and able to re-create and re-organize themselves to respond to competitive pressures and opportunities that define the new economic landscape. American social and economic institutions appear to be remarkably effective in generating innovators in producer and in *user* industries. Thus America has been, to a surprisingly large degree, the country of origin of the E-conomy.

The E-conomy is about changes in business organization, market structures, government regulations, and human experience. Innovation in information technology made these and countless other changes possible; they in turn shape the trajectory and pace of technological development. To the extent that the E-conomy radically alters economic life in industries and businesses far removed from Silicon Valley, it will turn out to be more than just another leading sector.

## Policy Frameworks and Choices

People come to Silicon Valley today much as people came to Manchester, England at the start of the industrial revolution in the nineteenth century, or to Detroit as the age of mass production emerged in the 1920s. They come to marvel at the accomplishments of new technology, new organizational forms and new industry. Mostly they come to try to understand what this all means.

When they leave, it would be good if they had a framework to structure the information, visions and debates. They need to understand what this shift in the economic landscape means, why it should command their especial concern, and the role of government policies.

The world wide web is getting inextricably entangled in the webs of law, custom, and commerce– the tissue of our daily lives. The consequence is that cyberspace will no longer be a policy-free zone. Indeed, it will be a focus for difficult– and therefore uncertain– policy making. The issues have moved from the narrowly technical through the narrowly legal into fundamental questions of how to organize our markets and our society. Under the best of circumstances the policy risks are high. The technology and the questions it raises pertain to matters far removed from the experience of the policy-making community. But because they are not narrowly technical or narrowly legal, they are not the kind of tech policy that could be confined to a small isolated community of experts. The E-conomy now enters into too many domains of daily life, affects too many economic interests, and raises too many broad social questions to continue in a policy-free incubator or enclave.

This background briefing on the E-conomy aims to provide a context and structure for those policy debates. It defines the stakes, the forces and issues in play, and presents an agenda– not a choice of outcomes– for policy debate. That policy agenda is structured under three broad headings:

- **Public investment** in science and technology, and in the technological education of people, that is needed to realize the benefits of the E-conomy. Included under this heading is the re-opened question of the role of government and the institutional structures that create launch markets for next generation technology.
- **Rule making for the E-conomy,** which extends across such thorny issues as privacy, security, and the definition of new property rights and responsibilities necessary for markets to function effectively and in consonance with enduring values and purposes.
- **Flexible and inclusive** institutions and labor markets.

Just as each of the advanced countries that are leading the E-business revolution has a distinct pattern of corporate governance, labor relations, and social welfare, there will be distinct trajectories of development of E-business. Indeed, just as new rules for privacy, security, taxation, and intellectual property are being built up in each country, so new international rules will be required to reconcile the several national arrangements.

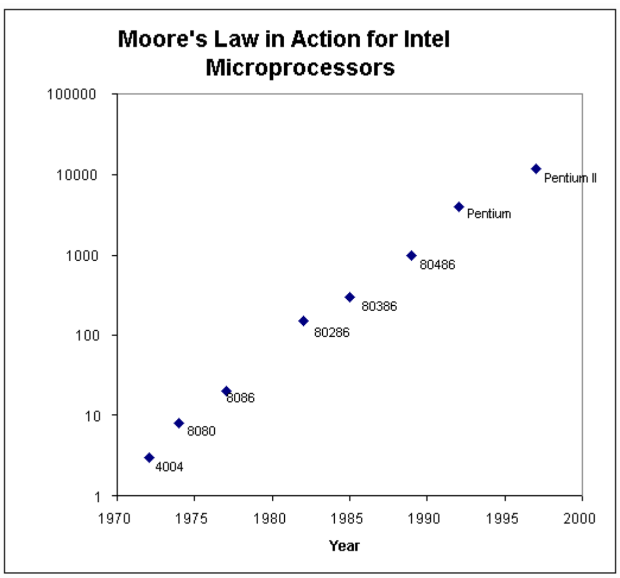
# The Information Technology Revolution

The story of the revolution in information technology must be told in two ways: first as a story of technology; second as a story of innovations in business organization and practice. Only the intertwined stories explain how the technology moves out of the laboratory, into the economy, and into daily life.

## The E-conomy Unfolds: The Technology Story

### *The Semiconductor Revolution: Power, Price, and Pervasiveness*

In the 1960s Intel Corporation co-founder Gordon Moore projected that the density of transistors on a silicon chip— and thus the power of a chip— would double every eighteen months.[1] Moore's law, as it came to be called, has held. Today's chips have 256 times the density of those manufactured in 1987— and 65,000 times the density of those of 1975. This continued and continuing every-eighteen-month doubling of semiconductor capability and productivity underpins the revolution in information technology.

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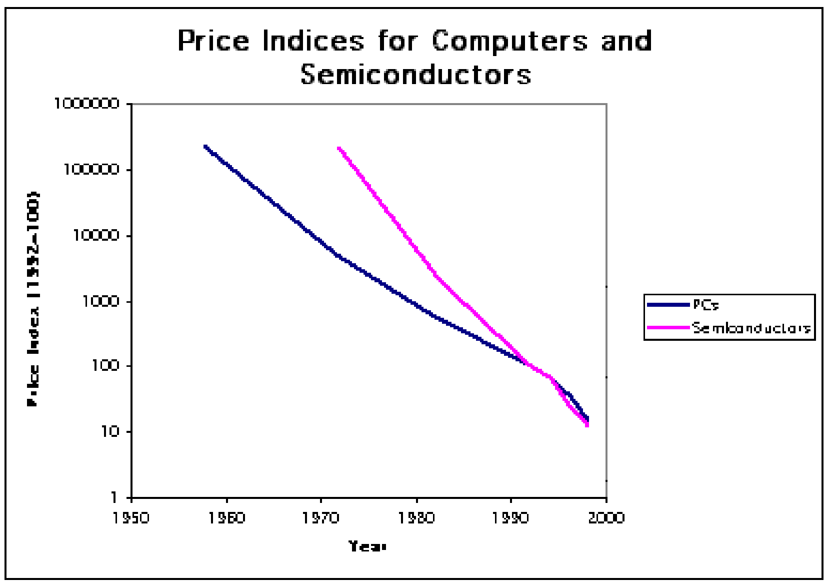
The increase in semiconductor density means that today's computers have 66,000 times the processing power, at the same cost, as the computers of 1975. In ten years computers will be more than 10 million times more powerful than those of 1975— at the same cost. We now expect— routinely— that today's $1,000 personal computer ordered over the Internet will have the power of a $20,000 scientific workstation of five years ago. And what was once supercomputing is now run-of-the-mill.[16] The past forty years have seen perhaps a billion-fold increase in the installed base of computing power.[17]

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### *User Industries Transform and Are Transformed by Computing*

But this enormous increase in raw processing power generated by the semiconductor revolution is only an economic potential. It becomes important only if this potential is utilized. Thus the key question as the semiconductor revolution has proceeded has always been: "what is computer power useful for?" And the answer had changed, is changing, and will change steadily as the price of computing drops, the size of a computer shrinks, and the possibilities for useful applications expand.

However, even though the answer has changed, the way that the question gets answered has not changed. At each point in the past forty years the critical step in the transformation of technical potential into economic productivity has been the discovery by users of information technology of how to employ their ever-greater and ever-cheaper computing power to do the previously-impossible. Thus leading-edge users and the innovative applications that they have developed have always been the creators of the demand for better, faster, and cheaper computers. And it is this demand created by user-side innovation that has sustained technological development.

At first computers were seen as powerful calculators. They were seen as good at performing complicated and lengthy sets of arithmetic operations. The first leading-edge applications of large-scale electronic computing power were military.[19] The burst of innovation during World War II that produced the first one-of-a-kind hand-tooled electronic computers was totally funded by the war effort. The coming of the Korean War won IBM its first contract to actually deliver a computer: the million-dollar Defense Calculator. The military demand in the 1950s and the 1960s by projects such as Whirlwind and SAGE [Semi Automatic Ground Environment]– a strategic air defense system– both filled the assembly lines of computer manufacturers and trained a generation of engineers.[20]

The first leading-edge *civilian* economic applications of large– for the time, the 1960s– amounts of computer power came from government agencies like the Census and from industries like insurance and finance which performed lengthy sets of calculations as they processed large amounts of paper. The first UNIVAC computer was bought by the Census Bureau. The second and third orders came from A.C. Nielson Market Research and the Prudential Insurance

Company.

The Census Bureau used computers to replace their electro-mechanical tabulating machines. Businesses originally used computers to do the payroll, report-generating, and record-analyzing tasks that electro-mechanical calculators had previously performed. But it soon became clear that the computer was good for much more than performing repetitive calculations at high speed. The computer was much more than a calculator, however large and however fast.

Innovative users began to discover how they could employ the computer in new ways. It proved at least as useful in stuffing information into and pulling information out of large databases as in performing calculations. American Airlines used computers to create its SABRE automated reservations system— which cost as much as ten airplanes.[21] The insurance industry first automated its traditional processes— its back office applications of sorting and classifying. But insurance companies then began to create customized insurance *products*.[22] The user cycle became one of first learning about the capabilities of computers in the course of automating established processes, and then applying that learning to generate innovative applications.[23]

As computing power has grown, computer-aided product design from airplanes built without wind-tunnels[24] to pharmaceuticals designed at the molecular level for particular applications has become possible. In this area— and also in the office in general, conquered for the microcomputer in the 1980s— computers' major function is neither a calculator-tabulator nor a database manager, but is instead a what-if machine. The computer creates models of what-if: would happen if the airplane, the molecule, the business, or the document were to be built up in a particular way. It thus enables an amount and a degree of experimentation in the virtual world that would be prohibitively expensive in resources and time in the real world. The value of this use as a what-if machine took most computer scientists and computer manufacturers by surprise: who before Dan Bricklin programmed Visicalc had any idea of the utility of a spreadsheet program? The invention of the spreadsheet marked the spread of computers into the third domain of utility as a what-if machine— an area that today seems equally as important as the computer as a manipulator of numbers or a sorter of records.

For one example of the importance of a computer as a what-if machine, consider that today's complex designs for new semiconductors would be simply impossible without automated design tools. The process has come full circle. Progress in computing depends upon Moore's law; and the progress in semiconductors that makes possible the continued march of Moore's law depends upon progress in computers and software.

And as increasing computer power has enabled their use in real-time control, the domain has expanded further as lead users have figured out new applications. Production and distribution processes have been and are being transformed. Moreover, it is not just robotic auto painting or assembly that have become possible, but scanner-based retail quick-turn supply chains and robot-guided hip surgery as well.

In the most recent years the evolution of the computer and its uses has continued. It has branched along two quite different paths. First, computers have *burrowed inside* conventional products as they have become embedded systems. Second, computers have *connected outside* to create what we call the world wide web: a distributed global database of information all accessible through the single global network.

### *Pervasive Computing: The Microprocessor Becomes Embedded*

What does it mean to say that computing is becoming pervasive? The new production and distribution processes that pervasive computing makes possible are visible to us at the check-out counter, at the gas pump, and in the delivery truck. At the checkout counter and the gas station computers scan, price, inventory, discount, and reorder before the groceries enter the bag or the nozzle is rehung. In the delivery truck handheld computers determine the next stop and record the paperless "paperwork."

The most important part of pervasive computing is the computers that we do not see. They become embedded in traditional products and alter the way such products operate. In automobiles, anti-lock brakes, air bags, and engine self-diagnosis and adjustment are performed by embedded microprocessors that sense, compute, and adjust. The level of automotive performance in systems from brakes to emissions control is vastly greater today than it was a generation ago because of embedded microprocessors.[25] There is another world of information technology in the design, production, marketing, sales, servicing, and resale of automobiles.

In toys embedded intelligence rests on very simple computing products. From cash registers and cell phones to hotel doors, elevators, and pacemakers, embedded microprocessors are transforming our world from the inside by adding features of intelligent behavior to potentially all our products.[26]

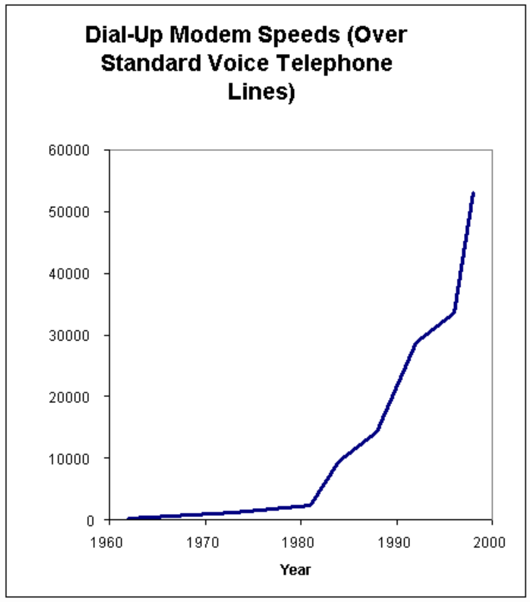
### *Computers Become Linked: The Spread of Networks*

As the cost of communications bandwidth dropped, it became possible to link individual sensing, computing, and storage units. Today we complain when it takes an ATM machine half a minute to verify the bank balance we hold in a bank in a distant city. The key point is not that rapid transmission has become *technically* feasible,[27] but that the costs of data communication are dropping so far and fast to make the wide use of the network for data transmission *economically* feasible for nearly every use we can think of.

With the early data use of data networks it was once again leading-edge users who created new applications in their pursuit of competitive advantage. The origins of today's Internet in the experimental ARPANET funded and built by the Defense Department's A[dvanced] R[esearch] and P[rojects] A[dministration] is well-known. Networking began either as private corporate networks or, as in the case of the French Minitel, as public networks with defined and limited services. Business experimentation began. And data communications networks began their exponential expansion as experimenting users found new applications and configurations.[28]

### *Computers Become Hyper-Linked: The Coming of the Internet*

But few saw the true long-run potential of high-speed data networking until the http protocol and the image-displaying browser– the components of the world-wide web– revealed the potential benefits of linking networks to networks. Every PC became a window onto the world's data store. And as the network grew, it became more and more clear that the value of the network to everyone grew as well. For the more people there are on a network the greater is the value of a network to each user– a principle that we now call Metcalfe's law.[29]

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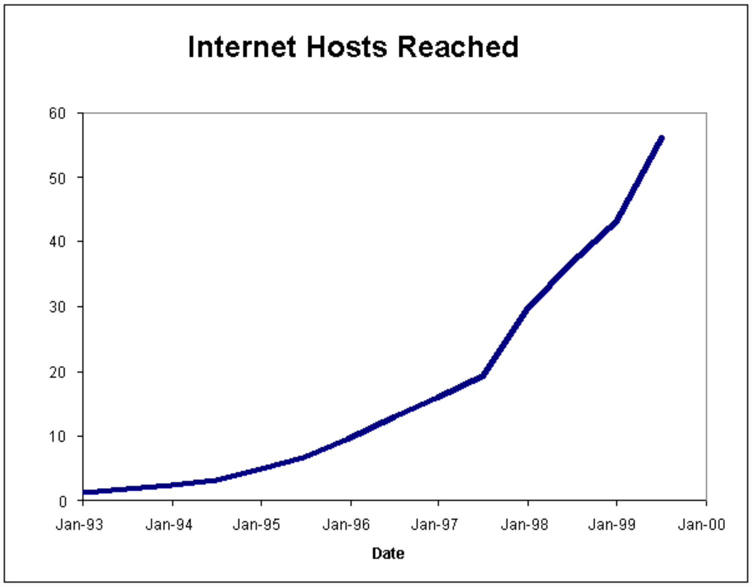
The build-out of the Internet has been so rapid in large part because the Internet could be initially run over the existing voice telecommunications system. Even before the new technologies designed from the ground up to manage data communications emerged– and they will replace data-over-voice– the global Internet had already established its incredible reach.[31] More than sixty million different computers were accessible over the Internet by late 1999.[32]

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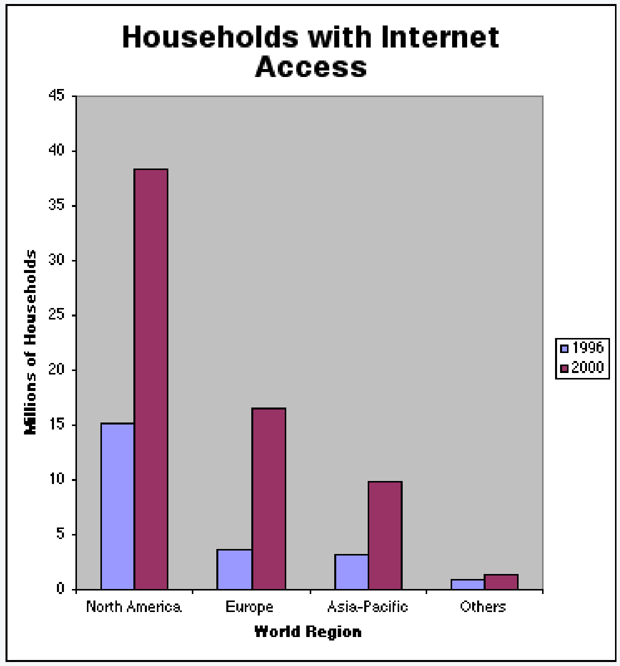
Some of the elements of next generation of data networks are already evident. First, for consumers and small business one dramatic advance will be broadband to the home to create high-bandwidth and low-latency connections. a file download that would have taken two hours will instead take two minutes, and following a hyperlink will take five seconds instead of thirty.[34] The acceleration in speed will change the kinds of tasks that can be accomplished over the internet: the increase in bandwidth and decrease in latency will mean not just a faster but a different Internet, with different more sophisticated applications.

