Services with Everything:

The ICT-Enabled Digital Transformation of Services[1]

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Introduction:

A fundamental transformation of services is underway, driven by developments in information and communications technology (ICT) tools, the uses to which they are being put, and the networks on which they run. Services were once considered a sinkhole of the economy, immune to significant technological or organizational productivity increases.[i] Now, they are widely recognized as a source of productivity growth and dynamism in the economy that is changing the structure of employment, the division of labor, and the character of work and its location.[ii] Yet, the actual character of this transformation is often obscured by the increase in jobs labeled as services and by a focus on the digital technologies that, certainly, are facilitating this transformation.[3] This transformation, central to the growth of productivity and competition in the economy, poses basic policy and business choices.

The core of our story of the services transformation is not about the growth in quantity or value of the activities labeled services, the conventional emphasis of much of the writing about services. Nor is it about the revolution in digital technology. Rather, it is about how the application of rule-based information technology tools to service activities transforms the services component of the economy, altering how activities are conducted and value is created. When activities are formalized and codified, they become computable. Processes with clearly

[3] The conventional view, summarized effectively by the National Academy of Sciences, is that growth since the mid-1990s was largely driven by the rapidly falling cost of processing power (following "Moore's law," which predicted that the number of transistors in integrated circuits – roughly, processing power – would double every two years) and heavy corporate investments into ICT Dale Weldeau Jorgenson and Charles W. Wessner, eds., *Enhancing Productivity Growth in the Information Age* (Washington, D.C.: National Academies Press,2007), Dale Weldeau Jorgenson, Mun S. Ho, and Kevin J. Stiroh, *Information Technology and the American Growth Resurgence*, Productivity ; V. 3 (Cambridge, Mass. ; London: MIT, 2005).

However, remarkably, the NAS report only notes the significance of services and ICT in a couple sentences; "A structural change most associated with the New Economy today is the transformation of the Internet from a communication media to a platform for service delivery [which has] contributed to the remarkable growth of the U.S. service economy… new business models, enabled by the web… will contribute to sustaining the productivity growth of [sic] U.S. economy." Jorgenson and Wessner, eds., *"National Research Council"*, 22-23. What they treat as an endpoint, this paper takes as the beginning.

defined rules for their execution can be unbundled, recombined, and automated. The codification of service activities allows the rapid replication, analysis, re-configuration, customization, and creation of new services. We call this the Algorithmic Revolution.[iii] Traditional business models can be made more productive, extended with ICT tools. And entirely new business models can be created, offering services previously impossible at any price. The Algorithmic Revolution in services is profoundly changing how firms add value.

There are significant implications for how firms compete. Services are increasingly the way that firms pursue value-added activities to avoid ever-faster commoditization of products, that is to avoid competition based solely on price when market offerings are relatively similar. However, the unbundling of services activities themselves accelerates this commodification, since competitors have the same efficiency-enhancing business process and infrastructure services available to them. Firms increasingly become bundles of services purchased on markets, and at the same time some of those in-house business functions that are maintained are then offered as services. A consequence is that the distinction between products and services blurs, as manufactured products are increasingly embedded within and recast as services offerings. Clearly, traditional sectoral boundaries break down, as information and services offerings bring previously unrelated firms into direct competition.

Likewise, the consequences for business organization, production, and work are profound, just as work was transformed by the evolution of manufacturing. The automation of basic activities both frees, but also requires, professionals to perform more advanced tasks. And the analytical tasks of managing information flows generated by ICT-enabled services often require a different set of skills than providing the service itself.

Capturing the possibilities from the services transformation presents new policy challenges for governments and regions. Services are deeply rooted in social rules, conventions, and regulations. Consequently, capturing the value possibilities inherently means recasting the rules, regulations, and conventions in which the services are embedded.[iv]

Our argument unfolds in three parts. Part I depicts the dramatic and pervasive transformation of services. Part II introduces several analytic concepts and provides a framework for analyzing the transformation. Part III explores the policy challenges raised by the transformation, outlining several recommendations.

Part I: The Services Transformation Unfolding

The transformation of services with ICT tools is dramatic, pervasive, and far-reaching. Activities are transformed, firms are turning to services in pursuit of value, and traditional boundaries are breaking down between products and services, manufacturing and services, and traditional industrial sectors.

The Algorithmic Revolution Transforms Activities

With the Algorithmic Revolution, tasks underlying services can be transformed into formalizable, codifiable, computable processes with clearly defined rules for their execution. The inexorable rise in computational power means that an ever greater range of activities are amenable to expression as computable algorithms, a growing array of activities are reorganized and automated.[v] Indeed, core activities in services from finance through nursing – can be captured and expressed as digital information. The examples abound, become commonplace. Bank ATMs have automated simple bank transactions, and consumers increasingly book airline tickets and car rentals online. In major enterprises, payroll processes have been reorganized and largely automated. Few employees, if any, within major firms still know how to compute payroll checks, with their myriad deductions, overlapping tax districts, reporting restrictions, and other variables. Instead, the knowledge and process details are embedded in software, usually offered as external specialist services.

Existing activities, when converted into computable processes, often take on new purposes and create new forms of value. For example, the act of making a purchase at a supermarket or retailer has transformed from a simple monetary transaction to a data-generating activity. At the beginning of the application of ICT to retail, of course, inventories were monitored.[vi] Then, increasingly fine-grained information of not only inventories, but of customers began to be collected to be analyzed – to capture consumer preferences and consumption patterns, as well as to manage inventories and supply chains, and sometimes, sold to third parties. Accenture transformed its data management service into a new value-added service of data monitoring. Its initial service, offered to pharmaceutical companies, was to manage the latter's clinical trial data. Accenture then leveraged its ability to analyze this data, offering back to pharmaceutical firms a service to monitor the reactions of test subjects to drugs.[vii]

In-house business functions become available as services for purchase. That is, firms can chose to outsource those previously internal business functions, purchasing them as services in the market. A firm may, conversely, package and sell those services to others. As the range of in-company business tasks that can be digitized and manipulated expands, activities can be *unbundled* – separated from surrounding processes and tasks – with ever-finer levels of granularity. Combined with the increasing ability of heterogeneous ICT systems to exchange information with others,[viii] tasks can be moved outside companies and offered as services. Business functions ranging from accounting, computing, payroll, supply chain management, and even semiconductor manufacturing and R&D, can now be purchased on markets. More than ever before, firms are becoming an agglomeration of services offered by others, linked by ICT systems.

This *unbundling* of service activities is the counterpart to the decomposition of manufacturing, in which modularity in product design enabled manufacturing supply chains to be broken apart and spread across multiple corporate boundaries (outsourcing) and national borders (offshoring).[ix] In both cases—the unbundling of services and decomposition of manufacturing—it is the re-composition that is critical to sustaining market position and driving productivity. The issue is how the elements are constituted into products and services, both in constituent modules/bundles and in final offerings, requiring constant innovation.

Repositioning Services to Avoid Commoditization

Intense global competition, the array of newcomers from diverse countries and the rapid diffusion of technology, means that many products face intense price competition. That is, the products become commodities, largely interchangeable from their rivals and hence competing principally on price, – even if they become more sophisticated. As firms seek to avoid ever-faster commoditization, many are repositioning the role of services in their core business models. Increasingly, firms see services as the solution to creating defensible positions in markets.[x] They use them in a variety of ways.

Firms' hardware offerings are increasingly enhanced in value by ICT-enabled services offerings. Apple's iPod is more than an attractively designed mp3 player. Its integration with the iTunes software was critical to its commercial success, and Apple's online music store revolutionized the way music is sold.[xi] Komatsu, a Japanese construction machinery firm, sells products with embedded sensors; these sensors send detailed information not only about the deterioration of parts, but also fuel usage and other information, to the company's headquarters. As a result, Komatsu can notify its customers in developing countries if fuel is being siphoned, and it can even remotely halt the operation of machines if lease payments are overdue.[xii] Similarly, John Deere offers agricultural equipment that embeds an array of services. Location-referenced soil samples can be collected, analyzed, sent wirelessly to a remote database, which both helps "map" the fertilizer applied and adjusts the fertilizer mixtures in real time.[xiii]

Some firms go further, *shifting their core businesses from selling products towards offering services, often delivered via ICT networks*. IBM, for example, transformed itself from a product company in which services support provided competitive advantage, to a services company embodying products in its offerings.[xiv] Emblematic of this transformation was IBM's sale of its Thinkpad notebook computer division to the Chinese company Lenovo, and its acquisition of PricewaterhouseCooper's consulting arm. While still deriving significant profits from its hardware offerings, IBM's central focus has been on its service offerings, which include management consulting, running firms' ICT operations, and providing a wide range of functionality for firms with its software. IBM's most recent "Solutions for a smarter planet" campaign, with a wide range of target customers ranging from banking, buildings, education, and energy to food, healthcare, government, oil, retail, traffic, water, and more, demonstrates just how far they have gone in focusing on services.

The array of examples of expands continuously. Some are engaging stories. Consider Wireless Fasteners. Helial screws – the screws we are familiar with today with a thread cut into it – was a revolutionary technology when introduced widely in the 1400. They were hand-made by craftsmen until the invention of a screw-cutting lathe in the late 1700s, and the mechanical production of screws and bolts played a major role in the industrial revolution. As mass production along the lines of Henry Ford's factories took hold in the early 1900s, an integrated nut-and-bolt system was invented, creating the tooling and nut and bolt mechanism that could be integrated into mass production environments. TZ Group, an Australian company, takes the next step in fastening technology. It designs wireless enabled fastening systemsmeaning that potentially labor-intensive tasks such as reconfiguring aircraft seats can be made more efficient. These wirelessly controlled ‘Nuts and bolts’ enable a technician to remotely unlock any number of seats to be reconfigured, and once repositioned or replaced, they can be re-locked on command. Similar systems are now being developed for use in many other industries, from automotive and marine applications to medicine and defense.

Consider the Chilean mining company CODELCO, the world’s largest copper producer. To increase worker safety and improve productivity, it has embarked on a program to retrofit heavy excavation equipment for robotic control through high speed, low latency, telemetry. This capability removed the need for workers to be collocated with the equipment enabling miners to move outside the mine into safe clean working environments. This remote control capability also dramatically reduced the number of miners required to deliver the same output capacity. These initial steps open up the possibility to view mining as a service business with remote controlled operations being offered to other companies and in other countries.

All these stories show that the traditional distinctions between products and services, never evident in the first place, are becoming ever less clear. *Products themselves can be transformed into services when delivered via ICT networks*. For example, software, which used to be a product distributed on physical media, is now increasingly repositioned as a service. Quicken, a software product if purchased on a CD in a box, becomes a service if the same software engine runs on the web, charging for access. Enterprise software for large companies increasingly takes the form of “Software-as-a-Service” (SaaS), with software delivered via the Internet and billed by usage. Even products as basic as data servers and computer processors are transformed into services delivered over ICT networks. Known collectively as "Cloud Computing," a large number of firms are offering storage and processing power, applications, and software development platforms remotely, with pay-as-you-go payment schemes.[xv]

Products can become portals to services, or are embedded in services. Apple's iPod is at once a product and a portal to its online music store. Likewise, Apple's iPhone is both a product and a portal to Apple's services platform; the iPhone's capability as a conventional phone is not its primary competitive attribute, as cellular handsets are increasingly commoditized. Amazon's electronic reader, the Kindle, is a product, but its primary value is in its integration with Amazon's online bookstore and magazine offerings.[xvi]

Conventional sectoral distinctions are collapsing into "value domains," in which the digitization of information brings previously physically distinct products and sectors into competition with one another, over less clearly defined customer bases.[xvii] The block of plastic we call a phone morphed into a smart phone that provides an array of different digitally founded functions and services.