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Second, wireless voice networks will soon be as extensively deployed as the wired phone network. Widely-diffused wireless data networks will set off another round of experimentation and learning, a round that is already beginning. This round of network deployment already brings both new applications, challenges to established equipment and software players, and struggles over standards complicated by the fact that wireless providers do not yet know which wireless applications will prove to be truly useful.

Third, the capacity and cost of the very backbone of the network will evolve dramatically over the next years, bringing new architectures, lower costs, ongoing experimentation and new applications. There will be, in some views, a veritable tsunami wave of new capacity, technical advance, and dropping costs.[36]

### *Networks Transform Industry*

But the full story of the emergence of the E-conomy cannot be told just by recounting the sequence of technologies. Focusing on the numbers that describe technological advance and diffusion hides much of the real story: the story of how the growth of the network will transform business organization and business competition.

Moreover, the numbers are grossly uncertain because the growth of the network promises to transform the whole society. One set of estimates places the Internet economy at $300 billion in 1998 and $400 billion in 1999, accounting for 1.2 million jobs.[37] Yet another set of estimates reports an Internet economy only one-third that size.[38] The differences spring from where different analysts draw the line between “Internet” and “non-Internet.” But to our minds the major lesson is that soon it will be impossible to talk about an “Internet economy”: the internet will be so much a part of daily life that it will make as little sense to talk about the Internet economy as to talk about the telephone economy. There will be no slice of the economy that can be carved out of the rest and assigned to the “Internet.” Instead, all of the economy will be linked to the Internet. Every business organization and consumer marketplace can make use of the information-processing and communications tools that constitute this current wave of technological advance.

How will the entire economy be linked into information processing and data communications? We do not yet know. Traditional businesses that act as intermediaries– like stock brokers and travel agents– will be irrevocably altered. Traditional products like automobiles are already being marketed in new ways. Stores will not disappear, but the mix of stores and what stores do will change. New ways of reaching customers will in turn drive new ways of organizing production and delivering goods to consumers. Today we can see a range of strategic experiments, in the form of new companies trying to exploit the web and established companies trying to defend their positions.[39] But we do not know which of these experiments in corporate information and network strategy will be successful.

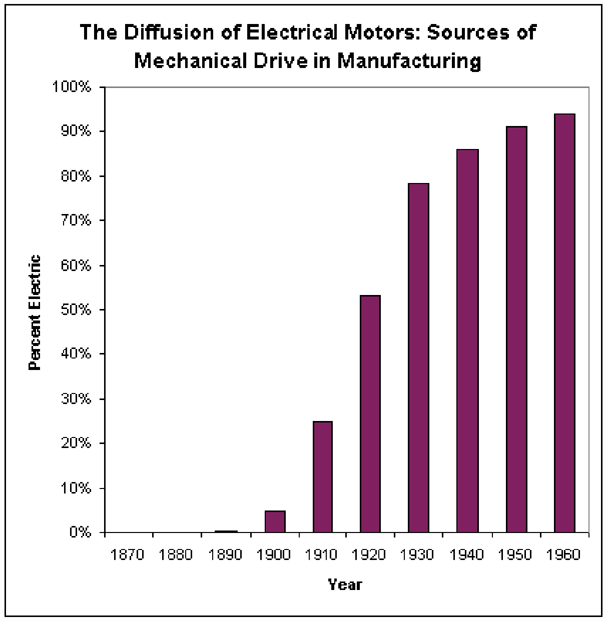
We can, however, see which strategies have been successful in the past. Consider Main Street, U.S.A., the home of the consumer-goods distributor Wal-Mart. Wal-Mart is not a company usually thought of as the leading edge of the dot-com revolution. Wal-Mart has, however, been extraordinarily successful at solving the problems of control and distribution needed to become a hyper-efficient retailer.[40] Wal-Mart’s extraordinary efficiency advantage can be credited in large part to its early investments in modern information technology, and to careful thought and skilled execution of how modern information technology can achieve economies of distribution. As Wal-Mart founder Sam Walton wrote in his autobiography:

> Nowadays, I see management articles about information sharing as a new source of power in corporations. We've been doing this from the days when we only had a handful of stores. Back then, we believed in showing a store manager every single number relating to his store, and eventually we began sharing those numbers with the department heads in our stores. We've kept doing it as we've grown. That's why we've spent hundreds of millions of dollars on computers and satellites– to spread all the little details around the company as fast as possible. But they were worth the cost. It's only because of information technology that our store managers have a really clear sense of what they're doing most of the time.[41]

These efficiencies went primarily to boost the real incomes of shoppers across the country who benefited from the lower prices and greater range of goods available at Wal-Mart and its imitators.[42]

### *The Future: The Emergence of the E-conomy*

We cannot see which uses of these new technological capabilities will be valued the highest by businesses and consumers. These uses will emerge only at the end of a process of experimentation and search– and may well be something that we do not now expect.[43] Economic historian Paul David points out that it took nearly half a century for business users to figure out the possibilities for increased efficiency through factory reorganization opened up by the electric motor.[44] Finding the most valued uses for the next wave of computer-and-communications technology will probably not take as long, but it will take time.

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This point is worth expanding. Changes in the powers and capabilities made available by modern information technologies are redefining efficient business practices, and sustainable market structures. They are redefining which activities belong inside a firm and which can be purchased from outside. They are changing business models and market structures. Those changes are only beginning. It is anyone's guess and any player's bet what the final outcome will be.

We do know that at every stage up to today the killer application of each wave of technological innovation has been a surprise. Indeed, if we are wise we should expect to be surprised by what will be the most valuable uses fifteen years from now. Who in the mid-1970s, before VisiCalc, understood that the greatest value of a computer to an office worker would come from a what-if spreadsheet program? Who at the start of the 1980s– besides the founders of Adobe– thought that desktop publishing would be important? Who at the start of the 1990s understood that most proprietary on-line services– no matter how good their content and connectivity– would be doomed by the end of the decade?

## The E-conomy Unfolds: Innovations in Organization and Business Practice

The on-going innovations in business strategy and organization we see today are yoked to the technological revolution in information technology. Innovations in business practice evolve out of day-to-day efforts to resolve real problems or take advantage of real opportunities. Out of the swirl of fads, frustrations, tactics and strategies— like just-in-time, total quality, downsizings, knowledge management, outsourcings, strategic alliances, mergers, demergers, spin-offs and start-ups— has emerged a new reality: a more entrepreneurial business world able to innovate and commercialize at much faster speeds than before.

The list describing this new business reality could be long: changes in where people work— links between business groups and home workers, changes in how organizations are structured— flatter organizations that reflect new possibilities in how work itself is organized made possible by faster and broader information flows— the traditional clerk becoming a marketer— the traditional salesperson absorbing into his or her networked PC many functions that were previously seen as "clerical."

However, lists of changes disappoint. They miss the point that these innovations in business and social practice begin as efforts to solve real problems and take advantage of real opportunities. They miss the fact that, taken all together, they amount to the creation of a substantially new business system— a system with two differentiating characteristics: constant on-going innovation, and speed to market.

To get a sense of how technological advances and innovations in business organization and practice co-evolve, we consider two important innovations in business practice: the response to the "innovation dilemma", and the response to the "production challenge."

### *Resolving the Innovation Dilemma*

It is often the case that large established firms are not very good at fully developing and commercializing technologies that disrupt their existing markets and procedures. Decisions in larger companies are rarely taken by one person alone (in spite of press focus on "star" CEOs). Most corporate decisions never even get to the CEO's radar screen. Parts of a large company, often the biggest and most powerful parts, are not eager to contemplate the risky development of a new technology that could end up cannibalizing *their* market and destroying *their* division. Typically that group will doubt the feasibility, the reliability, and the marketability of the potential technology. New markets are hard to imagine and harder even to assess quantitatively. By contrast, substantial enhancements to existing product lines can generate considerable returns. Established customers and suppliers shape companies' assumptions about how their industry will unfold. Companies that are responsive to their customers actually risk getting locked in to a set of arrangements that preclude them from grasping the competitive advantages of innovation.[46]

AT&T certainly asserted that an Internet-style communications system was impractical. Motorola, the leader in analog mobile phones, missed the step in the shift to digital. IBM missed Internet routers. Microsoft came late to the web browser, web server, and web development tools.[47]

Perhaps it is the case that the more effectively a company is tied into its network of customers and suppliers, the more likely it is to sustain a course of innovation that maintains its position within existing markets and technologies. Thus the less likely it will be to undertake radical innovation. And the more likely it will be to be blindsided by breakthrough technologies. The established company may generate and literally drip with technology, but nevertheless be unable to capture its value. The creation at Xerox PARC of the functioning GUI interface, the page description language, the Ethernet– and their commercial exploitation by others (Apple and Microsoft, Adobe, 3Com) is simply one of many examples of breakthrough technology lost inside of excellent established companies.[48]

Because of the inevitable organizational tension found in established companies, start-ups– entrepreneurial companies– have been the drivers of much of the radical innovation in the transition to an E-conomy. They have defined and developed new industries not just new markets. Large established firms are simply not very good at generating disruptive technologies. They are often blindsided by technological breakthroughs that alter their existing markets, their existing procedures. Established firms, to use Jim McGroddy's imagery, play chess in established markets. Start up firms play poker in the creation of new industries.[49]

Entrepreneurial start-up companies, however, face substantial problems. They require money, help developing business plans and strategies, supplier contacts, access to clients, legal advice, production and logistics services — the list of things that start-ups need but cannot generate easily from their own resources is very long.

America in the 1980s and 1990s has built up a business ecology that makes it not easy and straightforward, but possible to establish an entrepreneurial start-up. The economy has built up institutions that together amount to a new innovation system that has provided solutions to many of these requirements.

Institutions and policy have played major roles in developing this entrepreneurial community. Early venture money paved the way in making available the funds to start and develop a company. Changes in the prudent-man rule allowed institutional money to enter the venture business, and so greatly enlarged its scale.[50] The scale of investment changed, and funds were suddenly available for the venture world to move from niche to centerpiece.

In a similar fashion the growth of compensation through stock options that reward stunning success with stunning wealth allowed founders to share a significant portion of the risk and rewards of a new company with like-minded employees. The institution of stock options meant that a cut in pay and a move across country could suddenly represent an opportunity not a failing— if the reward were a share in value of a venture start-up. And large established firms followed by seeking ways to encourage and to participate in spinouts, start-ups, and venture funds.[51]

### *The Production Challenge*

Unexpectedly and abruptly in the 1980s, Japanese consumer durable and electronics products surged into American markets. Previous import surges in labor intensive products such as shoes, apparel, and low end assembled goods such as toys forced significant industrial reorganization and meant important social dislocations. But they did not challenge the sense that American producers and production methods defined advanced manufacturing and advanced industry.

The demonstrated competitive strength of Japanese auto and electronics producers were created by fundamental production innovations that meant that lower cost could also bring higher quality. A group of Japanese manufacturing firms had managed to create the first significant innovation in the organization of manufacturing business since Alfred P. Sloan. Reformulating the production and design process into a "lean production system" simultaneously eliminated inventories and their costs, permitted constant quality improvement, and reduced cost. In consumer durable products like autos and televisions that had lots of parts, complex innovations seemed to have established an enduring advantage in production. The shock of a basic challenge to position in the symbol of the industrial age, the auto, and the symbol of the emerging electronic age, the basic memory chip, was considerable. It forced American and European producers to reorganize fundamentally their production and business practices.[52]

The production challenge to both America's high technology and main-line manufacturing firms came when many firms discovered that the market advantages of many innovations are lost if the innovating firm cannot also be world-class producers, or at least have close access to world-class production. U.S. comparative advantage in mass production manufacturing was eroding extremely rapidly.

The challenge to traditional "mass production" American manufacturing became an irresistible onslaught and a rout in the mid-1980s, as lower and declining relative real costs in Japanese manufacturing combined with a dollar severely overvalued as a result of mistakes in macroeconomic policy. The result was the hollowing-out of large chunks of American manufacturing capacity– and in the process the destruction of a lot of valuable human- and firm-specific capital.[53]

Nevertheless, American companies have proved remarkably successful in the past decade at adopting their own version of "lean production" innovations. The Japanese manufacturers may have taught American producers a painful lesson, but the American producers really learned. By the mid 1990s– with a stronger yen and reconfigured American manufacturing processes– the balance of manufacturing advantage in high-technology industries appeared much more even.

Partly the eclipse of the Japanese challenge came about because the leading edge of consumer electronics shifted from broadcast / entertainment– TVs, VCRs, radios and related products– to wireless and computer based products where America-based producers had set standards. Partly it came about because companies such as Hewlett Packard now understood how large the long-run benefits from learning-by-doing were that came from controlling the low end of a market through high-quality volume production, even if cost accountants told top managers that low-end margins were low. With the inkjet printer, HP dominated the market by systematically defending the bottom end of the market as it introduced new low cost products.[54]

But a larger part of the change came with a finer division of labor. Producers discovered that they could lower their costs by concentrating on what they did best, and contracting to buy the rest from those with a firm-specific advantage in productivity or a nation-specific factor cost-based comparative advantage. Outsourcing across borders, a cross-national production system, and the emergence of contract manufacturing have been at the heart of the solution of the production dilemma.

Better communications have enabled firms to implement this "outsourcing" strategy. The ability to use modern data communications networks to transmit information allows client firms to specify in great detail what, exactly, they want their contractors to do. In a previous generation, with information flow limited to telephone, fax, mail, and air couriers, a lot of tacit knowledge about how the client branch of the organization would use the output and what the client organization's default operating procedures were was necessary in order for work to be distributed. Such tacit knowledge could best be gained through long experience. Hence large multidivisional enterprises that allowed the building within the enterprise of this tacit knowledge were an attractive organizational form.

The increase in bandwidth has allowed explicit directions and thick presentation of the overall project to substitute for tacit experience. It has allowed for a much finer division of labor and the creation of what we now call contract manufacturing. Because the world's nations are so highly differentiated in terms of labor skills and labor costs, the greatest benefits to producers from the finer division of labor may well come from the possibility of extending the firm's division of labor across nations: cross-national production systems.[55]

*First* came the shift from a market dominated by integrated producers to one in which firms located anywhere in the disintegrated value chain can potentially control the evolution of key standards and in that way define the terms of competition – not just of their particular segment, but critically in final product markets as well. Market power has shifted from the assemblers such as Compaq, Gateway, IBM, or Toshiba, to key producers of components (such as Intel); operating systems (such as Microsoft); applications (such as SAP, Adobe); interfaces (such as Netscape); languages (such as Sun with Java); and to pure product definition companies like Cisco Systems and 3COM.

What all of these firms have in common is that, from quite different vantage points in the value chain, they all own key technical specifications that have been accepted as de facto product standards in the market. The disruptive start-up companies have begun to define the direction and fate of the industry.[56]

*Second*, companies that had found production a weakness began to outsource both component production and assembly. But new highly flexible and adaptable production systems emerged. Cross-National Production Systems (CNPS) is a convenient label to apply to the consequent dis-integration of industrial value chain into constituent functions that can be contracted out to independent producers wherever those companies are located in the global economy. And such independent producers can locate wherever factor costs and local levels of technological development provide a comparative advantage.[57]

CNPSs permit and result from an increasingly fine division of labor both between firms and between nations. The networks permit firms to weave together the constituent elements of the value-chain into competitively effective new production systems, while facilitating diverse points of innovation. They are not principally about lower wages as such, nor about access to markets and natural resources– although these objectives often motivated initial investments. Rather they are about the emergence of locations that can deliver different mixes of technology and production at different cost-performance points.

*Third*, and perhaps most important, CNPSs have imbued supply chain management with a strategic meaning. This set the stage for companies such as Dell to integrate marketing and production and convert themselves into service businesses tying the design, production and delivery of the product directly to the customer.[58]

As American firms won initial market positions with innovative ideas and then defended positions with imaginative approaches to production and marketing, their total sales grew. Many firms found that maintaining quality and sustaining innovation was much easier if critical production innovations were kept close at hand. Industry analyses are confirmed by plant level studies. In plants that introduce innovative production technologies, employment grows. In plants that do not, employment shrinks and often disappears as production migrates. Winning firms generate jobs; losing firms do not.[59]

### *The Silicon Valley System*

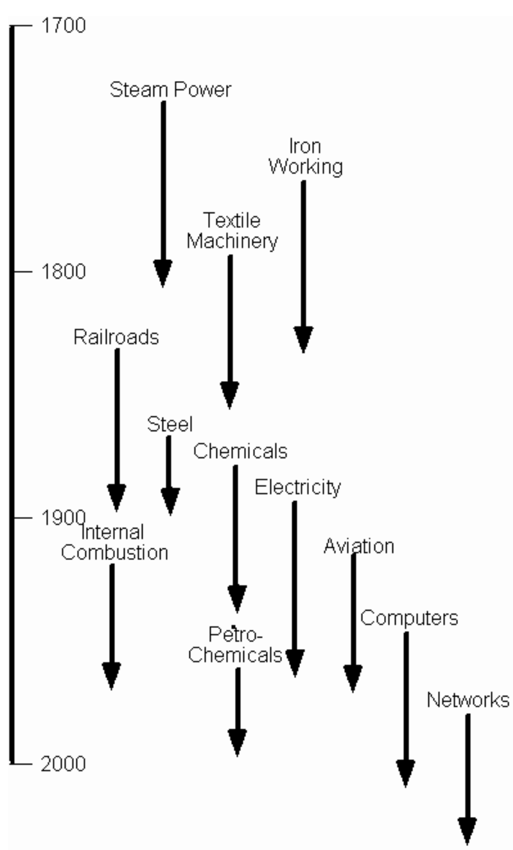
Silicon Valley has, over the past few years, transformed itself into more than just a vibrant locus of high tech firms and scientific research. It has become the center of a new kind of industrial ecology that provides better solutions to the "innovation dilemma" and the "production dilemma." Today the basic resources of the E-conomy– financial capital and high skilled human capital– head for the United States because in the U.S. is located the best economic environment for transforming those resources into the growing businesses of the E-conomy. Social institutions– such as research universities, venture capitalists, and specialized law firms– and market institutions– such as an extremely flexible labor market, incentive compensation, financial capital, and ultra-high-skilled people from the entire world– have come together to form a Silicon Valley system that is both bigger and different than a simple sum of its discreet parts.

Today an entrepreneurial company can reach out to all the services necessary for business operations, ranging from experienced business operations management through contact with overseas suppliers, customers and potential partners. Finally the company is backstopped with an on-call capacity for crisis management. The result is a new industrial ecology that makes it possible for new companies to do what only technologically and financially rich companies were capable– but too often unable– of doing: bringing innovations to market quickly and at scale. This new industrial system has become a critical growth engine for the world, and a strong source of comparative advantage for America– and will be until it is successfully imitated elsewhere.[60]

## What is at Stake? Assessing the Transformation

It is these social and organizational transformations that are the true answer to skeptics' dismissal of the information technology revolution as "just another leading sector." It is certainly true that there have been leading sectors of economic growth for more than two hundred years, and that each leading sector sees very rapid increases in productivity and concordant shifts in the pattern of production and consumption. The pace of productivity improvement offered by Moore's Law is exceptional; but during its heroic age of technological advance the automobile saw productivity improvements that gave you tenfold the car for your money over the course of a generation.[61]

***Successive Schumpeterian Leading Sectors***



Why, skeptics ask, are boosters of information processing and communications so sure that this current transformation is more important than the leading sectors we see every decade? Why are they so sure that the impact on our material welfare of the Internet is so much greater than the impact of the automobile, or of penicillin and other antibiotics, or of network television?

The answer is that we do not know that our modern wave of technological innovation is bigger than the increases in human material welfare produced by the leading sectors in the past. How would we make such measurements convincing? We have no reliable speedometer to measure the rate of increase in consumer utility. And it is true that network television, jet air transport, the automobile, and antibiotics were each a very big deal in the past.

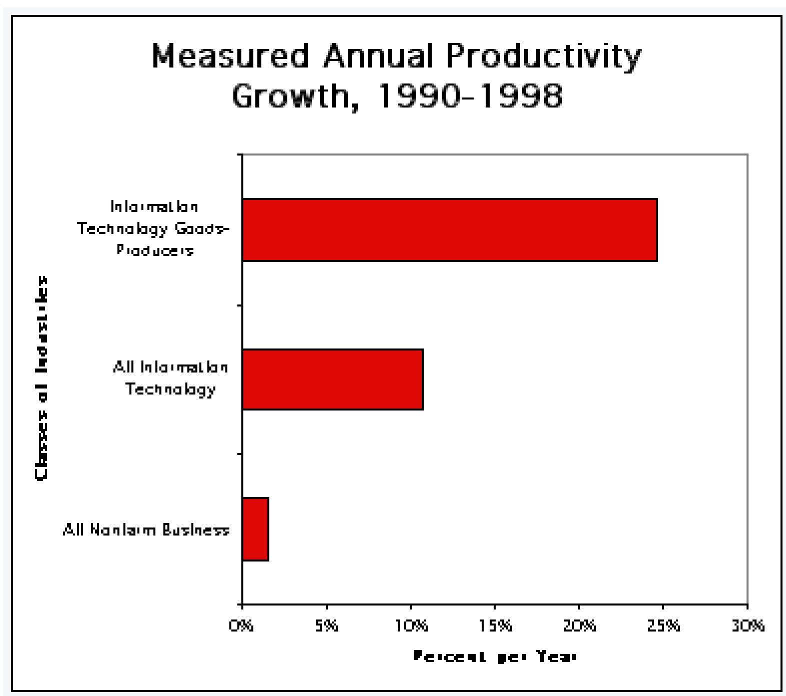
We do, however, know that our current wave of innovation is part of a different *process*. Leading sectors generate rapid productivity growth in the production of goods and services in a relatively small slice of the economy: treatment of infections for antibiotics, speed of getting to other cities for air transport, access to movie-like entertainment for the television. This is a transformation that creates tools for thought– and carries with it organizational and institutional changes and innovations.

### *The Productivity Paradox*

But if this wave of technological innovation is so important, why has it not yet had a more powerful impact on our picture of the overall economy? Back in 1987 Nobel Prize-winning MIT economist Robert Solow wrote in the *New York Review of Books:* "How come we see the computer revolution everywhere but in the [aggregate] productivity statistics?"[62] Solow shared the general view that computers-and-communications held a potential for economic revolution. Yet when he looked at the aggregate overall measurements of the state of the economy, he saw slow productivity growth.

The fourteen years from the date generally accepted as the beginning of the productivity "slowdown"– the oil crisis year of 1973– to 1987, when Solow wrote, had seen measured output per hour worked in the nonfarm business sector of the U.S. economy grow at a pace of only 1.1 percent per year. By contrast the fourteen years before 1973 had seen measured output per hour worked grow at a pace of 2.8 percent per year. The years after Solow asked his question— if computers are so revolutionary, why aren't they accompanied by rapidly-rising productivity?— saw productivity performance worsen: between 1987 and 1995 measured output per hour worked for the U.S. nonfarm business sector grew at only 0.8 percent per year.[63]

This "productivity paradox" was sharpened because at the microeconomic level economists and business analysts had no problem finding that investments in high technology had enormous productivity benefits. MIT economist Erik Brynjolffson and his co-authors found typical rates of return on investments in computers and networks of more than fifty percent per year. Firms that invested heavily in information technology and transformed their internal structures so that they could *use* their new technological capabilities flourished in the 1980s and 1990s— and their lagging competitors did not.[64]

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## Partial Answers

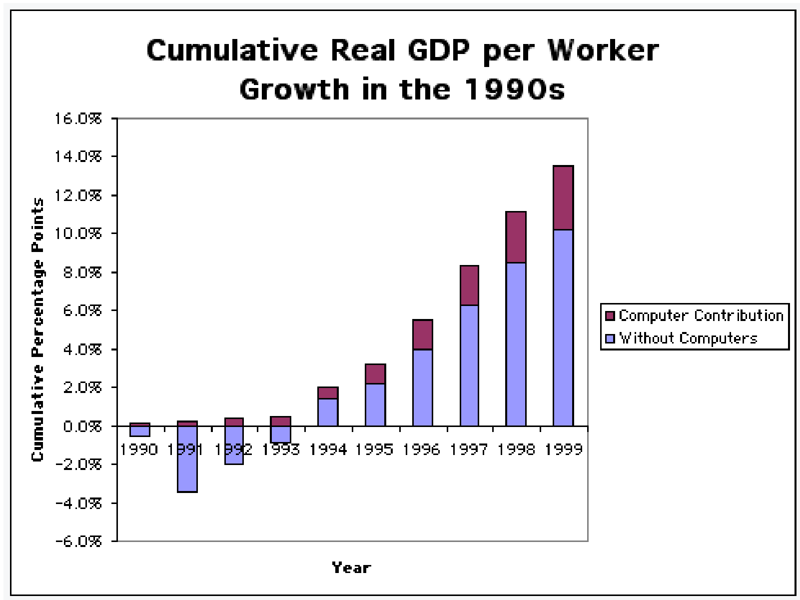
Part of the resolution of this "productivity paradox" comes from Stanford historian of technology Paul David's observation that it takes considerable time for an economy to restructure itself to take full advantage of the potential opened up by a revolutionary technology. David claims that it took forty years for the American economy to realize the productivity potential of the dynamo. Electric power became a reality in the 1880s. But it was not until the 1920s that there had been enough experimentation and use of electricity-based technologies for businesses to learn how to use electric power effectively, and for the inventions of Edison and Westinghouse to pay off in giant leaps in industrial-sector productivity.[66]

Another part of the resolution of this "productivity paradox" comes from the fact that observers of technology and national income accountants are focused on two different things. Observers of technology look at the leading edge of innovation and implementation. National income accountants see changes reflected in their aggregate data only when what was the leading edge becomes standard practice. Economic historian David Landes points out that something very similar happens when historians of technology and historians of national income try to date the original industrial revolution. Historians of technology look at inventions and innovations and date it to the 1760s. Historians of national income do not see a marked acceleration of economic growth until the 1840s and 1850s when industrial technology diffused widely.[67]

Thus, as Federal Reserve Board economist Dan Sichel pointed out, in the 1970s and 1980s computers were simply too small a share of total investment and total GDP to expect to see a strong imprint on aggregate economic growth – even if for each investing company the rate of return on information technology investments was very high.[68]

However, as Sichel points out, what was true in the 1980s is no longer true in the 1990s: now investments in information technology are more than half of total investment. The contribution of the computer sector to overall GDP growth is now high.[69]And in the past four years productivity growth has been accelerating: the productivity slowdown of 1973 to 1995 may well be over–

awarded responsibility for this recent acceleration in American economic growth.[70]

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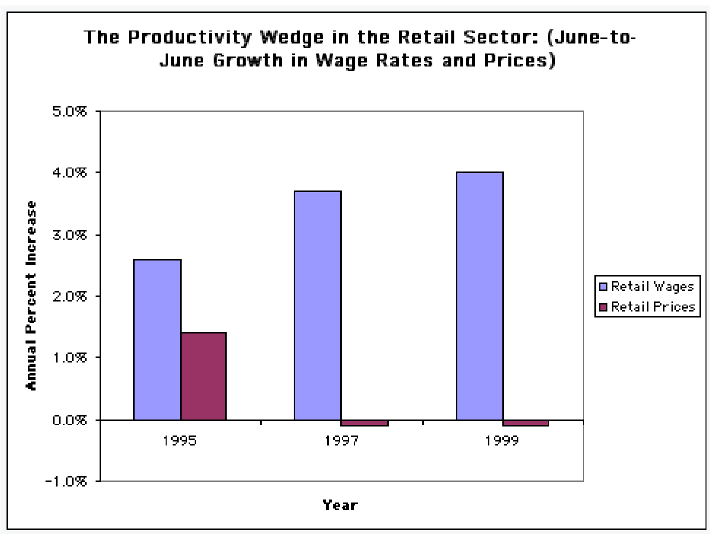
## Problems of Measurement

Yet these partial answers are not sufficient to explain all of the productivity paradox. The overwhelmingly likely possibility remaining is that there are systematic flaws in the process by which real GDP is estimated– systematic flaws that have led us to overstate inflation and understated true economic growth in recent decades. Popular awareness of these flaws has been largely the result of the Boskin Commission, which tentatively concluded that true economic growth had been understated in recent decades by somewhere between one and two percent per year– enough to double material productivity in 72 years (at one percent per year) or 36 years (at two percent per year).[72]

Whether you accept the conclusions of the Boskin Commission or not, there is no doubt that a number of individual components of productivity growth have been significantly understated. The Bureau of Labor Statistics does not know how to measure the benefits of the shift in American consumers' purchases from department to discount stores.[73] In industries comprising one-eighth of the entire American economy, measures of real output growth assume no change in productivity growth: estimates of production are created from estimates of employment growth alone. Anyone who goes to the bank today and went a generation ago can gauge an enormous– and mostly pleasant– shift largely driven by banks' use of information and network technology to provide extra flexibility, convenience, and service. Yet prior to 1999 important elements of this improvement in service were completely missed by measurements of GDP.[74]

In education, health, general government, finance, and even transportation, good measures of productivity growth are next to impossible to achieve.[75] The national income accountants– doing the best they can– have been strongly tempted to assign zero productivity growth to sectors that they cannot measure.[76] And all this leaves completely to one side the problems in accurately assessing the increase in material well being and productivity that arises from the invention of genuinely new goods and new types of goods.[77]

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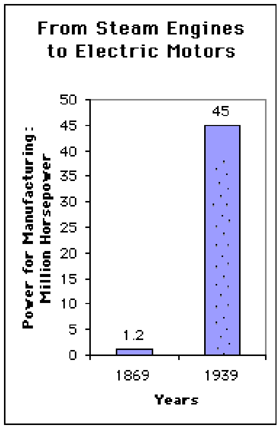
Moreover, all this leaves completely to one side the problems in assessing increases in productivity that do not generate an immediate revenue stream from final consumers to producers. Does anyone doubt that Americans' material standard of living– as consumers, at least– was raised in the 1950s and 1960s by the coming of network television? Yet because network television's revenue model is based on advertising, it shows up in the national income and product accounts as an intermediate cost but not as a final service– it shows up as a reduction in measured economic productivity.[79]

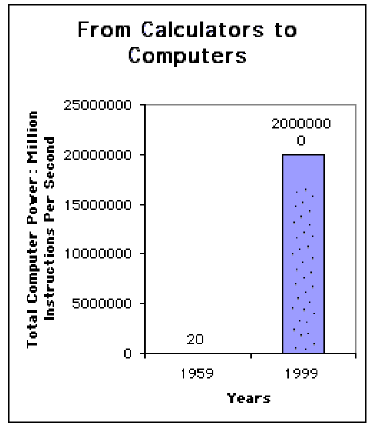
This proposed resolution of the productivity paradox has an important implication. The typical benefits of the computer-and-communications revolutions that have been largely missed in the past few decades by the national income accountants were benefits that showed up as better quality to banking customers, and as lower prices to discount-store shoppers. These benefits are widely distributed: every American who has used an ATM or shopped at WalMart has benefited– directly– from the coming of the E-conomy. Yet most shoppers at WalMart do not recognize where its competitive edge and low costs came from. Most users of ATM machines do not think about the network necessary to sustain transparent access to your home bank. And so many do not recognize the stake they already have– the benefits they have already gained– from the E-conomy.

### *Historical Analogies*

Serious attempts at forecasting the future development and implications of these technologies and organizations are hazardous: the history of technological development teaches us that the most productive uses of new technological capabilities are likely to surprise. Thus we should expect our forecasts of the likely future important uses to go awry. The best we can do to look forward is to look back at relevant historical analogies, and try to sketch out the kinds of developments that may follow.

Throughout we have contrasted this epoch with the original nineteenth-century Industrial Revolution. Here, however, we look back at previous revolutions in information technology in the hope that examining their consequences and implications will help inform us of today's information technology revolution.

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This revolution in information technology is the broadest and deepest of a long series of innovations in "information technology". In their day, the broadcast media of radio and television, the communications infrastructures of telegraph and telephone, and the book printed with moveable type gave humanity new information capabilities with powerful consequences. These clusters are themselves not superseded, but are altered by today's digital information technology. Information technology affects *all* of the above – broadcast, communications, books – inevitably altering patterns of communication and social interaction, raising exponentially the abilities to communicate and process information generated by all the previous technological revolutions noted above.

Let us now review these earlier changes. First, the twentieth century's one-to-many broadcast technologies, radio and television, created widely shared channels of information and widely shared forms of entertainment. They allowed for centrally created programs to be transmitted to large communities, thereby creating larger communities. Digital possibilities both expand the media and transform them. Digital TV makes an infinity of channels possible, and makes it easy to acquire detailed information about each of them. It makes many-to-many communication possible. Sophisticated computer databases and online video will make one-to-one advertising and customized distribution possible as well.

Second, the systems of communication born in the 19th century, telephone and telegraph, altered business communication. Ultimately the telephone altered social community as well. Consider the simple telegraph. It could only transmit a few bits of information, but those few bits could be transferred in real time. And they were the highest value bits, telling shippers of prices in destination cities, and allowing business organizations to keep track on a day-to-day basis of key market conditions in other locations.[81] Furthermore, the telegraph nearly halved the capital requirements of running the railroads of the mid-nineteenth century. With a telegraph in operation a single-tracked railroad can effectively carry goods and passengers in both directions. Without a telegraph in operation, railroads *must* be double-tracked.[82]

The 15th century gave us the original modern information tool set– moveable type– and hence the book. The book altered how information was stored, diffused and controlled. It is surely no accident that the intellectual flourishing of the humanities and sciences happened in short order after the invention of printing by movable type. The invention of printing via movable type amplified access to the accumulated store of human knowledge. Duplicating a book no longer required three months of work by a highly-skilled literate professional. The number of written sources that a reader not immured in a monastery could have access to in a lifetime rose from approximately 300 to approximately 30,000 in less than a century. As intellectual historian Elizabeth Eisenstein argued, printing was necessary for the Renaissance to be a true upward step in knowledge, rather than a transitory flowering of intellectual inquiry that– like all the previous, more minor Renaissances– would soon dissolve and disperse.[83]

Does the new mechanism of storing and transmitting information presage such dramatic social evolution? One cannot know. But certainly the very possibility of being able to seriously ask the question suggests that something profound is afoot. Certainly one of the most important of the future transformations opened up by modern computer and communications technologies may be the universal online library. The possibility of the universal online library means that very soon many of us may have transparent access to virtually the entire collective knowledge of humanity. If the answer to a question is known– or even if it isn't known, but many people have opinions– each of us will be able to get that answer within five minutes.