Consider the evolving competition surrounding cellular handsets, digital cameras, portable music players, music distribution, and software. Until the early 2000s, Nokia competed in cellular handsets against firms such as Motorola, Ericsson, and the Japanese and Korean handset manufacturers. However, as digital cameras became embedded in cell phones, handset manufacturers were offering a function in the smart phone that implicitly competes with basic camera offerings from companies such as Canon, Nikon, and Casio.[xviii]

As digital music players became increasing popular, led by Apple's iPod and its iTunes online store – which proved consumers were willing to pay for legally downloaded music –

Nokia, other handset manufacturers, and cellular carriers entered this value domain. Cellular handset manufacturers began incorporating digital music player capabilities into their handsets, offering digital music services, such as Sony Ericsson's Walkman brand handset and Nokia's one-price, unlimited-use music licensing with its "Comes with Music" service. Cellular carriers around the world began offering their own music download services.[xix] Microsoft, which began its life as a software company, also entered this domain, offering its own mp3 music player and music download service.

As the computing performance of cellular handsets improved, bringing them ever closer to that of computers, they became an entry point for a different set of firms interested in their performance as a portal for online service offerings. Apple's entry into the cellular handset business, the iPhone, was not simply a handset, but a portal for an online mobile applications store. Microsoft already had mobile handset operating system offerings – it was on its sixth version when Apple introduced the iPhone – but Apple was first to recognize the potential of linking the handset to a services platform. Carriers in countries such as Japan and Korea were already offering mobile Internet service platforms, tightly linked to domestic handset offerings, but these services were confined to their domestic markets.[xx] More recently, Google moved from web-based services into the handset operating system and handset markets as well, with its Android platform followed by a handset offering.

Thus, competition within distinct sectors has extended into competition over "value domains." More players are involved, and there is less clarity over the boundaries of previously distinct product and user categories.

Blurring the Boundaries Between Manufacturing and Services

As the market border between products and services is eroded, the analytical distinction, and therefore the policy debates, between manufacturing and services is also blurred. The distinction between products and services was never completely clear; a window washer in a GM plant was classified as a manufacturing worker if employed by GM, but became a service worker if employed by subcontractor, even if the person and the task remained unchanged.[xxi]

This distinction between manufacturing and services has long been a fundamental assumption underlying economic analyses and policy debates. As the Algorithmic Revolution extends the range of computable activities, and as developments in software, processing power, and ICT networks enable increasing portions of corporate activity to be outsourced, the breakdown of this distinction is accelerating.

In the current era, manufacturing itself is offered as a service, with examples ranging from Taiwanese "fabless" semiconductor manufacturing firms to a company such as Flextronics, which manufactures electronic products under contract to brand-name suppliers (Original Equipment Manufacturing – OEM). For national accounting purposes, to understand sources of productivity, and to analyze the nature of labor and employment for policy debates, the question is whether these OEM firms should be considered manufacturing or service firms. On the other side, firms such as Apple and Amazon design their iPhones and Kindle electronic reader devices, but manufacture them on an OEM basis; does this mean they are not engaged in manufacturing?

The reality is that firms and their suppliers are often increasingly intertwined, especially at the higher ends of production. The relationships between Unimerco, a Danish company with sophisticated knowledge about materials and tools, and its clients, provide an example. As ICT tools enabled advances in materials science, leading to a proliferation of new materials engineered for specific tasks, firms such as Airbus, Audi, and Ford turned outside their organizations for sophisticated knowledge and tools to work with the new materials. Unimerco transformed itself from a traditional toolmaker (manufacturing) into a firm that assists clients to develop production processes on the basis of its sophisticated management of knowledge and know-how of production systems more generally (services). The question is whether to consider Unimerco employees working on the floor of an aircraft or automobile factory helping to design the assembly line as manufacturing or service workers.

Finally, the myriad of accounting, legal, marketing and other service firms that take on formerly in-house tasks performed by large “manufacturing” firms blurs the distinction further.

Part II: Understanding The Services Transformation

The services transformation is pervasive. Consequently we need some tools to sort through the developments. First, we distinguish the underlying services activities, placing them on a spectrum ranging from irreducible to automated. We then consider the implications for productivity gains for each type of activity and lay out the limits of the transformation – a case for the enduring role of human judgment. Then we turn to a range of transformations in the business models built on top of the services.

The Services Spectrum

There is a range of services activities to consider, from irreducible, to hybrid, to automated. (see Figure 1)

Figure 1: The Services Spectrum

Irreducible Services	Hybrid Services	Automated Services
←	→	
Rely on humans to deliver services, which are typically created at the same time and in the same place they are delivered	Rely on a combination of humans and electonic tools to deliver services, using ICT and other systems to leverage or enhance human capabilities. This combination is often constituted as a system.	Rely on ICT or other technologies to deliver services that have been codified, digitized, and made available, often using electronic communication or distribution tools

Irreducible services rely on humans to deliver them. They are provided strictly by human beings, either because they require personal skills or attributes that only humans can offer, or for simple reasons of practicality and cost. Examples include the services provided by hairdressers, judges, psychologists, and priests.[4] In most cases, irreducible services are created at the same time and in the same place where they are delivered and used; such services cannot truly be said to "exist" apart from their delivery by humans in a particular moment and location. Irreducible services originally constituted the full range of services available in the economy, and they still make up the majority of services sold. The constant evolution and growing power of ICT tools constantly increases the range of services that can be "transformed" into automated or hybrid services.