There remains the problems of figuring out which people's opinions are worth paying attention to, and of possessing the background needed to *understand* the answer. Nevertheless, ignorance on any subject matter will be harder to maintain in the future than in the past. And as everyone who has ever used an Internet search engine knows, current information technologies have not solved the problem of gathering the information relevant to a query and presenting it in an organized and comprehensible fashion. But the arrival of much better information organization and retrieval tools is a matter of time, software design, and Moore's Law.[84]

Each of these three distinct information / communications infrastructures– broadcast, communications, and print– entangled with its own economic and social revolutions, is being reformed or challenged by digital information developments. It is not just that DVD movies can now be played on your computer, or that your TV can be a web access device. Rather fundamentally different business models of music distribution, publication, advertising, and marketing have developed. It is not just that e-mail, or indeed instant messaging, is an alternative to paper mail or the phone call, but rather that the TCP / IP based networks are a fundamental challenge to the underlying economics of the traditional telephone communications system. It is not just that e-mail attachments replace faxed documents, but that entire systems of supply base management, management of the logistics of production, have emerged. But most powerfully, all three have become intertangled.

The effects of this phenomenon are diverse. Included among them, the lines between private communication and media broadcast become blurred as all the above modes of communication and information retrieval are transformed from separate analog systems to interconnected digital representations. Instead of several parallel essentially analog infrastructures, a single digital infrastructure is emerging with the information embodied in broadcast, communications, and books represented in the same digital form, transmitted over networks with compatible rules. Of course the effects of these changes are multiplies when we recognized information is flows just from people to people, but also from the physical world to people through their senses. It is a matter of observing and controlling the physical world. Take one case from the world of "sensors", the invention of the microscope in the 16$^{th}$ century multiplied sensory power. When little creatures were observed in a drop of water, a new universe opened that was to generate modern medicine and organic chemistry.[85] Information technology takes the power of sensory devices into wholly domains. Biomedical science and the new modern materials science are just two of the implications.

The way to look at the future of information and communications technology is as an order-of-magnitude improvement in *all* branches of communications-and-information processing, all happening at once. Surely, we don't know what further possibilities for the use of these technologies will prove to be truly valuable– and we don't know what organizational and institutional changes will open up the way to these truly valuable uses.

However, the historical analogies discussed above illustrate that technological changes of this magnitude have long-term impacts far greater than anticipated in their time.

## The American E-conomy in A Global World: The Production Paradox

The American E-conomy will not evolve in isolation. The other advanced industrial economies will soon become E-conomies. They will evolve along different trajectories and at different paces. The developing world's hopes and possibilities will be reset as well by the electronic linkages that bind production and finance. Inter-connected digital networks ever more intimately weave together national economies and societies around the world. Events in other nations have the potential to become more important parts of our business environment. And actors in the United States have limited direct influence over such events. Innovations– such as the Japanese lean production system which shocked the American manufacturing establishment– play out ever more quickly on larger stages, in regional and "global" theatres.

The fact of expanding market and political interconnections is not at question.[86] However, their pattern and significance is at issue. The lesson of the past years, we are told often, is that everything is "global." "Globalization" emerged as a code word for the uncertainty of an industrial world in which unanticipated challenges came from unanticipated directions. The "globalization" story, however, has several different versions, each implying different stakes, concerns, and issues.

A *first* version of globalization presses the sense of international forces sweeping past the capacity of nations to respond, channel, or control. The Internet *does* radically increase connections, generating a seemingly placeless homogeneous cyberspace that for some is a reality of its own. In this vision, the critical policy challenge is to assure the rapid deployment of the broadest possible network in which all have a stake. The rapid development of a broad network creates great gains for each participant, just as the value of the telephone increases with the number of your possible correspondents who likewise have phones. As other countries develop and deploy this technology, they generate markets and opportunities for American companies, and new possibilities for American consumers.

The global information economy and society is a network that crosses borders in a world organized into nation-states. This automatically creates a role for national governments. How fast this networked world evolves depends on how effectively governments, often jealous of their sovereignty, ensure that their separate and distinct economies are effectively connected. That in turn requires, if not common rules, then harmonization, compatible rules that allow the economic networks to operate as a single large global system. From a purely American vantage, openness is a matter not just of open networks, but of open markets for the equipment for these networks and the tools for the network. For example, since the origins and the first uses of much of this technology much of the distinctive Internet network equipment, routers and access equipment has been developed in the United States.

Indeed for some, the global spread of information processing and communications technology– the world of the Internet– is primarily an American innovation.[87] Thus in this first vision of globalization the principal task is to assure a sufficient agreement on standards to permit the operation of global networks and the continued vigilance to assure markets for equipment, tools, and applications open. This is not simply a matter of taking down, dismantling, existing barriers. Rather, new rules and arrangements, both for the networks but also for services and commerce aided by the networks are being put in place. Those new rules will, unless attention is paid, themselves constitute new barriers and obstacles, sometimes intended to create national advantage and sometimes unintended as a reflection of different purposes and values.

In a *second* vision, the national differences in rules and business practice are not simply inconveniences, unwanted obstacles to a single network, that should simply be wiped away. Rather, those varied rules and structures will generate distinctly national patterns of use and application of the Information Tools. It is not simply a matter of who leads a race toward an information future, but equally which road they are following and which future they are building. Internet access patterns may vary nationally, and, even more importantly, distinctly national patterns of Internet and iformation technology use are likely to emerge. They are rooted in different social principles about matters such as privacy, consumer protection, and corporate governance. In this second version of the globalization story, several distinct national E-conomies are generated as the new technologies are channeled through quite different societies.

For example, the United States, France, Germany, Japan are all rich capitalist market democracies, but each has distinct patterns of corporate governance, labor relations, and social welfare. Indeed, just as new rules for privacy, security, taxation, intellectual property are being built up in each country to allow the new information technologies to operate, a new global market framework with new international rules will be required to reconcile the several national arrangements and to permit the seamless flow of information. Consequently, as the United States has first mover advantage, it must as it makes policy, ask not only how the rules it makes will affect the development of our own system but also, if they are applied abroad to our firms, whether we can live with those implications.

The *third* view of globalization is that national innovations and developments are played out more quickly on larger stages, regional and "global' theatres. Globalization is not simply the wiping away of national boundaries but rather a series of often unexpected challenges from sources on the global stage. In this innovation based economy position in one phase is no guarantee of leadership in the next.

Certainly producers headquartered in America are in a confident position now, with leadership in a broad range of innovations and applications of information technology. Yet the clear European surge in wireless application and deployment has meant that many American companies are turning to Europe to commercialize and hone their innovations. Two of the world leaders in cellular are Scandinavian– a thoroughly unexpected development. Indeed, many believe that while American firms have dominated the personal computer era and the first phases of the Internet revolution, the next network phase will be defined by wireless leadership.[88]

These three versions of globalization in an information era point to the challenges, the stakes and the tasks. Gaining full value from the emergence of the E-conomy depends on: 1) sustaining the transformation at home, 2) assuring the interconnected global network (with common or compatible national rules as well as assuring open markets) and 3) benchmarking local business practices to the best-practice found abroad, and so adopting and absorbing the successful innovations in policy and business practice that will be made elsewhere. In the long run it will not be sufficient to just keep one's gaze fixed on Silicon Valley.

## Life in an Information Age

It is difficult at best to forecast the longer term course of technological evolution, even harder to foresee how specific applications will unfold, but next to impossible to project exactly how the particular innovations will combine and recombine to alter how we work and live our lives. If, as argued, the amplification of brain power is to this era what the application of energy to machines and transport was to the industrial revolution, if the Internet is to the organization, storage, control of information in this era what moveable type and the book were to life before the Renaissance, then we should expect the changes to be profound. The problem is that we cannot see what they will be.[89]

# POLICY FOR THE E-CONOMY

We are moving into the transformed economic landscape with no roadmap and no reliable speedometer. At least the basic directions we must travel are evident. America must stay at the forefront of technology leadership in a broad range of domains. We now depend for our prosperity on the capacity to create and introduce new technologies and new business forms. Over the past twenty-five years, at great pain to many Americans, we have shed major elements of our comparative advantage in mass production and mass commercialization. Other nations have moved into those roles. We have substantially restructured our economic strengths, redesigning the American economy to specialize in the permanent frontier of new technology. But in so doing, we have signed-on to a path of constant effort, investment and innovation. Keeping to that path will require considerable political effort and skill of the kind the previous two generations of Americans were able to muster.

For the past fifty years, US government policy has played a major role in enabling America to lead in developing information technology– and just as important– in creating the conditions for America to lead in the use of information technology throughout the economy. Over this long period, the US Government has largely gotten the broad contours of policy right, and not just by blind luck, even if we might all debate many particulars. Applause is due. Government got policy right under two important headings: public investments and rule making. American policy has invested resources in fundamental research, advanced engineering, and science and engineering education to create the intellectual, human, and financial capital needed for the development of information technology. The focus of rule making – the systems of public and private governance and market organization required to make the market for information technology work– has been on creating and preserving open institutions and open competition.

While the policies of the last years point in the right direction, we do not have the luxury of simply updating our past policy successes in order to adapt them to our future. Policy over the past years was more than just a string of individually successful initiatives. A policy dynamic which emerged in the post-war period supported technological development and diffusion. One task ahead is to restructure that creative tension between public investment, rule making, and private competition to fit quite new circumstances.

We divide the discussion that follows into policy issues of resources, rules, and flexibility with inclusion.

## Resources for the E-conomy

Since World War II, the U.S. government has invested in technology development and in the creation of a pool of highly trained scientists and engineers to facilitate that development. The investments in technology development constituted one half of the creative tension between public investments and competitive market development. Those investments were made in the form of support for basic research and as developer and launch user of critical, usually military or space, technology.

Now with changing corporate research strategies largely reducing spending on fundamental research, public investment in research becomes all the more critical. With the end of the Cold War, and the changing relation between military and civilian technologies, that public role as critical launch user has diminished both in scale and sophistication and must be re-evaluated. At the same time that the pool of engineering and science talent must expand, a skilled and numerate workforce becomes equally important to sharing broadly the gains possible from the E-conomy.

### *The Creative Tension Between Public Investment and Private Market Competition*

There was in the post-war years a creative tension between government *investment* in technology development and policy *rules* that assured competitive markets for both the development and application of new technologies. It must be a guide to present policy choices.

Let us consider three instances of this creative tension:

*First*, consider the subject of the day, the Internet. The Defense Advance Research Projects Agency (DARPA) set out to create a national communications network that could survive nuclear disaster.[90] The underlying network architecture, and the technological conceptions, differed starkly from those of a traditional switched network. That network (DARPANET) made its protocols publicly available. It was transferred from DARPA to the National Science Foundation (NSF) for broad educational use to become the Internet and was later turned over to commercial use.

That investment provided the boost for an important US lead in the Internet explosion because it was coupled with a significant rule change: deregulation of the telecommunication networks and of major telecommunications user industries such as finance and airlines. Telecommunications deregulation opened the way for competition in providing innovative services to firms eager to experiment; deregulation in finance and airlines provided a compelling stimulus for firms to experiment with new strategies and new technologies. The market result was American domination of a new and powerfully significant segment of communications technology, and ultimately the Internet boom.

Consider a *second* case, the semi-conductor. Two generations ago the transistor was developed at Bell Labs, the heavily funded research arm of the publicly regulated telephone monopoly, ATT. Because of regulatory controls over what markets ATT could enter and what it could do in those markets, Bell Labs played a para-public research role, functioning somewhat as a national electronics/communications laboratory. Then government anti-trust policy obliged ATT to actively make the technology available to all comers. Finally, a government mission– the military's needs for miniaturized electronics– created a launch market for the new technology and further forced diffusion of production technologies and basic know-how.

The result of this creative tension in policy was a merchant semiconductor industry. Firms such as Fairchild, Intel and AMD literally made their living by teaching other firms how to exploit the possibilities of the new technologies,[91] and enabled a diffusion rate far faster and broader than one could imagine under different circumstances. In both cases public investments spawned new technologies and government rules structured the competitive markets that innovated new product possibilities.

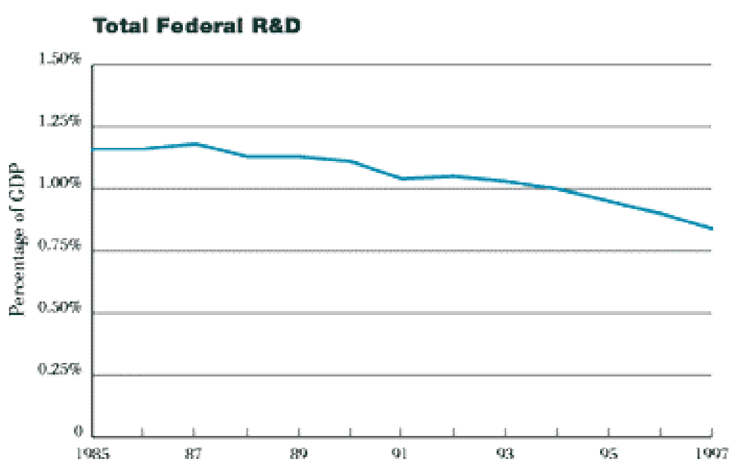
Now, of course, the institutional underpinnings of that creative tension between rule making and public investment in research and public procurement as a launch market, has been changed. After the AT&T break-up, Bell Labs no longer functions in its para-public role. The military, which once defined next generation technology in computing, now struggles to keep abreast of commercial developments. New policy initiatives require a new institutional basis. *Third*, consider bio-tech. This revolutionary family of technologies and know-how is a direct result of investment in fundamental science supported principally through the National Institutes of Health but exploited commercially in the private sector. The pay-off is proving to be spectacular, both in simple economic terms, and in terms of major improvements in the length and quality of life.

Policy will not, consequently, be just a matter of sustaining public investment in basic science and considering whether there should be publicly sponsored technology objectives in a post-cold war era. Nor will it be a matter simply of assuring open markets for private development. But much more difficult – the task is to restructure that creative tension between public investment, rule making, and private competition.

### *Investing In Technology Development: Fundamental Research and Advanced Education*

Information technology is based on more than two generations of formal, scientific research done mostly at our leading research Universities.[92] Unlike the innovations that launched the industrial revolution at the dawn of the nineteenth century, or even the work of Edison and Bell at the end of that century, this technology is not the work of self-taught tinkers. Clever engineers working in the family garage are standing on the shoulders of those fundamental, formal, academic scientists who created the enormous body of research and development on which the E-conomy rests. Investment in basic research was critical in the past and remains so now. It is basic research that creates the next technological frontiers. And being close to basic research– having a constant flow of personnel back and forth– is a powerful aid to firms seeking to live on the technological frontier.

Yet, no company could seriously indulge a business strategy based on the uncertainties of basic discovery. First, it is extremely difficult to keep fundamental results and principles as the intellectual property of a single organization. Second, even if a company could have known in advance that such research would yield such extraordinarily promising commercial results (an impossible condition), modern investment allocation models would assign an extremely low value to the very-long term payoffs. Only governments– or giant, enduring monopolies like the old Bell System that are largely immune from capital market discipline– can be expected to undertake the kind of long-term, open-ended investment program in fundamental research that will generate basic principles – principles that will not necessarily create rapid innovation but will become part of the general knowledge base. Most of the start up entrepreneurial boom rests on research and first stage development done elsewhere, whether in a corporate lab such as Xerox Parc or a university lab, but somewhere other than the innovating firm. Corporate downsizing has led to refocusing industrial research away from basic science toward ever more mission-oriented development. That is fine, and appropriate, but the seed corn must be renewed systematically and institutional changes are radically reducing commitments of large corporate laboratories to basic research.

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Though it may be difficult to imagine, we may be only at the beginning of the technological revolution that is propelling our economic transformation. Yet right now we appear to be using up our seed corn in so far as investment in research is concerned. Funding for research outside the biological sciences has not increased with need and opportunity. In most areas, federal support has fallen as the "discretionary spending" part of the budget has been squeezed.

Sustaining investment in advanced research may be the necessary first effort, but assuring the quality of that research is just as important. The core strength of American research has lay in the workings of our unique system of research universities. That system had three characteristics that nations around the world are now trying to imitate. They are worth emphasizing:

*1)* *Peer Review*: Selection of projects for funding is made by committees of scientists (peers). Bureaucrats and politicians keep clear of project selection. This system is beginning to be undermined by politicians who treat major research efforts as pork to be distributed by politicians on the basis of political geography.

*2)* *Openness to Business:* American research universities work closely with business to quickly move new technology and young research-trained students out of the university lab and into commercial development.[94] Other nations with distinguished scientific traditions (for example, France and Germany) are now attempting to break down the barriers that have separated their research communities from their business communities.

*3)* *Openness to Worldwide Talent:* This inflow of human capital is critical to our ability to invent, develop, and deploy new applications. Refugee scientists fleeing Hitler's Europe helped launch the great age of scientific research at American universities. Today American universities are the world leaders, but we depend upon highly educated foreign born talent for that excellence. In top university electrical engineering and computer science departments, for example, between one-third and two-thirds of the graduate students are foreign born – and of the faculty too! That dependency now extends to high-tech companies. The competitive advantage of Silicon Valley, and of US high tech more broadly, increasingly is to be found in our great advantage in attracting financial capital from the entire world and combining it with very highly skilled engineers and entrepreneurs also recruited from all over the world. Today not only will you find a great proportion of the engineers at the latest generation of Silicon Valley high tech start-ups coming from India, SE Asia, Israel, France and just about everywhere else, but perhaps as many as one-third to one-half of the start-ups are now headed by foreign born entrepreneurs. The dependency has become a major strength. But there is no mistaking the fact that the dependency is real. [95]

## Investing In Technology Development: Launch and Lead Users

Certainly sustained investment in science and technology is essential. But what about the other part of the government's role in the creative tension of technology development, that of lead user or "launch market"?

In the electronics heart of information technology — chips, computers, software, communications — government not only played a crucial role in financing the earliest fundamental research, but also acted as a critical "launch user." The government after World War II was able to act as a critical lead user for two reasons. The government had clear priority objectives such as military defense and space development that had leading edge technology requirements. Those technological requirements were in advance of the civilian sector, but along what proved to be the same general lines of development. Government programs, therefore, could finance the speculative research, risky development, and heavy initial deployment costs. The U.S. Government was the first user of advanced super-computers for defense and security purposes. By the time Lucas Films bought a Cray Supercomputer for the purposes of doing advanced animation, something had clearly changed. Civilian applications in media, finance and oil exploration, among others, could define profitable uses for the most advanced computing technologies, and pay for them. The commercial sector quickly pulled ahead of the military in terms both of sophistication as well as volume. The components in a Sony Camcorder were suddenly more sophisticated than those in a military system because with the long delays in developing complex military systems the underlying components were often out of date before the equipment was incorporated into a deployed system. The huge volume and the rapid pace of innovation in consumer and business applications meant that leadership in many electronic domains passed to the civilian sector.

Can the government still play the role of innovative lead user? If not, how can the creative tension between basic research (usually government supported) and innovative market applications be sustained? Government policies of deregulation (partial) in telecommunications, finance, and air travel, for example, helped to generate competitive lead users who began to exploit advances in technology for market advantage. How will the dynamics of innovation and development change as lead use passes from a government sector seeking radical jumps forward, disjunctures, for price insensitive missions, to civilian companies seeking market advantage? Will the result be an enormous activity of innovation along established lines, but fewer fundamental innovations such as semiconductors, advanced computing or the Internet?

### *Investing in Numerate and Literate Americans*

A second major commitment of government resources has been investment in education. The GI bill and large scale, sustained Federal support for the build-out and build-up of our universities in the 1950s and 1960s provided America with a large cohort of scientists, engineers and managers who developed the technologies and moved them into the economy. In the 1950s and 1960s the United States had the highest proportion of its labor force educated in college and beyond. But, as has repeatedly been called to the nation's attention, we failed to make an analogous effort to improve the quality of American education in grades K to 12.

Thus today's educational paradox: universities that are the best in the world and that draw students from all over the globe sitting on top of primary and secondary education systems that all agree are much less effective than they could or should be. America has not invested enough or sufficiently well in education. In the age of the E-conomy the consequences are more handicapping than in the past.

Only a relatively small number of scientifically educated people are needed to launch a scientific revolution. But very large numbers of literate and numerate people are needed to apply that technology in just about every area of the economy and work with it. The differences in wages between those with more formal education and those with less, and between those with more technology-using experience and those with less, has been growing rapidly over the past decades. It is one indicator of the magnitude of change and of the severity of the problem.

Moreover, what was perhaps sufficient twenty-five years ago as an average level of educational attainment during secondary school no longer is. Elsewhere in the world, people have made deliberate, enormous, and successful investments in education. Compared to the benchmark provided by other nations' secondary educational systems, the U.S. system looks more and more inadequate. And it is hard to see how an economy can stay relatively rich and powerful when its workers lack the education of their competitors. Selective immigration, attracting and admitting the best and the brightest of other nations is now, de facto, our short term economic solution to this problem. Any approach based on successful educational reform is necessarily long term.

## Conclusion

There are then, two conclusions, and each conclusion poses a question. First, sustained investment in basic science, engineering, and technology is required. The enormous corporate and entrepreneurial success rests on major public investments in science and technical education. The open question is whether the government can play a role of sophisticated lead user as part of its objectives and missions? Second, the system of higher education has worked well to create and diffuse knowledge and to spawn a community of sophisticated engineers, entrepreneurs and managers. Yet a shortage of technologically educated talent exists, and with the ever greater technological demands for talent, that shortage will likely grow. At the same time, in the ever more sophisticated E-conomy, it is not enough to develop and deploy advanced information technology. It is ever more necessary to have a well trained workforce. Without that, the ability to use and develop the E-conomy will be limited. The question becomes how to expand usefully and sensibly that pool of engineering and scientific talent and at the same time assure the broad improvement of the nations' primary and secondary system. Those objectives are not alternatives. They must both be accomplished. They must not be set as alternatives.

## Rules of the Road: Adapting Old Principles to New Settings

For the past two generations US Government rule making – and rule eliminating – despite up and downs, ins and outs, kept a strategic focus: create and preserve institutional and market openness and lively competition. Many very good decisions about market rules have helped bring us this far. Consider the rapid expansion of the Internet. Decisions that provided open access for Internet Service Providers and assured a fixed monthly charge for the local modem dial-in to the internet, over the local telephone system, to the local Internet Service Provider — though the accessed sites were distributed around the globe — facilitated the rapid residential expansion.[96] Or, second, consider that at one policy moment there was a notion that the government should build or promote the construction of an information "superhighway." The policy analogy was to the interstate highway system of the auto era. Quickly, however, it was realized that competition and deregulation were driving private players to construct advanced networks that together — the network of networks that is the Internet — constituted a privately constructed superhighway. Or, finally, consider the flood of venture capital. The change in what is called the "prudent man rule" permitted pension funds to participate in the venture business.[97] The consequence was a substantial increase in the scale of funds available for entrepreneurial start-ups and innovative undertakings. Consider the role of stock options in creating incentives for risk taking. Those stock options depend critically on both tax and accounting rules.

### *The New Policy Challenge*

The new E-conomy poses difficult challenges for policy, in part because it challenges so many of the institutions that underpin our existing market rules. All market economies require rules of the road; their individual markets rest on rules. Most rules are formal; they are part of the legal system. For markets to work there must be rules about property, defining who owns what; in many cases these must get rather specific. There must also be rules about deal-making, about what in a contract can be enforced by law and about what responsibilities are expected from the parties making the deal.

As tools for thought, information technology increasingly touches everything in an economy; the rules for that E-conomy will increasingly define not only how individual markets work, but also how the over-all market economy works. Consequently the decisions we make about the E-conomy will be critically important as both rules for the networks of information technologies that are defining new market relationships and for the new business system that has driven its development, use and value. Debate will ultimately be about the regulations and rules that shape the kind of network world we have, what kind of code-constructed realities and businesses we develop, and hence what kind of economy we build. The debates will be real and tough: we are beyond the point where simple tinkering will suffice and beyond the point where we can sustain the illusion that the Internet can exist apart from and independent of the rest of the economy and society. The cyber world is intertwined with, not independent of, our traditional world. We will not have a cyber world free of regulation.

Translating the old rules for a new era, not to mention creating totally new rules for totally new phenomena, requires real choices and decisions, not just casual tinkering. The new circumstances, often involving qualitative changes in business and social life, re-open established policy bargains. And the choice of rule will often have major outcomes in terms of private gain. New rules require that the political bargains among different interests and objectives that defined the current policies be renegotiated. In many important cases whole new political outcomes will be necessary. There will be debates about what kind of E-conomy, about what rules for Internet facilitated business reorganization, about what sorts of virtual communities with what rights of speech and anonymity, about what types of network arrangements, about which architectures of code are called for. Those debates will re-open, as we have noted, a diverse range of old but significant policy issues in new guises. These include access (the Internet Age equivalent of Universal Telephone Service), taxation, consumer protection, and communications security, as well as the difficult redefinitions of property and privacy. What these issues all have in common is that the existing policy balances of purposes and values will have to be recalibrated.

Privacy is one dramatic example of the necessity, and difficulty, of striking new political bargains. Extraordinary amounts can be known about any of us by monitoring our activities in a computer-based economy. The problem of privacy, arguably, becomes qualitatively new, reopened by technologies of private or public surveillance of a new and distinct kind. The bank or credit card company knows what we buy, and when and where we bought it. (It may monitor those spending patterns in search of anomalies, for example, unusual flower or jewelry purchases, that might suggest credit risks such as divorce.) The supermarket knows what you eat. The drugstore knows. So does the phone company as well as various web sites. An Intelligent Transportation System that manages traffic flows may know where you are, where you go, and when.

How may the data be used? Can it be combined? Or sold to an insurance company? Or provided to the IRS? Is the law in the United States, originally crafted to protect the citizen against the state and state actions such as wiretap, appropriate in an era in which privately controlled data may be provide a precise picture of our life? What rights should individuals, companies and governments have to this privately collected data?

One proposed policy approach would provide individuals with property rights in data about ourselves that we as individuals can elect to sell or withhold. A second approach would propose that the law require privacy for citizens, that there must be limits on the personal data that can be gathered or dispensed. Once encryption is proposed as a solution to questions of privacy and security of communication and transaction, the question quickly shifts to considerations of balance between privacy and community safety and protection. Whatever one may believe is the appropriate approach to privacy or the correct balance between privacy and community safety, new and significant issues about privacy and security are being raised – issues that will not be easily resolved.

What such issues as privacy, intellectual property, free speech, consumer protection or taxation have in common is that the debate about the kind of communities we would prefer becomes entangled with the way we will run our new electronic market places. For example: How, in the Internet era, do we balance between free speech and the protection of minors against inappropriate content? Should the solutions be technical and private, filtering devices that block access to what parents would reject; or solutions that require public rules? Some issues will be forced as network based transactions multiply. Whatever your views on taxation of e-commerce, simply imagine the consequences of most transactions taking place on the net, but untaxed. What happens to Main Street merchants– and to Main

Street itself? Public services from roads to schools, currently financed by sales taxes, would not end; but the structure of taxation would have to change. Indeed, the early conceptions of Internet governance with the notion that government could not, and certainly should not, intrude into a new world of cyber-space are themselves being adapted to the realities of commerce and social life.

Consider the question of security and encryption. Once again the balance between personal privacy and national security as well as police purposes has to be reset. Similarly the question of jurisdiction (which political entity is responsible) for matters such as taxation and consumer protection have to be rethought, and refought. The question of consumer protection asks whether the burdens on small companies will be as great as on large while still assuring the consumer that they are protected in e-commerce from the less scrupulous – but in cyber space often invisible – company.

Complicating these debates is the fact that rule making cannot be settled in one country alone. If privacy rules are different in Europe and the United States, how do companies from AOL to IBM operate? While particular issues are thought out and fought out, care must be taken to assure that diverse national solutions are sufficiently reconciled to assure the operations of the global information system

Because we are in the middle of a fundamental transformation, we should not be surprised that the policy choices are knotty. There are not going to be simple answers to these knotty problems, we must acknowledge that at the beginning. Instead, there will be difficult and often profound and important debates. Past policy– success that it has largely been– can only be a partial guide to the issues that confront us. It provides a frame to open a discussion of how to proceed in the next years.

## The Critical Rule-Making Decisions Define the Marketplace

Before turning to the particular issues, let us clarify the importance of getting regulation by, once again, by looking backward in order to see ahead. There have been of course other historical points at which property rights and systems of governmental regulation have been redefined. Past economic transformations have necessitated redefinitions of property rights, economic institutions, and the rules that govern economic activity. Consider, for example, a case from the early days of mass-production a little more than a century ago: the combination of the telegraph, the railroad and the refrigerated boxcar made possible the sale of cheap mass-produced meat. Chicago-based corporations invented the assembly (or rather disassembly) line, mass-dressed the beef in Chicago, shipped it to the population centers on the East Coast, and undercut east coast slaughterhouses by perhaps a third. The power of mass production could be realized– unless long-distance shipment was blocked by state regulatory agencies requiring on-the-hoof inspections within the state before slaughter. Without new rules– in this case federal preemption of health and safety regulation affecting interstate commerce– America would not have developed a high productivity, mass production Chicago meatpacking industry. Without changes in the rules that govern economic activity other mass-production industries made possible by new technologies would not have been able to transform our economic landscape. Consider investment in that earlier era. Massive investments in large factories were needed to realize the economies of scale possible in serving the mammoth national market; these required that savings be gathered out of tens of thousands of pockets to provide the equity capital. But who, in the absence of the protecting shield of limited liability, would commit their savings to equity investments in huge bureaucratic enterprises over which they had no control? At the time, limited liability was viewed by many as an exorbitant new privilege for investors. Yet in retrospect we see it as necessary if the possibilities for economic organization opened up by the new technologies were to be realized.

There will always be a pressing set of immediate and urgent issues, but each immediate issue brings us back to underlying and enduring questions. It is those essential questions that we must keep track of. Consider the question of visas for immigrant engineers. The diffusion of the new technology makes inevitable ever greater demands for scientific, engineering, and technical talent. Extraordinarily tight high-tech labor markets threaten to drive engineering and design to relocate to larger talent pools. The underlying question is how to assure an adequate supply of trained American engineers. Consider next the matter of stock options. There is a debate about how best to account for them, how to handle them on a company's books. Whatever the appropriate answer to the specific issue, the general discussion quickly turns to how to sustain an entrepreneurial economy, how to assure that the risk taking is channeled and liabilities clearly understood. Similarly, on-line trading may create ever more efficient markets, but it alters the dynamics of equity and bond markets. One discussion is how to maintain the financial stability of the economy in a fundamentally new financial and banking environment.

Three categories of rules require comment.

***Creating and Preserving Competitive Markets:***

An interplay between innovative technology producers and creative users has assured broad learning and experimentation throughout the market. Producers develop technology, but they don't do it alone. Lead users seeking competitive advantage from the application of the new technologies to their business problems are the other necessary half of innovation. Innovation is a process of experimentation and learning between technology producers and users.[98]

Once telecommunications deregulation began, deregulation in air travel and finance (banking, brokering, insurance) freed major companies in those industries to experiment with new applications of computing and telecommunications. The newly competitive environment in their own industries gave them every possible incentive to try to gain advantage on their competitors. Subsequently, other companies had to imitate the innovators, or leap-frog them by developing still newer applications– usually in conjunction with information-technology producers. Deregulation thus created eager experimenters willing to try new applications developed by information technology firms.

The critical role of lead users may explain the surprising (to some of us at least) jump ahead by U.S. producers as makers and U.S. user industries as consumers of the latest, network, stage in information technology in the past ten years. Producers and user industries in other technologically-powerful nations, for example Japan, with important advantages that seemed to fit well with patterns of technological development in past decades, seem from today's perspective to have sputtered and lagged behind during the build-out of the network phase of the E-conomy. Why? Japanese producers and Japan as a country did not lack access to the basic science, good engineers, or experience at developing a comparative advantage in electronics technologies. Japanese producers had achieved and still possess extraordinary levels of productivity in many sectors of advanced consumer electronics– TVs, VCRs, Camcorders, recorders, watches, microwaves– as well as memory semiconductors and semiconductor equipment.

But in the U.S., deregulated companies in key user industries eagerly sought new competitive tools and experimented with new organizational forms and new products and services. In Japan, telecommunications remained a regulated monopoly, and so established companies and entrepreneurial groups could not experiment in how they used telecommunications: they could do only what NTT (the monopoly telephone company) had planned for them to do. Japanese banks and brokerages remained regulated, so there was little competitive pressure to seek out new information technology applications to transform their businesses. Both the possibilities of experimenting with new uses for telecommunications and the supply of lead users eager to do that experimenting were absent.

More generally, user created networks have been essential throughout the American development of advantage in network and Internet technologies. This has been true from the days of networks based on private protocols of particular users through the current Internet. As we and colleagues have written:

> Experimentation by users and competition among providers, across the range of segments that constitute the Internet, generated a surge of self-sustaining innovation. Perhaps the most dramatic single example is the emergence and evolution of the World Wide Web, driven almost entirely by Internet users who pioneered all of its applications. The World Wide Web in turn facilitated a new surge of innovation that has ushered in Internet based E-commerce. This network openness and the user-driven innovation it encouraged were a distinct departure from the prevailing supply-centric, provider-dominated, traditional network model. In that traditional model a dominant carrier or broadcaster offered a limited menu of service options to subscribers; experimentation was limited to small scale trials with the options circumscribed and dictated by the supplier.[99]

Policies assuring competitive markets, deregulation and competition policy, were essential. In the very beginning it was antitrust that moved the infant transistor technology into the competitive realm. The then-monopoly AT&T was forced to make the new technology– invented at its Bell Labs– available to all. Had the transistor remained under monopoly control as AT&T's development review process tried to think of uses for it, recent industrial history would be fundamentally (but unknowably) different. It is highly likely that innovation and diffusion would have proceeded more slowly and narrowly, resulting in both fewer innovative products and fewer innovative competitive technology firms. New companies such as Fairchild, Intel, AMD, National Semiconductor took the new technology and led the process of innovation and risk taking that has brought prices down further and faster, and performance up further and faster, than with any other major new technology in history.