By contrast, ICT *automated services* rely on digital ICT to manage information and deploy it in ways that are useful and valuable to customers. The services provided by a bank ATM, an Internet travel agency, or electronic systems for collecting road and bridge tolls are familiar examples.[5]

Some automated services compete with and threaten existing manual services, or extend their reach. In one sense, eBay's online auctions compete with traditional suppliers of human-based auctions services, such as Sotheby's, Christies, and hundreds of local auction houses. However, their real business success rests on extending the auction model to products and communities it that model could never reach without ICT tools.

Others offer entirely new services that could not be provided manually – for example, Google's online search capability can perform functions analogous to those of a traditional human librarian or research assistant, but with a degree of speed, efficiency, accuracy, and thoroughness that no human service provider could ever hope to duplicate. On-demand

[4] These examples, just four among scores that could be named, suggest the wide range of income levels, required training, and social or professional status among the providers of irreducible services.

[5] But not all automated services use digital ICT: for example, a self-service Laundromat is an automated provider of services that typically does *not* employ ICT, except to the extent that modern washing machines use microchips to control some functions.

delivery of video content by companies such as Netflix, allowing consumers to stream content previously only available on DVD or through illegal downloads, is another example.

Finally, *hybrid services* combine human and machine-based capabilities, either harnessing technology to improve and leverage the abilities of people, or depending on human talents to augment, deliver, customize, personalize, or otherwise add value to automated services. (They are not simply services in which some of the information involved in the process or transaction is captured electronically – such as a massage therapy business using digital software to manage reservations and accounting. Rather, a central element in the creation of value is digitally processed.)

A growing fraction of the most valuable and popular services are now hybrids. For example, accountants often rely heavily on software containing significant information about tax rules, bookkeeping systems, and financial principles that is able to store, analyze, update, and manipulate large amounts of data with ease, speed, and accuracy. However, she supplements the power of the software with personal judgment that helps her provide advice and insights suited to particular situations. Similarly, travel agencies handle most transactions digitally, but use human agents to handle complex cases and particularly high-value customers.

This system is highly dynamic, with particular services, service companies, and even entire industries moving, rapidly or slowly, from one position on the spectrum to another. As new technology and business systems are devised, the nature of possibilities continues to evolve. Services once practically unobtainable – access to vast stores of information now provided by a routine web search engine, for example – can now be obtained at virtually no cost in terms of time, money, or effort. The local limitations that constrain the availability of traditional human-delivered services are also reduced or eliminated by digitization.

The Services Spectrum and Potential for Productivity Gains, Transformations

Fully automated systems, the evidence suggests, offer the greatest potential productivity gains. Because they rely on digital systems, the power, efficiency, and affordability of algorithmic services can be expected to improve in accordance with exponential increases in computing capabilities. As chips improve and multiply, and the networks they form become exponentially more powerful, the possibilities for fully automated digitized services expand dramatically.

It is in the hybrid sector, where human delivery is combined with automation, that the deepest economic transformations are occurring. The value of hybrid services depends on human capabilities being augmented by increasingly sophisticated ICT systems.

Existing data on productivity, organized by traditional industrial sectors, is not optimal for measuring productivity increases across our divisions of activities – automated, hybrid, and irreducible. A rough estimate, taking select industries in which the bulk of activities fit into one category rather than another, yields the following (See Table 1).

Table 1: Productivity increases, US (1995-2003), Selected Industries

Activity Type	Industry	Productivity Increase
Automated	Telecommunications	70.5%
Hybrid	Retail Trade	53.0%
	Financial Intermediation	66.2%
Irreducible	Business Activities (Consulting)	16.9%

Source: Groningen 60-Industry database

The Limits of the Transformation: The Need for Human Judgment

The ultimate limits of the domain of the computable have been a significant source of debate among many observers, including the authors of this chapter. One extreme view is that the domain of the computable will eventually push out human judgment altogether. The opposite view is that human knowledge will continue to dominate—that core facets of knowledge can never be reduced to algorithms. Our view is that, while the domain of human activity that can be codified and automated increases, human judgment will continue to be critical.

We consider the financial debacle of 2008 to be the first major crisis of the information era.[xxii] Whatever its other implications, it will stand as a stark demonstration of the new logic of value creation, the transformed character of the service economy, and—paradoxically—the *heightened importance of human judgment* in a world where electronic tools for gathering, analyzing, and managing information are more ubiquitous and powerful than ever.[xxiii]

Modern finance is possible only with the ability to analyze enormous amounts of data, to perform complicated mathematical calculations and to act in real time. But how those possibilities are used—whether they create widespread benefits or generate disaster—depends on the judgments and talents of people.

In the case of the financial innovations of the 1990s and 2000s, disaster struck for a variety of reasons having to do with the mismanagement of financial knowledge. The possibility of complex computation often hid, and hid from the practitioners, the problems with the information they were using and the nature of risk itself.

First, loan companies and mortgage grantors took heavy advantage of the seeming clarity of credit scoring systems reduced to computerized algorithms, such as Fair-Isaac's FICO. Produced by credit bureaus, credit card companies, and specialists with access to tens of millions of loan records and the ability to analyze, these systems were found to be better predictors of repayment than the personal judgments of most loan officers. But tools like these work *only* if the factual underpinnings are correct and the models valid. Neither was the case in the subprime lending market—no-verification loans became quite common and were known among some bankers by the affectionate title of “liar’s loans,” while the possibility of massive foreclosure episodes was not taken into account in the scoring process.