Most of the large integrated companies that dominated vacuum-tube consumer electronics– RCA, Philco, Sylvania– were soon bypassed by the new companies that were born and grew with the new technology. New (and some reborn) technology producers working closely with innovative users created new applications, many of which were not initially obvious: from automobile door locks and ignitions, through medical imaging and surgical equipment; to ATMs, personal computers and gene sequencers.

The creation of competitive markets in telecommunications was not an easy policy to establish or to implement. Deregulation, as it is typically called is, perhaps, a misleading term. Regulation did not disappear. Indeed, direct regulation has proven necessary in order to create competitive markets, and the process is far from complete. Initiative did not originate in the Congress, or in the Executive; it fell to the courts on anti-trust grounds, as did years of detailed oversight to implement the decisions. Creating open and competitive market places in the heart of the new E-conomy is likely to prove to be even more difficult. There are core products, such as software, that have high fixed costs for development and extraordinarily low costs of replication and distribution; many also have "network externalities," as in the value to me of using a particular software increases the more other people use it. The Microsoft case raises many of these considerations.

### *Next Generation Network Regulation*

Deregulation and competition drove the rapid build-out of private networks in the United States and the rapid private take-up of Internet access. American leadership in equipment and application was intertangled with the leadership in network deployment. Now, as we move to next generation Internet, wireless networks, and high speed Internet access in homes and small businesses, the question reposes itself: how to sustain competition and in which parts of the market? The answers will be critical.

### *Rules for Intellectual Property and Regulatory Authority*

The E-conomy is an "idea economy." Certainly economic growth has always been motored by ideas: moveable type, steam engines, power looms. Given the increasing pace of innovation that rests on ever new ideas and the importance of information based products that are easily diffused in perfect form over digital networks, the question of intellectual property becomes central. The growing specialization of the US economy in the industry of innovation itself means that we now have an economy that is more specialized in the high-value added role of creating and commercializing ideas. The notion of Intellectual Property and the economics of ideas now matters to us in an extremely serious way.

Ideas and "information goods" have particular characteristics that distinguish them from ordinary goods. These include 1) marginal costs of reproduction and distribution that approach zero; 2) problems of transparency (in order to buy it I should know what the information or idea is; once I know it, in many cases, there is no need to buy it); and 3) non-rival possession. (If you have a hamburger, I cannot have it. But if you know something, and I learn it, you still know it. Once I know it, I no longer have an incentive to compensate you to teach me.) Together, these characteristics conspire to make market solutions problematic. [100]

Consequently as property, ideas are legal constructs. They pose knotty kinds of policy problems. We want the ideas to circulate in an intellectual commons. Otherwise how do we have progress either in technical forms or in the arts? Yet, if my ideas are available to you without cost, my economic incentive to generate those ideas is reduced. Ordinary property law must create an incentive to produce (keep the fruit of your labor) as well as protect the right of possession. Intellectual property law aims only to create the incentive to produce; it ignores the rights of possession. Patent and copyright law defines a fixed period for the property right; ordinary property law does not say that after a certain time, you lose possession of your shares or your house.[101] The policy question, then, is how do we balance incentives to inventors, authors and entrepreneurs to generate new ideas, while at the same time sustaining the intellectual commons, the possibility for others to use ideas as building blocks for new ideas. The emergence of a digitized E-conomy opens out a broad range of issues. That E-conomy creates new products and transforms established industries with the new ways it transforms storage, search, diffusion, and indeed generation of ideas and information. It reopens issues such as rights to copy because previously copies generally involved degraded quality – a photocopy is not the equivalent of an original – or substantial cost. Intellectual property, of course, covers many things and does so in so many forms that the debate will be difficult and constant.

There are five debates that situate the policy problem. Those debates appear over and over. The first debate concerns what should be covered by intellectual property. We have already touched on the notion of whether our personal information – data about us as economic, social, and indeed genetic beings should be covered. Should business models, such as the idea of an electronic auction, be covered? Should the look and feel of a computer screen be covered, as Apple argued in a court fight with Microsoft when Windows took on the texture of Macintosh? Should the description of the human genome be owned? The second debate concerns who should own the property right? Do I own information about myself, and anyone wanting to use that information or sell it to a user, must obtain my explicit permission. Or should the compilers of data bases, the banks, merchants and agencies who electronically track my activities own that information? The third debate is about how strong the coverage should be. Too often the instinct will be to resolve a problem by extending strong intellectual property rights when the problem may require other solutions. The fourth debate is about the appropriate mechanism of protection. Conventionally, patents cover discovery or invention with a specified, practical application, while copyrights cover forms of expression. What is "software" used to control a robot or direct a web browser: expression or invention? But set aside this evident debate, should I simply protect my intellectual property with digital code, the digital architecture of the product itself. I can instruct the program to self-destruct the fourth time it is installed, or for copied music or photos to steadily degrade as copies are made. Evidently code will not protect all IP, but it will protect much. Or, should contract between buyers and sellers, those complex agreements we all ignore when we rip open many software packages or click on past the restrictions required by a web site, shape the use of ideas and information. Fifth, as European-American disputes and debates about matters such as data base protection and privacy suggest, these matters can no longer be solved separately in each country, or unilaterally by any one.

## Flexibility and Inclusion

The E-conomy is about structural transformation: about doing new things and doing old things very differently in different organizational forms. Thus it demands flexibility to generate prosperity, and it rewards adaptability. Many observers in Europe and Japan credit the superior performance of the American economy over the past ten years to its superior flexibility: government has tried to keep markets open and competitive; new companies can be created quickly and easily; new institutions such as venture capital firms can assess risk and provide capital; stock options and other forms of payment via ownership rights make it possible with very little real money to recruit a work force willing to share the risks of a new venture in exchange for a share in the potential gains; dense networks of supplier firms permit access to key materials, components and capabilities, ranging from financial management right through manufacturing itself. Flexibility already characterizes many industries. But this new business system for structuring and restructuring business, best exemplified in the Silicon Valley system, is only the tip of the flexibility iceberg. For the big benefits in productivity to be realized, these new technologies must diffuse throughout the economy, often with difficult changes and adaptations. Ultimately that means making the E-conomy work for the community; one can choose to do that because it is necessity for development or because one believes it is simply the right thing to do, but it will be necessary.

In the narrowest sense inclusion is a matter of avoiding what has come to be called a digital divide. Inclusion must mean access to the new fabric of information, community, and transaction. Generations ago America chose to include all Americans in the telephone system. We created a doctrine of Universal Access that served us well. But it was easier to create rules for Universal access to the telephone than it will be for Internet based information systems. First, once a phone was run into a house and a dial tone activated, the definitions were easy: so many minutes within a particular distance. The existence of a monopoly provider made implementation of these rules rather easy. The phone company would adjust rates to provide the cross subsidies. Finally, the telephone took no special knowledge to use. Everyone could quickly learn to dial and talk.

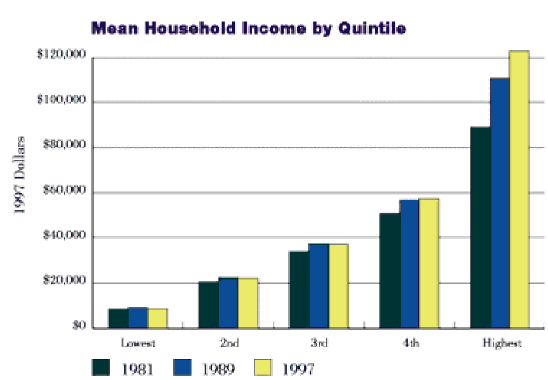
For the Internet the definition of access, and appropriate equivalents of "universal access," is much trickier. There is no simple provider to internalize the cross subsidies. There is no simple equivalent of a dial tone and a local call. Questions pose themselves: Is broadband necessary? Access to what kinds of services? Finally unlike the telephone or television, education creates a formidable differentiation between Internet information haves and have-nots. The greater the education level the greater the value, in most cases, of the benefit of Internet access.

There are, of course, substantial private benefits to be won by private firms providing Internet access and, beginning now, assuring broadband always on Internet access. The competitive struggle to provide residential broadband access among Bell Operating Companies offering Digital Subscriber Line providers, AT&T offering cable broadband access, and soon certainly, some form of wireless connection. Nonetheless, there will be geographic and economic have-nots. Geographic have-nots are those who for reasons of location cannot reasonably access the new networks on terms comparable to their city cousins. Social have-nots are those who cannot afford such access. The policy question is obvious. Should there be policy to assure a more rapid roll-out of the possibility for connection, of policy to subsidize access for particular groups?

Inclusion and flexibility, critical for enabling and smoothing this transition rest, more fundamentally, on at least two policy areas. The first is education. Formally educated Americans, whatever their academic field, find it easier to adapt to new organizational forms and the need for new skills as their jobs change, or to switch companies.[102] Education is the key to productivity, flexibility and inclusion. It starts at the quality and orientation of education in our public schools– serious achievement in math, reading, writing; hands-on experience with Internet based research and communication. It extends through specialized training and life-long training and education programs.

The second critical policy area is full-employment. Nothing makes flexibility easier than full employment. If employees know they could get a roughly equivalent job quickly should their current job disappear or become intolerable, they are much more prepared to accept the risks and pursue the benefits of change. Our economy's ability to sustain full-employment rests on correct macro-economic policy by our government. Specific policies such as pension and health insurance portability (meaning that such social protections are maintained when jobs change) greatly reinforce the positive impact of a full employment environment.

As has been the case throughout industrial history, development has meant the destruction of particular jobs, professions, specialties, and the emergence of new ones. But often the people who fill the new jobs are not the people who filled the old ones. Flexibility is discomforting; it is, by definition, up setting. Institutions– and people– resist changes that are not clearly and visibly to their benefit. Flexibility must be based on inclusion. For if the benefits are not broadly understood, broadly seen as accessible, and broadly shared, the transformation will be stunted, at whatever economic price. Policy aiming at flexibility must, therefore, aim at inclusion.

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# CONCLUSION

Our tools for thought– our modern information technologies– magnify and focus brain power in a way analogous to the way the tools of the Industrial Revolution magnified and focused muscle power– and changed the world. Information technology is the most powerful tool-set yet: in addition to enabling wholly new things (e.g. biotechnology, wireless communication), information technology significantly enhances the power and finesse of all previous tools.

With unprecedented speed and scale information technology has shot out of the lab, past the phase of esoteric lead uses and into the broader society. Cyberspace is not just entering the broad economy; it is transforming it. In so doing, information technology, especially its spearpoint, the Internet, is losing its innocence.

The World Wide Web is getting inextricably entangled in the webs of law, custom and commerce – the tissue of our daily lives. The consequence is that cyberspace will no longer be a policy free zone. Indeed, it will be a focus for difficult – and therefore uncertain – policy making. The issues have moved from the narrowly technical through the narrowly legal into fundamental questions of how to organize our markets and our society. Under the best of circumstances the policy risks are high. The technology and the questions it raises pertain to matters far removed from the experience of the policy making community. But because they are not narrowly technical or legal, they are not the kind of tech policy that could be confined to a small, isolated community of experts. The E-conomy now intrudes into too many domains of daily life, affects too many economic interests, and raises too many broad social questions to continue in a policy-free incubator or an expert enclave.

This background briefing on the E-conomy aimed to provide a context and a structure for those policy debates by defining the stakes, the forces and issues at play, and an agenda – not a choice of outcomes – for policy debate. That policy agenda is structured under three broad headings:

- **Public investment** in science and technology and in the technologically educated people needed to realize the benefits of the Economy. Included under this heading is the re-opened question of government's role and the institutional structures which launch markets for next generation technology.

- **Rule making** for the E-conomy, which extends across such thorny issues as privacy, security, and the definition of new property rights and responsibilities necessary for markets to function effectively and in consonance with American values and purposes.

- And the basic issues of institutional and labor market **flexibility and inclusion**.

It is a tough agenda.

# NOTES

1 Alan Greenspan (1999), "Testimony of Chairman Alan Greenspan Before the Committee on Banking and Financial Services," U.S. House of Representatives, July 22, 1999. http://www.federalreserve.gov/boarddocs/hh/1999/July/testimony.htm, downloaded January 22, 2000. Characteristically for a central banker, Greenspan went on to add that the evidence for this shift is "compelling but not conclusive."

2 For just a few of the attempts to understand and analyze this shift in the economic landscape, see Daniel Bell (1973), *The Coming of Post Industrial Society: A Venture in Social Forecasting*

Moreover, those important changes in the business cycle that do take place may well be driven by forces independent of the rise of the E-conomy. Christina Romer, for example, argues that the real change in the business cycle is more likely to be due to the rise of independent central banks. See Christina D. Romer, "Changes in Business Cycles: Evidence and Explanations," Journal of the Economic Perspectives 13:2 (Fall), pp. 23-44.

4 See Intel Corporation, "Processor Hall of Fame," Intel Online Museum; http://www.intel.com/intel/museum/25anniv/hof/moore.htm, downloaded January 22, 2000.

5 See Jack Triplett (1999), "Computers and the Digital Economy" (Washington, DC: Brookings Institution); http://www.digitaleconomy.gov/powerpoint/triplett/sld001.htm, downloaded January 22, 2000.

6 Authors' approximate calculations based on estimates in Martin Campbell-Kelly and William Aspray (1996), *Computer: A History of the Information Machine* (New York: Basic Books).

7 For example, it took more than a century and a quarter after the invention of the steam engine in Britain before steam became the dominant source of power in nineteenth-century Britain, then the most industrialized nation in the world. Similarly it took seventy years following the initial commercialization of electricity for electric motors to replace steam as the source of power in America's factories. See Warren Devine (1983), "From Shafts to Wires: Historical Perspectives on Electrification," *Journal of Economic History* (June), pp. 347-372, p. 351. Similar comparisons are made in Paul A. David (1991), "Computer and Dynamo: The Productivity Paradox in a Not-too-Distant Mirror," *Technology and Productivity: The Challenge for Economic Policy* (Paris: OECD), pp. 315-347. The telephone, upon its initial commercialization around 1876, took until 1920 or roughly 45 years to reach a diffusion rate of 35% of households. See U.S. Department of Commerce, Historical Statistics of the United States, Part 2, Tale R-12, p. 783. Broader arguments on this point are made in Carl Shapiro and Hal Varian (1998), *Information Rules: A Strategic Guide to the Network Economy* (Boston: Harvard Business School Press), p. 9.

8 For a maximalist interpretation of the scope of the current transformation– a claim that it is producing not just an E-conomy but an

E-society and an E-polity as well as a genuinely new E-culture– see Manuel Castells (1996), *The Rise of the Network Society* (London: Blackwell). Castells argues that we are seeing the development of an "informational mode" that transforms production, experience, and power, and that gives rise to a society fundamentally based upon networks of information exchange.

9 A central term in Schumpeter's analysis of business cycles as technology-driven episodes in the uneven progress of economic growth. See Schumpeter (1939), *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process* (New York: McGraw Hill).

10 For an argument that rapid technological progress *alone* is insufficient for a true economic revolution, see J. Bradford DeLong (1999), "Old Rules for the New Economy," *Rewired* (December 9) http://www.rewired.com/97/1209.html, downloaded January 22, 2000 (A reaction to an early draft of Kevin Kelly (1998), *New Rules for a New Economy* (New York: Viking). Schumpeter's 1939 *Business Cycles* (New York: McGraw-Hill) in fact classifies the standard dynamic of economic growth by the particular leading sector of the moment. He sees a first wave of industrial growth from the 1780s until the 1840s based on steam power, followed by a second wave from the 1840s until the 1890s based also on railroads and steelmaking, and by a third from the 1890s until the late 1930s in which economic growth was based on the four leading sectors of electricity, motors, autos, and chemistry. See Schumpeter (1939), p. 170.

This notion of technological cycles or waves based on discrete technology-driven leading sectors has been taken up more recently by theorists such as Richard Nelson and Sidney Winter, Giovanni Dosi, Carlota Perez, and Christopher Freeman. See Giovanni Dosi et al. (1988), Technical Change and Economic Theory (London: Pinter). Peter Hall and Paschal Preston (1988), The Carrier Wave: New Information Technology and the Geography of Innovation 1846-2003 (London: Unwin Hyman) have written about a fourth and the current fifth wave, based on information technology.

11 See David Hounshell (1984), *From the American System to Mass Production, 1800-1932: The Development of Manufacturing Technology in the United States* (Baltimore: Johns Hopkins University Press).