Second, the pricing of derivatives is based on massive simulations of risk scenarios; the most complex multi-level derivatives require astonishing amounts of computing power to evaluate. These derivative products became feasible only when investment firms gained access to supercomputer-grade hardware and expert computer scientists and mathematicians. Certainly, the models were only as good as the assumptions and data underlying them; for example, most models did not take account of nation-wide decrease in house values. As important, many of the models rest on finding fits to historical data, rather than considering how the parameters and variables evolve, which makes them inherently immune to significant innovations in business strategies and unforeseen market conditions.[xxiv]

Third, the trading of securities, options, and other derivatives is dominated by “program trading”—computers making decisions and placing bids in thousandths of a second. This increased volatility, as programs kicked in response to swings in prices and other conditions stipulated in their code.

Finally, the securitization and sale of complex instruments became a global business, pulling in capital from around the world over networks. Few actually understood, for example, the real risks in the mortgages underlying the packaged securities.[xxv] Few individuals or companies had anticipated the true counter-party risks that were being undertaken. Crucially, there was a lack of transparency in the system which hid how risk was increasingly concentrated rather than diluted. The result was global financial disruption, and very nearly a catastrophic depression.

The lesson: Those who live by information also can die by it. One again, the old I.T. slogan, “Garbage in, garbage out” was validated.

Steve Lohr of the *New York Times* put it this way:

> …the larger failure…. was human—in how the risk models were applied, understood and managed. Some respected quantitative finance analysts, or quants, as financial engineers are known, had begun pointing to warning signs years ago. But while markets were booming, the incentives on Wall Street were to keep chasing profits by trading more and more sophisticated securities, piling on more debt and making larger and larger bets.[xxvi]

We see the same message in many other industries, though delivered in less dramatic fashion.

Now that we have covered the spectrum of how services activities are transformed by the Algorithmic Revolution, led us now turn to how they affect business models built on top of service activities.

A Range of Services Business Model Transformations

There is a range of business model transformations made possible by the Algorithmic Revolution. Many business models entail delivery of the services themselves. Others are extended or transformed by the underlying tools available to them. (See Figure 2)

Figure 2: The Range of Business Model Transformations

ICT Services Enhance Efficiency of Traditional Business Models	Traditional Business Models Extended with ICT Services	Completely new Business Models through ICT

At one end, firms can use *ICT services to enhance traditional business models*, often by increasing their efficiency. For example, life insurance was among the first industries to transform their business models with the massive application of computing resources and algorithms. Wal-Mart's early and extensive use of ICT to link suppliers and distribution radically increased its operational efficiency.

Firms can also *extend traditional business models with ICT-Enabled Activities.* Amazon extended a catalog retailer's business model with an online storefront and user-generated reviews and ratings. The Chilean mining company introduced earlier took its traditional business of operating mining machines and shifted them to ICT-enabled remote operations. Now that its machines are remotely operated, it can offer remote mining operations as a service worldwide.

Existing firms often progress from one step to the next; they first enhance their traditional business model to improve efficiency, then move to extending the business model in new ways. Wal-Mart and other big box retailers' moves into online retailing is an example.

For new entrants, the ability to begin afresh with new business models that extend traditional ones offers an array of entry points. Amazon, for example, was not a traditional bookseller or retailer, starting from the ground up with an ICT-extended business model.

At the far end of the spectrum, *entirely new business models are invented*. Google is the prime example, linking advertising revenue to search. An interesting example of an entirely new business model can be found in virtual currency; users using real money to purchase virtual gifts, avatars, or other virtual goods within an online game or social networking site. Some estimate the virtual currency market in the US was over $1 billion in 2009.[xxvii] There are relatively few examples, but many hope to discover and develop the next completely new business model.

The Services Dilemma

We have seen that the ICT enabled service transformation involves both including a services component in the business model and transforming service activities, particularly routine activities, into computable processes. This is just the beginning of the competitive story.

The services dilemma pits potential productivity gains against the threat of commoditization. If the services component of a business model or activity is primarily irreducible, it will tend to avoid commoditization resulting from other firms applying ICT tools to achieve similar results. However, it is then susceptible to Baumol's productivity trap. On the other hand, if the services component is highly codified and automated, productivity can be won, but at the cost of a continuing threat of commoditization. Thus, the need for innovation in offerings, processes and business model continues.

Drivers of the Transformation: Why Now and Why So Fast?

The transformation of services has been unfolding rapidly, accelerating in the last decade or so. In order to understand why it is unfolding now, and why it is unfolding so fast, we need to look at what is driving the services transformation. The primary drivers of the services transformation are technological developments in the areas of computing, storage, software and networking, and competitive pressures in a global, digital world. The result is that production is being decomposed, manufacturing modularized and services unbundled into their basic activities. Technology extended and intensified competition, changed how firms operated, and provided new solutions to the ever intensifying competition.

Two matters must be noted. First, the application of ICT to existing service activities, the automation of existing activities, is always the beginning of the story – a cycle. What one firm automates, another firm copies; the initial "automation" provides short-lived limited advantage.[xxviii] Continuous learning and innovation is therefore required. The final offerings need to be rethought, reconceived, and implemented anew.

Second, even for radical new services, such as online search or twitter which open entirely new domains, the competitive problem is how to maintain advantage. Google's constant introduction of new functionality and new possibilities is part of its effort to hold its users, and hence its advertising rates.

The Spiral of Ever Increasing Commoditization and Competition: Pressure from a Global, Digital Era

There has been a spiral of intensifying competition and a resulting commodification of goods and services, that is increasing competition based on price alone as more and more competitors emerge for the routine and established. That spiral is driven by a digitization of information and globalization of markets.

` We know that as information is digitized, it can be stored, moved, and manipulated, allowing information-based activities to be relocated, transformed, and recombined. Information takes on new value. For example, many financial services are essentially encapsulated information, with algorithms determining patterns of trading and the composition of derivatives-based products. For digital media, such as CDs and DVDs, streamed video content, and online databases, the information itself is the product. Moreover, the digitization of information drives the breakdown of traditional sectors into value domains, as noted earlier. Firms in traditionally distinct sectors are brought into competition, adding to the pressure to find differentiated business models or defensible points in the market.

These same ICT tools facilitated the communication that encouraged an extension of competition. New competitors from countries seeking to industrialize entered the marketplace. The new competitor usually began with basic products, either borrowing technology and producing for their home markets or sending basic exports to wealthier more advanced countries. Meanwhile companies from the advanced countries moved production off shore. Sometimes those advance country firms produced off shore themselves; sometimes they contracted with other firms to produce off shore for them, outsourcing abroad. As ICT tools became ever more sophisticated producing both goods and services abroad, developing product abroad, and managing the complex operations this implied, all became easier and less expensive. The consequence, though, was straightforward. Competition for standard product—products that were in essence commodities differentiated by price or by branding—became ever more intense. The competitive pressures that have accelerated commoditization in a global, digital era are pushing firms towards seeking value in
ICT-enabled services

ICT enabled services are one competitive response to the market and price pressures of commodization. There are two mechanisms, which we have already noted. One is that firms increasingly include a services component in their business model to avoid the consequences of the commoditization of the product itself, with Apple's iPod perhaps the most discussed example. Second, the application of ICT can transform all services. Yet, though ICT enabled, they are no panacea. That which is routine is likely to be automated. And while automating routine operations may create temporary benefits, they remain routine. And automation of the routine is easily copied. So decisive advantage comes by sustaining the pace of automation of the routine, by innovative ways of approaching traditional activities to create new and distinct values, and by generating entirely new ICT based products and services.

We have a particular vantage on globalization. Globalization is not simply a story of worldwide convergence—it is also a story of national innovations played out on a larger stage. In the classic view, global competition begins with falling transport and communication costs leading firms to do more and more business over distance. In this view, it becomes a flat world in which ICT tools, cross national production networks, outsourcing and offshoring allow corporations to reconstitute themselves as orchestrating lego block-like nodes of activity, buying R&D from here, production capacity from there, and so forth .[xxix] The decomposition of value chains with outsourced manufacturing allowed multiple points for innovation and entry by new actors. Governments are constrained in this vantage, since activities of home-grown firms can relocate anywhere, with "immobile resources" chasing "mobile assets."[xxx]

However, we contend that although the global does mean a larger set of points for innovation, more competitors, and factor price convergence, it is still a story about national developments interacting on a global stage.[xxxi] Lean production, developed in Japan, clearly diffused to production processes around the world. Although not all Japanese companies adopted the Toyota production innovation, lean production would not have developed were the Japanese nascent auto industry not protected from imports and direct investment while gaining access to the US and global export markets. Similarly, the Finnish firm Nokia was a unique firm within Finland, but much less likely to have dominated global mobile handset markets if Nordic roaming standards had not been adopted, followed by GSM as a European standard, giving Nokia access to broader markets.[xxxii] China's current trajectory of development was rooted in cross national production networks and policies harnessing inflows of foreign investments.

India's success as a business process outsourcing and offshoring destination was initially sparked by the combination of educational strength and telecommunications liberalization within India, the rapid buildout of transpacific fiber cable in the context of the US dot-com boom, and the shortage of software engineers in the US.[xxxiii]

The sequence of national stories produces a sequence of challenges in the form of new competitors and new competitive strategies for companies and countries. The result is an enduring tension between the dislocations and challenges of the global against adaptations and adjustments of particular firms and places.

In short, competition in the global, digital era is characterized by unexpected, constant disruption, both from countries and companies. A myriad of new entrants in various points along value networks and production processes, combined with the increasing ability for granulized production and the purchase of business processes on markets, causes firms to experience an intensified struggle against ever-faster commoditization.

Technology Drivers: Evolving Computing Platforms, Captured by Organizations

The technology drivers of the services transformation include the exponential growth in computing power, the increasing speed of networks, evolution of software, and the progression of computing platforms.[xxxiv] Computing platforms evolved along two dimensions—from stand-alone to networked, and from mainframe computers to PCs.[xxxv] The result was an ever-increasing power to digitize information and then process store and transmit information in digital form.[xxxvi] Each technology step opened new possibilities for the application of ICT to services. The ever increasing processing power, expanded storage, and connectivity meant a whole variety of things. All that brought greater functionality to the desktop, but it also meant small phones, increasing connectivity and distributed sensors embedded in everything. The advent of the Internet as a platform for the delivery of services and business activities ushered in the contemporary era in the transformation of services.

An evolution to the next computing platform is currently underway. Cloud Computing, a combination of technologies and business models, will kick off another major round of innovations and new entrants. Cloud Computing, in essence, offers 1) computing resources (such as applications, services, and data) on demand via networks, 2) which can be scaled up or down rapidly according to the users' needs (providing users with the illusion of infinite scalability) and 3) are often offered as pay-as-you-go schemes, requiring no up-front commitment.[xxxvii] For users, Cloud Computing allows computing to become an "enhanced utility."[xxxviii] Firms can avoid capital expenditures of building their own data centers, instead paying for computing resources as they need. Entry barriers into computing-intensive areas are lowered, capabilities for experimentation are increased, and it becomes easier than ever for startups and new entrants to scale up rapidly to become major players.

The technologies, of course do not produce their own use, do not generate their own value. The services transformation is not simply a technology story; the advantage of ICT tools is captured by organizations. The argument put forth by Stephen Cohen, Bradford DeLong and John Zysman to understand the first phase of the ICT revolution still stands: "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."[xxxix]

Innovative lead users, in the form of large and small firms discovering new uses for information technology, were critical. Information technology was adopted to solve a particular problem, or to cut costs. Innovative users then discovered new uses. For example, Citibank took advantage of flat-rate telephony, moving its back-offices not only into the area surrounding Manhattan, but all the way to South Dakota. The organizational shift enabling this move – modularizing the back-office operations – facilitated moving select back-office operations much further, to places such as India. Continual organizational experimentation and innovation, adopting new technologies, and finding new business models and services possibilities, will continue to drive the services transformation.