12 Hip surgery is only one example of many medical procedures that information technologies will help revolutionize. Medical ro-

botics will eventually (though perhaps not for another two decades) move into brain and heart surgery as well. In addition to advances in "micromachining" that make possible the operating instruments themselves, technologies that manipulate information are at the forefront of this field. Recent advances vastly increase the usefulness of imaging, allowing surgeons– whether with their hands or via robotics– to adapt their procedures more closely to the patient's individual needs. In the case of hip surgery, this promises to reduce the need for costly follow-up operations 10 to 15 years later. See: http://www.redherring.com/mag/issue54/edge.html, downloaded January 22, 2000. And the forthcoming genetic engineering revolution would simply not be possible without modern information technologies.

13 See Michael J. Boskin, Ellen R. Dulberger, Robert J. Gordon, and Zvi Grilliches, "The CPI Commission: Findings and Recommendations," *American Economic Review*, Volume 87, no. 2 (1997), pp. 78-83. Michael J. Boskin, Ellen R. Dulberger, Robert J. Gordon, and Zvi Grilliches (1997), "Consumer Prices, the Consumer Price Index and the Cost of Living," *Journal of Economic Perspectives* (Fall).

14 A relationship called Moore's Law. Moore was initially somewhat overoptimistic: his first formulations saw a doubling every twelve months. In its eighteen-month formulation, Moore's Law has held up remarkably well since the 1960s.

Moore's Law still has at least several more doublings to go. How many more, however, is not clear. Researchers at Intel along with other academic scientists believe that Moore's Law may soon run into limits imposed by the molecular structure of silicon-based transistors. See John Markoff (1999), "Chip Progress Forecast to hit a Big Barrier," New York Times (October 9). Nevertheless, the semiconductor industry is currently poised on the threshold of a major milestone in the form of the gigahertz chip that cycles a billion times per second. Both IBM and Intel expect to produce these gigahertz chips by the second half of 2000. Lawrence M. Fisher, "New Era Approaches: Gigahertz Chips," New York Times, Februray 7, 2000.

15 Intel; http://www.intel.com/intel/museum/25anniv/hof/moore.htm, downloaded October 12, 1999.

16 Indeed, recent Apple commercials make much of the fact that its personal computers are now "personal supercomputers": classified

as "supercomputers" not to be exported to potentially hostile countries because of potential military uses. While Apple has made much of this classification of its systems based on the IBM-Motorola PowerPC G4 as supercomputers, the company is seeking a change in the law. It wants to sell the computers to the more than 50 countries covered by the ban. See http://cnn.com/TECH/computing/9909/17/g4.ban.idg/index.html, downloaded January 22, 2000.

17 At the end of the 1950s (when electronic computers had largely replaced electromechanical calculators) there were roughly 2000 installed computers in the world with average processing power of about 10,000 instructions per second. Today, forty years later, there are approximately 200 million active computers in the world with processing power that averages perhaps 100,000,000 instructions per second– a billion-fold increase. See Martin Campbell-Kelly and William Aspray (1996), *Computer: A History of the Information Machine* (New York: Basic Books).

18 Jack Triplett (1999), "Computers and the Digital Economy" (Washington, DC: Brookings Institution); http://www.digitaleconomy.gov/powerpoint/triplett/sld001.htm, downloaded February 2000.

19 Even before then the lead user had been the government. Charles Babbage's difference engine had been a British government-funded research and development project. The earliest application of large-scale electronic tabulating technology had been the government, specifically the Census Bureau. The national census of 1880 required 1500 clerks employed as human computers to analyze the data– and it took them seven years to do so. See Margo Anderson (1988), *The American Census* (New Haven: Yale University Press). By 1890 the Census Bureau was a testbed for Herman Hollerith's mechanical calculator.

20 Martin Campbell-Kelly and William Aspray (1996), *Computer: A History of the Information Machine* (New York: Basic Books), quote from Thomas Watson Jr.'s autobiography that "it was the Cold War that helped IBM make itself king of the computer business." SAGE accounted for one-fifth of IBM's workforce at its peak. See Thomas Watson Jr. and Peter Petre (1990), *Father and Son and Company* (London: Bantam Press). Relying on Flamm (1987, 1988), Campbell-Kelly and Aspray (1996) state that 2000 programmer-years of effort went into the SAGE system in the 1950s and early 1960s. Thus "the chances

[were] reasonably high that on a large data-processing job in the 1970s you would find at least one person who had worked with the SAGE sytem."See Kenneth Flamm (1987), *Targeting the Computer: Government Support and International Competition* (Washington: Brookings Institution); Kenneth Flamm (1988), *Creating the Computer: Government, Industry, and High Technology* (Washington: Brookings Institution).

21 SABRE was the first large-scale real-time information processing system. See James McKenny (1995), *Waves of Change: Business Evolution Through Information Technology* (Cambridge: Harvard Business School Press).

22 See Barbara E. Baran (1986), *The Technological Transformation of White Collar Work: a Case Study of the Insurance Industry* (Berkeley: UC. Berkeley Ph.D Dissertation).

23 The literature on this topic of the lead role played by users in generating innovation is vast. See B.A. Lundvall, *Product Innovation and User-Producer Interaction*, Aalborg, Aalborg University Press, 1985; Bangt-Ake Lundvall, "Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation, in Giovanni Dosi et al., *Technical Change and Economic Theory*, London, Pinter, 1988, pp. 349-369; Nooteboom, Bart. *Innovation, learning and industrial organization*. Cambridge Journal of Economics v23, n2 (Mar 1999):127-150. Slaughter, Sarah. *Innovation and learning during implementation: A comparison of user and manufacturer innovations*. Research Policy v22, n1 (Feb 1993):81-95. Hatch, Nile W; Mowery, David C. *Process innovation and learning by doing in semiconductor manufacturing*. Management Science v44, n11, Part 1 (Nov 1998):1461-1477.

24 Boeing's 777 is the best-known example, but computer-assisted engineering, design and manufacture are transforming the entire aerospace industry– not just a single firm or a single product. There are at least five major design-tool programs in use by such major aerospace firms as Lockheed Martin, Boeing, British Aerospace, Aerospatiale and McDonnell Douglas. See http://www.ndu.edu/ndu/icaf/isar.html, downloaded .

25 Microprocessors in cars today control windows, door locks, cruise control, braking systems, fuel mix, emissions control, and more. The number of microprocessors in a typical automobile has passed 30.

The hardware cost of these semiconductors was then some $1500. The software cost of programming and debugging them was perhaps the same. See David Mowery and Nathan Rosenberg (1998), *Paths of Innovation* (Cambridge University Press).

Note that this $3000 of today's computing power would have cost $90,000– more than four times the entire price of the automobile– at 1990's levels of semiconductor, computer, and software productivity. See James Carbone (1998), "Safety Features Mean More Chips in Cars," *Purchasing Online* (September 18)

http://www.manufacturing.net/magazine/purchasing/archives/1998/pur0915.98/092enews.htm, downloaded February, 2000. "High Tech Industry Positively Impacts Economies, Globally and Locally," The Kilby Center (September 9, 1997) http://www.ti.com/corp/docs/kilbyctr/hightech.shtml, downloaded February 24, 2000.

26 It is difficult to produce reliable estimates of the scope of the embedded microprocessor business. It is, however, possible to see the imprint and importance of this segment in computing in the decisions made by the producers of microprocessors. For example IBM is ceasing production of PowerPC microprocessors for mass-market microcomputers in order to concentrate on production for high-end embedded sales in automotive applications, communications devices, consumer electronics, and internet hardware. See "The PowerPC 440 Core: A High-Performance Superscalar Processor Core for Embedded Applications," IBM Microelectronics Division, Research Triangle Park, NC http://www.chips.ibm.com:80/news/1999/990923/pdf/440_wp.pdf, downloaded February 22, 2000. Motorola continues to produce PowerPC microprocessors for use in Apple mass-market microcomputers, but has also worked closely with purchasers who pursue applications unrelated to personal computers: a "PowerPC-based microcontroller for both engine and transmission control of next-generation, electronics-intensive automobiles due in 2000" that can handle "the highly rugged automotive environment," for example. See Bernard Cole (1998), "Motorola Tunes PowerPC For Auto Applications," *EE Times* (April 21) http://www.techweb.com/wire/story/TWB19980421S0011, downloaded February 22, 2000. Intel as well has put a considerable share of its mammoth venture capital funding into supporting the development of and purchasing technologies to enhance its competitiveness in the market for embedded chips. See Crista Souza, Mark Hachman,

and Mark LaPedus, "Intel Weaves Plan to Dominate Embedded Market," *EBN Online* http://www.ebnonline.com/digest/story/OEG19990604S0024, downloaded February 22, 2000.

27 It was technically feasible, after all, to send bits across 4000 miles at lightspeed during the reign of Queen Victoria– by telegraph. But it was very costly. See Tom Standage (1998), *The Victorian Internet* (New York: Berkley Books); Neal Stephenson (1996), "Mother Earth, Mother Board," *Wired* Volume 4(12), December. See also Yates, Joanne, and Benjamin, Robert I. (1991), "The Past and Present as a Window on the Future," in *The Corporation of the 1990s: Information Technology and Organizational Transformation*. Michael S. Scott Morton, ed. (New York: Oxford University Press) pp. 61-92.

28 On the role of users in promoting the trajectory of innovation in the telecommunications and data networking industries see Michael Borrus and Francois Bar (1993), "The Future of Networking" (Berkeley: BRIE); Francois Bar *et al*., "Defending the Internet Revolution: When Doing Nothing is Doing Harm."

29 After Ethernet inventor and 3Com founder Bob Metcalfe, who said that the value of a network is proportional to the square of the number of nodes on the network. See Carl Shapiro and Hal Varian (1999), *Information Rules: A Strategic Guide to the Network Economy* (Boston: Harvard Business School Press), pp. 173-225.

30 Kim Maxwell (1999), *Residential Broadband: An Insider's Guide to the Battle for the Last Mile*

31 Ever since 1987 the Internet Software Consortium (http://www.isc.org/) has run a semiannual survey to count the number of "hosts" on the Internet. By the end of 1999 their count will hit 60 million computers, all accessible one to another through the Internet. In October 1990 there were only 300,000 computers on the Internet. In August of 1981 there were only 213.

32 Jakob Nielsen argues that bandwidth increases at 50 percent per year in a Moore's Law-like manner, albeit at a slower pace. See Jakob Nielsen, "Nielsen's Law of Internet Bandwidth" http://www.useit.com/alertbox/980405.html, downloaded January 22, 2000.

33 Nua Internet Surveys; http://www.nua.com/, downloaded October 17, 1999.

34 Whether the first generation of high-bandwidth low-latency connections will be cable modem, DSL, or wireless connections will be a matter of market competition heavily influenced by policy choices. But the connections will arrive quickly. And there are subsequent generations of still higher-bandwidth connections on the horizon. Kim Maxwell forecasts video-on-demand beginning in 2003, and fiber optic cable to the home starting around 2015. See Kim Maxwell (1999), *Residential Broadband: An Insider's Guide to the Battle for the Last Mile* (New York: John Wiley and Sons). Note, however, that as of the end of 1999 less than 2.5 million people worldwide had broadband connections to the internet. See http://www.instat.com/pr/2000/mm9914bw_pr.htm, downloaded January 22, 2000.

For an analysis of the importance of low latency and high speed connections in making the internet useful, see Jakob Nielsen, "Usable Information Technology," http://www.useit.com/, downloaded January 22, 2000.

35 Jupiter Communications.

36 Vinod Khosla (December 17, 1999) "The Terabit Tsunami" slide presentation, Kleiner Perkins Caufield & Byers, khosla@kpcb.com.

37 These are the results from a series of Cisco-sponsored studies of the "Internet economy" See the University of Texas's Center for Research in Economic Commerce, http://www.internetindicators.com/indicators.html, downloaded February 2000.

38 See Robert Atkinson and Ranolph Court (1999), "The New Economy Index" (Washington: Progressive Policy Institute); http://www.neweconomyindex.org/.

39 For a brief survey of some of these experiments and their consequences, see A. Michael Froomkin and J. Bradford DeLong (1999), "Some Speculative Microeconomics for the New Economy" (Berkeley and Miami: U.C. Berkeley and Miami Law School) http://econ161.berkeley.edu/OpEd/virtual/technet/spmicro.html. Published in *First Monday* 5:2 (February 2000); http://www.firstmonday.org/issues/issue5_2/delong/index.html

40 Between the turn-of-the-last-century Sears catalogue and today, many entrepreneurs have thought that the relatively small stores of small town America incurred very large inventory and other distri-

bution costs, and that there should be a way to combine economies of scale in purchasing with economies of scale in distribution in order to satisfy small-town and rural consumers at significantly lower cost. Yet only Wal-Mart has managed to successfully accomplish this task.

41 Sam Walton (1992), *Made in America: My Story* (New York: Bantam Books), p. 281.

42 Note that these increases in real incomes were missed by the Government's statistical system, which did not take account of the rise of discount stores like Wal-Mart in its estimates of the cost of living. See United States Advisory Commission to Study the Consumer Price Index (1997), "Toward a More Accurate Measure of the Cost of Living: Findings and Recommendations of the CPI Commission" (testimony before the Senate Finance Committee, January 28, 1997). A secondary effect was to enrich Sam Walton, his family, and his associates. And a third effect was to bankrupt old-style competitors on Main Street, U.S.A. who couldn't or who failed to make the investments in "computers... satellites." Thus there is a sense in which Sam Walton was the first network deka-billionaire.

43 In part because these elements of economic destiny are not an equilibrium position predictable in advance but are *path-dependent*. See Paul David (1993), "Historical Economics in the Long Run: Some Implications for Path Dependence," in Graeme Donald Snooks, *Historical Analysis in Economics* (London: Routledge), pp. 29-40; Nathan Rosenberg (1996), "Uncertainty and Technological Change," in Jeffrey C. Fuhrer and Jane Sneddon Little, eds., *Technology and Growth* (Boston: Federal Reserve Bank of Boston), pp. 91-110; Giovanni Dosi *et al.*, eds. (1992), *Technology and Enterprise in Historical Perspective* (Oxford: Clarendon Press).

44 Paul David, "Computer and Dynamo: Computer and Dynamo: The Productivity Paradox in a Not-too-Distant Mirror," *Technology and Productivity: The Challenge for Economic Policy* (Paris: OECD), pp. 315-347.

45 Richard DuBoff (1964), "Electric Power in American Manufacturing" (U. of Penn. Ph.D. Diss.); Warren DeVine (1983), "From Shafts to Wires: Historical Perspectives on Electrification," Journal of Economic History 43:2 (June).

46 See Clayton M. Christensen (1997), *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Boston: Harvard Business School Press).

47 See Charles Ferguson (1999), *High Stakes, No Prisoners* (New York: Times Books).

48 See Katie Hafner (1996), *Where Wizards Stay Up Late: The Origins of the Internet* (New York: Simon and Schuster); Michael Hiltzik (1999), *Dealers of Lightning: Xerox PARC and the Dawn of the Computer Age* (New York: HarperBusiness); Douglas Smith and Robert Alexander (1988), *Fumbling the Future* (New York: Morrow).

49 James McGroddy, interview at UC Berkeley, California, Fall 1998.

50 See Josh Lerner (1999), *The Venture Capital Cycle* (Cambridge: MIT Press.)

51The US has been particularly successful in facilitating the activities of venture capitalists. In 1999 venture capital investments reached record levels in the U.S. amounting to $48.3 billion which represents a 152% increase over the $19.2 billion figure for 1998. Internet-related firms attracted two-thirds of this sum for 1999 with $31.9 billion. Northern California with $16.9 billion in venture funds was by far the largest regional recipient of venture largesses, almost double the next largest region, the Northeast. See Venture Economics News, February 8, 2000 at http://www.securitiesdata.com/news/news_ve/1999VEpress/VEpress02_08_00.html, downloaded February 8, 2000. See http://xent.ics.uci.edu/FoRK-archive/august97/0400.html, downloaded February 22, 2000.

52 The reorganization of manufacturing techniques and the principles of lean production are described in detail in James P. Womack *et al*. (1990), *The Machine that Changed the World* (New York: Simon & Shuster). For a somewhat more critical view of the lean production system see Martin Kenney and Richard Florida (1988), "Beyond Mass Production: Production and the Labor Process in Japan," *Politics and Society* 16:1, pp. 121-158.

53 See Robert Z. Lawrence (1984), *Can America Compete?* (Washington DC: Brookings); "The Hollow Corporation," *Business Week* (March 3, 1986), pp. 57-85; Bennett Harrison and Barry Bluestone (1982), *The Deindustrialization of America: Plant Closings, Community Abandonment, and the Dismantling of Basic Industry* (New York: Basic

Books); Michael Piore and Charles Sabel (1984), *The Second Industial Divide* (New York: Basic Books).

54 On the strategic choice of HP to defend the low-cost end of the printer market by introducing the inkjet printer, see class lecture, Sara Beckman, BA 290A-2 (Fall 1999). Maintaining inkjet market share also increased HP's bargaining position vis-à-vis Canon, the supplier of the laser printing engine itself. (The situation is further complicated by the fact that the inkjet printer was HP-developed technology while the laser printer was not, and HP had a bias toward invented-here technology.) Nevertheless, this strategy contrasts with the classic strategy of defending the high end of the market. See Stephen S. Cohen and John Zysman (1987), *Manufacturing Matters: the Myth of the Post-Industrial Society* (New York: Basic Books).