Thus, the interplay of technology, organizations, competition in a global, digital world creating pressure to escape commoditization, and the evolving computer platforms are driving the services transformation.

Part III: Capturing the Services Transformation

The question for firms and government is how to capture the value possibilities opened up by the services transformation. Before we turn to the policy and strategy issues, we need to develop the two notions that have been implicit in our discussion. First, services are a form of production ever more supported by Information and Communications Technologies. Second, precisely for that reason, ICT enabled services are driving productivity growth.

To capture this productivity growth and the potential benefits from the services transformation, there are three areas we focus upon. They include: 1) connectivity – the availability of ICT tools and infrastructure, 2) people – the skills the capacities to implement technology, and 3) government – not only as a promoter and educator, but a rule-setter and user.

We turn first to recasting the notion of services, including them as part of the conception of production.

ICT based Services as Production: Recasting the Policy Debates

Classic conceptions of services revolved around the notion that services were market activities that did not produce or transform material goods. Consequently, they could not be stored or shipped, and were consumed in the same moment and at the same place they were created. This is still mostly true for traditional services. ICT-based services differ because they often require massive (and ongoing) investments on a new industrial scale to support the future services.

With the application of ICT tools, services can be incorporated into larger systems – systems that change the level and character of investment required for delivery. Google invests massively into creating automated systems that create and deliver the actual services at a later time, anywhere. ICT based services can often be scaled far beyond traditional services.

The development and deployment of ICT-enabled services should be considered a form of production. ICT based services have to be built and produced, or at least the ICT systems have to be designed, developed, built, and implemented. The tools, including software, have to be "built," and the online services themselves have to be "constructed."[6] Consequently they are very much open to innovation and productivity increases. From a policy standpoint, the question is how to conceive, design, develop and build and deploy the new system. The "good" jobs, high value added functions, are in the innovative development and deployment of these systems. Policy makers need to employ strategies that will help communities and firms to develop the competencies required for this new form of production.

The continuing debate in political, economic and public policy circles about the relative value of manufacturing jobs and service-sector jobs is increasingly irrelevant to policy debates in the real economy. Just as it is inaccurate to assume that manufacturing jobs are secure and well paid, it is also inaccurate to consider service jobs to be dead-end, low-wage, unskilled positions. This model ignores not only the lawyer and physician, but also the computer programmer, the financial analyst, and the web designer—each a high-paid, highly skilled service worker. Rather than focusing on the increasingly irrelevant distinction between manufacturing and services, the conversation should be recast. If the word production includes not only traditional manufacturing but also the development of I.T.-based services—with the know-how, skills, and tool mastery they require—then we see that, in this broader sense, production remains of vital importance in the digital age, not just in the traditional manufacturing industries but in the services sector as well. And production workers—including not only assembly-line employees but also many kinds of knowledge

[6] This is particularly true for Cloud Computing-based services, in which new services are often literally "constructed" by combining other Cloud services as building blocks.

workers in service industries ranging from finance, health care, and I.T. to education, media, and entertainment—are now more important than ever.

Services Driving Productivity

Services were once seen as a sinkhole of the economy, immune to significant technological or organizationally driven productivity increases. As Baumol and Bowen put it in the 1960s, it still takes the same amount of labor to play a Beethoven quintet.[xl] "Baumol's Cost Disease," as it became known, pointed to services as a drag on aggregate economic growth as their role grew in the economy.[xli] It didn't work out that way. At the same time that Baumol was writing, another article announcing Moore's law pointed the way to the explosive expansion of digital information processing.[xlii] That capacity, as Baumol himself notes, is transforming the services industry, and the economy.[xliii]

Services are now widely recognized as a source of productivity growth and dynamism in the economy. The US experienced a rapid labor productivity surge starting in 1995. Baumol's disease was cured; new data showed that services, which we contend were transformed, drove the productivity surge. That transformation was every bit as important as investment and innovation in the manufacturing sectors.[xliv]

Services were originally a "residual" in national accounting after manufacturing and agriculture. Since "services" was a catch-all category not thought to be central to the processes of innovation and productivity, little attention was given to how to measure them or the productivity increases. And they are inherently difficult to measure in any case; measures of services price, quantity, and quality are problematic.[xlv] Let us consider a few instances. For major industries driving productivity growth, which include banking, insurance, securities, and real estate among others, there is debate over what constitutes a unit of output. Measures of value added can be influenced by stock market bubbles. Investment activities that fall outside traditional business categories may not be captured – insurance firms invested in derivative hedging operations, for example. Other sectors, such as retail, have benefitted from reorganization and shifting the format and product mix of retail stores, not captured by traditional performance indices. The quality of output for medical services, for example, is difficult to determined, and the output "product" of business services such as management consulting is also problematic.[xlvi] Since measures of productivity rest on output units or value added, measurement errors in the data are likely to have played a significant role in the observed slow productivity growth of services until 1995.[xlvii] (The measures have since improved.[xlviii])

The adoption of ICT is now clearly identified as a driver of productivity growth in services.[7] New data and improved measures available from the early 2000s revealed that ICT contributed to the surge of US aggregate labor productivity since 1995. This resolved the confusion until then, that the data did not show ICT contributing significantly to productivity growth – the "productivity paradox."[xlix] Of the aggregate labor productivity growth from ICT industries and implementation, services industries contributed a majority – 80 percent, according to Triplett and Bosworth.[l]

Capturing the Benefits of the Transformation

To capture the benefits of services transformed by ICT tools, government policies surrounding ICT will play critical roles. Put simply, the key areas are: connectivity, people, and government as a direct actor.