55 Timothy J. Sturgeon, "Turn-key Production Networks: The Organizational Delinking of Production from Innovation" in: New Product Development and Production Networks. Global Industrial Experience, Ulrich Juergens, ed. (Berlin: Springer Verlag, 1999, forthcoming October, 1999); Timothy J. Sturgeon, *Turnkey Production Networks: A New American Model of Industrial Organization?* BRIE Working paper no. 92A Berkeley: Berkeley Roundtable on the International Economy (1997a); Timothy J. Sturgeon, *Does Manufacturing Still Matter? The Organizational Delinking of Production from Innovation*, BRIE Working paper no. 92B Berkeley: Berkeley Roundtable on the International Economy (1997b).

56 On the theoretical and historical process of standard setting see Paul A. David, "Some New Standards for the Economics of Standardization in the Information Age," in The Economic Theory of Technology of Policy, Partha Dasgupla and P.L. Stoneman, eds., (London: Cambridge University Press, 1987), chap. 8; Paul A. David and Shane Greenstein, "The Economics of Compatibility Standards: An Introduction to Recent Research," Economic Innovation and New Technology," Vol. 1, no. 1 (1990), pp. 3-41. David makes a distinction between "standards agreements" that are negotiated, and "unsponsored standards" that arise more generally, even spontaneously, in competitive environments. While many of these unsponsored standards may emerge as optimal solutions to specific technological problems, it is sometimes the case that standards result from initial first mover advantage, that is, from initial specifications of a new technology established by start-up firms. Once es-

tablished, standards create positive feedbacks, lock-in, and path dependence owing to high switching costs that ensue as standards diffuse. Paul David, "Historical Economics in the Long-Run," op. cit. See also Shapiro and Varian, op cit. On the role of users in standard-setting see Michael Borrus and John Zysman (1997), "Globalization with Borders: The Rise of Wintelism as the Future of Global Competition," *Industry and Innovation*, 4:2, pp. 141-166.

57 On cross national production systems and networks of companies see Stephen S. Cohen and Michael Borrus (1996), "Networks of Companies in Asia" Berkeley Roundtable on the International Economy; Gary Gereffi and Miguel Korzeniewicz eds.(1994), *Com-*

*Silicon Valley and Route 128* (Cambridge: Harvard University Press, 1994); Stephen S. Cohen and Gary Fields, "Social Capital and Capital Gains in Silicon Valley," *California Management Review,* volume 41, no. 2 (1999), pp. 108-130.

61 See Daniel Raff and Manuel Trajtenberg (1995), "Quality Adjusted Prices for the American Automobile Industry, 1906-1940," http://papers.nber.org/papers/W5035, downloaded January 22, 2000.

62 Quoted in Leah Lievrouw, "Paradigm or Paradox? ICTs and Productivity," http://www.icahdq.org/publications/newsletter/sept_99/sept_articles.html, downloaded January 22, 2000.

63 See Council of Economic Advisers (1999), *1999 Economic Report of the President* (Washington: GPO).

64 See Erik Brynjolfsson and L. Hitt (1996), "Paradox Lost? Firm-level Evidence on the Returns to Information Systems Spending," *Management Science* (April); Erik Brynjolfsson (1993), "The Productivity Paradox of Information Technology," *Communications of the ACM*, Vol. 36, No. 12, Dec. 1993; Erik Brynjolfsson and L. Hitt (1998), "Beyond the Productivity Paradox," *Communications of the ACM* (August). All can be found at http://ccs.mit.edu/erik/, downloaded January 22, 2000.

65 Industry Standard website; http://www.thestandard.com/, using BEA and BLS data; updated by the authors.

66 See Paul A. David (1991), "Computer and Dynamo: The Productivity Paradox in a Not-too-Distant Mirror," in *Technology and Productivity: The Challenge for Economic Policy* (Paris: OECD), pp. 315-347.

67 See David Landes (1997), "The Fable of the Dead Horse; or, the Industrial Revolution Revisited", in Joel Mokyr, *The British Industrial Revolution* (Boulder: Westview Press), ch. 2, 132-70.

68 See Daniel Sichel (1997), *The Computer Revolution: An Economic Perspective* (Washington: Brookings Institution).

69 See Daniel Sichel and Steve Oliner (forthcoming), "Computers and Productivity," *Journal of Economic Perspectives*.

70 As Macroeconomic Advisors put it on September 9, 1999:

> From 1973, when postwar productivity growth

> slowed dramatically, through 1995, output per hour in the private nonfarm business sector grew just 1.0% per year on average. However, from 1995 through 1998 that rose to 1.9% and, over the last four quarters, productivity expanded at a 2.9% pace, rivaling rates last enjoyed consistently during the 1950s and 1960s. This acceleration is unusual so deep into a business expansion. If even part of it is sustained, the implications for the US economy are far-reaching. In the near term, faster growth in productivity makes accommodative monetary policy not just acceptable but maybe even desirable. Over a longer haul, the impact on the US standard of living would be profound, radically changing perceptions on issues ranging from the sustainability of today's equity prices to the affordability of the current Social Security System...

From "Productivity and Potential GDP in the 'New' Economy," http://www.macroadvisers.com/execsum.pdf, downloaded January 22, 2000.

Macroeconomic Advisors attributes about 2/5 of the recent acceleration in productivity growth to computers– both the increasing productivity of those who make computers, and the increasing productivity of those who use computers.

The senior principals of Macroeconomic Advisors are Joel Prakken, Chris Varvares, and Ken Matheny. The firm was formerly– before Laurence Meyer was appointed to the Board of Governors of the Federal Reserve– called Laurence H. Meyer and Associates.

71 Brent Moulton (1999), "GDP and the Digital Economy" (Washington, DC: Department of Commerce).

72 See Michael J. Boskin, Ellen R. Dulberger, Robert J. Gordon, and Zvi Grilliches, "The CPI Commission: Findings and Recommendations," American Economic Review, Volume 87, no. 2 (1997), pp. 78-83.

73 See Katherine Abraham, "Testimony of Katharine G. Abraham, Commissioner of Labor Statistics, Before the Subcommittee on Human Resources House Committee on Government Reform and Over-

sight April 30, 1997," http://stats.bls.gov/news.release/cpi.br043097.brief.htm, downloaded January 22, 2000.

74 See Jack Triplett and Barry Bosworth, "Productivity in the Services Sector," http://www.brook.edu/views/papers/triplett/20000112.htm, downloaded January 22, 2000.

75 Yet these improvements are surely an important, and possibly the dominant, sources of improvements in well-being. William Nordhaus argues that improvements in life expectancy *alone*– leaving improvements in the quality of life due to better medical care to one side– are as important as all other effects of economic productivity growth. See William Nordhaus (1998), "The Health of Nations: Irving Fisher and the Contribution of Improved Longevity to Living Standards" (New Haven: Yale xerox).

76 For example, this has been the ruling convention in measuring the product of government since the beginning of national income and product accounts. See Simon Kuznets (1948), "National Income: A New Version," *Review of Economics and Statistics,* 30:3 (August), pp. 151-179.

77 For a sample of recent work in this area, see Timothy Bresnahan and Robert Gordon, eds. (1997), *The Economics of New Goods* (Chicago: University of Chicago Press).

78 Wells Capital Management; *Business Week*, September 20, 1999.

79 Since network television programs are not a final output sold through the market– no one pays to view them– they do not show up as either consumption, investment, or exports in estimates of real GDP. They do, however, show up as a cost: as an input into the making of advertising services, which are an input into making the advertised goods and services. Thus the spread of network television showed up in the national income and product accounts as productivity regress.

80 Warren Devine (1983), "From Shafts to Wires: Historical Perspectives on Electrification," *Journal of Economic History* (June), pp. 347-372; Martin Campbell-Kelly and William Aspray (1996), Computer: A History of the Information Machine (New York: Basic Books).

81 See Tom Standage (1998), *The Victorian Internet* (London: Walker and Company).

82 See Alexander James Field, "The Magnetic Telegraph, Price and Quantity Data and the New Management of Capital," Journal of Economic History, Volume 52, no. 2 (1992), pp. 401-413; Robert Luther Thompson, Wiring a Continent: The History of the Telegraph in the United States 1832-1866 (Princeton: Princeton University Press, 1947); Alfred Chandler (1980), *The Visible Hand: The Managerial Revolution in American Business* (Cambridge: Harvard University Press).

83 See Elizabeth Eisenstein (1980), *The Printing Press as an Agent of Change* (Cambridge: Cambridge University Press).

84 When these tools do arrive, those who know how to use them effectively will have a significant role to play. Back in the early days before the world wide web Internet pioneer Ed Krol expressed amazement at the quality and quantity of information that could be turned up by someone skilled in keyword classifications and searches– by a librarian, in other words. See Ed Krol (1992), *The Whole Internet Guide and Catalog* (Sebastopol, CA: O'Reilly).

85 See I. Bernard Cohen (1987), *Revolution in Science* (Cambridge: Harvard University Press).

86 Economic historians debate whether the world today is more "globalized" than it was back on the eve of World War I. See Michael Bordo, Barry Eichengreen, and Jongwoo Kim (1998), "Was There Really an Earlier Period of International financial Integration Comparable to Today?" in *The Implications of Globalization of World Financial Markets*, (Seoul: Bank of Korea); Robert Wade, "Globalization and Its Limits," in Suzanne Berger and Ronald Dore, eds., National Diversity and Global Capitalism (Ithaca: Cornell University Press, 1996), pp. 60-88. However, there is no doubt that business organizations are more able to reach across national borders to finely organize their *internal* divisions of labor than ever before. See Michael Borrus and John Zysman (1997), "Globalization with Borders: The Rise of Wintelism as the Future of Industrial Competition" (Berkeley: BRIE) Working Paper 96B.

87 See Richard Barbrook and Andrew Cameron (1998), "The California Ideology," http://www.wmin.ac.uk/media/HRC/ci/calif5.html, downloaded January 24, 2000.

88 In many ways the recent merger of Vodafone Airtouch and Mannesmann, the largest merger in history at $183 billion, is a bet that wireless communications represents the future of the Internet.

See also Michael Mattis, "Your Wireless Future," Business 2.0, August, 1999; Nora Isaacs, "New Wireless Phones are Offering PC-Style Connectivity," Red Herring, October, 1999.

89 M.I.T. computer scientist Olin Shivers argues that Vernor Vinge's novella "True Names" is the best introduction to life in the information age. He writes that: "In my grad student days, we loved to sit around and discuss the implications of Vernor's ideas. Sixteen years later, I do research at MIT, and it's still fun to sit around and talk about how Vernor's ideas are coming to be... " See http://www.amazon.com/exec/obidos/asin/0312862075/, downloaded January 24, 2000; and Vernor Vinge *et al.* (forthcoming), *True Names and the Opening of the Cyberspace Frontier* (New York: Tor Books). Other visionary and cautionary works worth reading include David Shenk (1998) *Data Smog: Surviving the Information Glut* (San Francisco: Harper San Francisco); Gene Rochlin (1999), *Trapped in the Net* (Princeton: Princeton University Press); Shoshana Zuboff (1989), *In the Age of the Smart Machine* (New York: Basic Books); David Hudson (1997), *Rewired* (New York: Macmillan Technical Publishing).

90 On the origins of the Internet see John Naughton (1999), *A Brief History of the Future: the Origins and Destiny of the Internet* (London: Weidenfeld & Nicolson); Katie Hafner and Mathew Lyon (1996), *Where Wizards Stay Up Late : the Origins of the Internet* (New York: Simon & Schuster); see also the excellent review essay by Roy Rosenzweig, "Wizards, Bureaucrats, Warriors, and Hackers: Writing the History of the Internet," *American Historical Review* (December, 1998), pp. 1530-1552.

91 On the early history of the semiconductor industry and the diffusion of semiconductor technology among firms see: Martin Kenney, ed., *Silicon Valley: Anatomy of an Entrepreneurial Region* (forthcoming, Stanford University Press); Michael Borrus, James Millstein and John Zysman (1982), *U.S. - Japanese Competition in the Semiconductor Industry* (Berkeley: Institute of International Studies); Richard Florida and Martin Kenney (1990), *The Breakthrough Illusion: Corporate America's Failure to Move from Innovation to Mass Production* (New York: Basic Books).

92 On this connection between universities, scientific research and the commercialization of technology see in particular David C. Mowery and Nathan Rosenberg, *Paths of Innovation: Technological Change in 20th-century America* (Cambridge: Cambridge University

Press, 1998). Richard R. Nelson, "Institutions Supporting Technical Change in the U.S.," in Technical Change and Economic Theory, Giovanni Dosi et al., eds. (London: Pinter, 1988), pp. 312-329; Nathan Rosenberg, "The Commercial Exploitation of Science by American Industry," *in The Uneasy Alliance: Managing the Productivity - Technology Dilemma*, edited by Kim B. Clark, Robert H. Hayes, Christopher Lorenz. eds. (Boston: Harvard Business School Press, 1985); National Science Board, University-Industry Relationships (Washington: National Science Board, 1982); for a comparison of the U.S. with other countries see Richard R. Nelson, *National Innovation Systems: A Comparative Analysis* (Oxford: Oxford University Press, 1993). For a summary of the findings in this study see Richard R. Nelson, "National Innovation Systems: A Retrospective on a Study," Industrial and Corporate Change, Vol. 1, no. 2 (1992), pp. 347-374; Nathan Rosenberg, "Science, Invention and Economic Growth," Economic Journal (1974).

93 Robert Atkinson and Ranolph Court (1999), "The New Economy Index" (Washington: PPI); http://www.neweconomyindex.org/, downloaded February 2000.

94 This phenomenon is perhaps visible most clearly in the way universities are fueling high technology development in the regions where they are located. In addition to areas such as Silicon Valley, Seattle, Route 128, Austin, and the Raleigh-Durham Area, where University involvement in the creation of high technology corridors is particularly compelling, the University of Texas at Dallas, the university of Pittsburgh, university of Alabama at Birmingham and the universities of South and Central Florida are also awning high technology corridors. See Carey Goldberg, "Across the U.S., Universities are Fueling high-tech Booms," NYT, October 8, 1999, pp. A1, A 20; Research Institutions "are indisputably the most important factor in incubating high-tech industries." They provide companies with ideas as well as a steady stream of engineering talent. See Ross C. DeVol, America's High Tech Economy: Growth, Development and Risks for Metropolitan Areas, (Santa Monica: The Milken Institute, July 13, 1999).

95 See in this regard AnnaLee Saxenian (1999), *Silicon Valley's New Immigrant Entrepreneurs* (San Francisco, Public Policy Institute of California).

96 On the relationship between open access and the expansion of

Internet users see Francois Bar, et al., *Defending the Internet Revolution in the Broadband Era: When Doing Nothing is Doing Harm.* BRIE Working Paper 137.

97 On the changes in the so-called "prudent man rule" that transformed the venture capital industry see especially, Josh Lerner (1999), *The Venture Capital Cycle* (Cambridge: MIT Press).

98 The literature on learning and innovation is vast. See especially Christopher Freeman (1982), *The Economics of Industrial Innovation*, London: Pinter; B.A. Lundvall (1985), *Product Innovation and User-Producer Interaction*, (Aalborg, Aalborg University Press); Bangt-Ake Lundvall (1988), "Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation," in Giovanni Dosi et al., *Technical Change and Economic Theory*, London, Pinter, pp. 349-369; Nooteboom, Bart (1999) *Innovation, learning and industrial organization*, Cambridge Journal of Economics v23, n2 (Mar:127-150); Slaughter, Sarah (1993) *Innovation and learning during implementation: A comparison of user and manufacturer innovations.* Research Policy v22, n1 (Feb:81-95). Hatch, Nile W; Mowery, David C. (1998) *Process innovation and learning by doing in semiconductor manufacturing.* Management Science v44, n11, Part 1 (Nov:1461-1477).

*99* This quote comes from Francois Bar et al., (1999), "Defending the Internet Revolution in the Broadband Era: When Doing Nothing is Doing Harm" BRIE Working Paper 137, p. 7.

100 Brad DeLong, using insights from Paul Romer, raises the possibility that as information assumes more of the value in goods and services produced and traded over electronic networks, markets appear increasingly less capable of pricing such items. He goes on to conclude that in an economy when the typical commodity is non-rival and no transparent, and most of the value produced is in the form of information goods, "... we can expect monopoly to become the rule rather than the exception in the structure of industry...The antitrust division of the Justice Department might become the most important branch of the government, as it tries to keep the structure of industry as competitive as possible." J. Bradford DeLong (1998) "How 'New' is Today's Economy?", *Wilson Quarterly*, and http://econ161.berkeley.edu/comments/how_new.html

101 See Lawrence Lessing (1999), Code and Other Laws of

Cyberspace (New York: Basic Books), pp.133ff.

102 The unemployed in California as of 1992 averaged two years of education more than the unemployed in Michigan in 1983. The first found new jobs paying a substantial fraction of their old jobs at a rate nearly twice as fast as the second. See Bakos, J.Y. and Brynjolfsson, E. (1997) "Organizational Partnerships and the Virtual Corporation," Chapter 4 in *Information Technology and Industrial Competitiveness: How Information Technology Shapes Competition* (Kluwer Academic Publishers).

103 Robert Atkinson and Ranolph Court (1999), "The New Economy Index" (Washington: PPI); http://www.neweconomyindex.org/, downloaded February 2000.