[7] Until the productivity surge from 1995 became apparent in the early 2000s, economists had puzzled over a "productivity paradox"; massive ICT investments were not showing up in productivity growth data.

Connectivity

By connectivity, we refer broadly to the availability of ICT networks and tools. The notion of connectivity has evolved over time, causing a parallel shift in the potential role of the government in ensuring connectivity.[li]

The original notion of connectivity consisted of ensuring universal telephone access, to remote geographic regions and across all income levels. With the advent of the Internet, connectivity expanded to cover Internet access, with concerns over the “digital divide” between those with and without access. More recently, connectivity was expanded to include broadband speeds, with different countries defining different throughput thresholds. The diffusion of mobile technologies further widens the notion of connectivity, as the Internet may be best accessed through mobile networks, especially in developing regions.

Although the notion of connectivity continues to evolve, it is clear that without connectivity, very little is possible in the way of taking advantage of the production and consumption of digitally transformed services.

Rapidly shifting technologies and market conditions have made the government’s task in ensuring broad public connectivity more both difficult, and easier. The old argument was that government should adopt policies to push for broadband for public access. Cross-subsidization schemes, the expansion of funds for increasingly broadly defined universal service, and direct subsidies to public telecommunications carriers were among the traditional policy tools. Over the past few years, the ownership of infrastructure has been evolving. The role of public telecommunications carriers is changing. Increasingly, infrastructure is privately held and operated by services firms. For example, Google has built high speed access points around the world and invested in global fiber optic infrastructure, including transpacific and transatlantic fiber networks. As a result, data connections over the Internet jump onto Google’s private network increasingly early on, especially in developing countries. Thus, in Africa, for example, connections jump onto Google's private network at a very early point, circumventing as much of public networks as possible. The rise of private networks as conduits of Internet traffic is shown clearly in recent data.[lii] The emerging policy debate is over what market needs are to be provided by public and private actors.

People: Skills and Capacities

Even if technology and connectivity are available, they are useless without people capable of using and implementing them. This is clearly understood; human skills affect what can be done.

While purely routine tasks will become increasingly automated, human tasks remain. There will always be new problems to be solved, new processes to be codified, new services to be automated through the creation of algorithms. For example, in the automation of healthcare, as medical knowledge is advanced, new systems need to be constructed, new monitoring and intervention patterns will be needed, and human interventions will still ultimately be necessary.

There will also remain an almost endless array of services relying on the application of both tacit knowledge and pattern recognition. Competitive companies will continue to depend on human abilities to identify and integrate sources of new knowledge and insight, to communicate this information with others through rich verbal and written interactions, to apply expert judgment based on tacit knowledge and pattern recognition, and to understand the significance of an entirely new problem and devise create ways of addressing it.

A first implication is that at the basic education level, a new definition of literacy is needed. Reading, writing, and arithmetic—the traditional basics of elementary schooling—are no longer enough. Instead, basic education must also focus on abstract reasoning and communication skills—the ability to identify, structure, and solve problems, both qualitative and quantitative; to access and organize information; and to communicate ideas and logical connections to others. The high school graduate (or equivalent) of tomorrow must be prepared either to help build the new technologies or to apply them in a human context—that is, either to work in services design and production or in services delivery.[8]

A second implication of the new workforce dynamic is that the balance between specific skills and general skills is shifting.

Until recently, the specific skills developed by years on a particular production line or in a particular business function (marketing, finance, design) were vitally important to organizations. Today, the value of such specific skills is rapidly eroding. With the accelerating introduction of new products and new services based on new technologies and new production methods, and with the growing use of I.T.-driven tools to automate processes that are purely routine, knowledge of "how things have been done" is increasingly perishable.

By contrast, such general skills as the ability to understand and cope with the unusual and the unexpected, and the ability to learn quickly in ever-shifting environments are becoming more and more critical. People who can pull together information from various expert systems and knowledge bases, crossing domains and identifying patterns and connections will create the most economic value in societies. This kind of abstract thinking—the ability to combine sensory data with an intuitive sense of what is right and wrong in terms of the meaning and quality of data—is extremely difficult to reduce to a digital algorithm, and will probably remain so for many years to come. Therefore, this uniquely

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8 Notice that this "new literacy" does *not* imply a reduction of the elementary and secondary curricula to courses in math, English grammar, and perhaps computer programming. Many subjects, including such traditional ones as history, can be used as vehicles for the teaching of analytic skills, problem-solving, logic, communication, and the other talents needed by the knowledge workers of tomorrow.

human capability needs to be emphasized and developed as much as possible in both educational systems and in knowledge-management programs at the company level.

The implications for worker training and recruitment programs have yet to be worked through. How does a country or a company maintain the capacity to sustain vital skill domains (cutting metal, for example) when the technologies and techniques dramatically change (as when lasers replace diamond-tipped tools in metallurgy)? It is not just a matter of hiring smart, well-educated people, but about hiring people whose greatest skill is the ability to develop, absorb, and communicate ever-changing knowledge. As futurist Alvin Toffler puts it, "The illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn."[liii]

Government as an Actor

Governments play several roles: as major users of technology, they can shape the ICT environment; as regulators, they create the market rules that influence how the private sector deploys and uses new technologies; as promoters, they can identify distinctive opportunities.

Governments are major users of information technology. There is a running debate over the continuing importance of the government as a buyer, and whether or how it will shape industry. Government spending on IT is certainly not trivial. In 2008, for example, Gartner estimated that in worldwide IT spending, governments were the third largest spenders, behind financial services and manufacturing, a pattern projected to continue in 2009.[liv] The US government spent an estimated $80 billion a year on IT for the past few years,[lv] and in Europe, the UK government alone planned to spend $36.8 billion in 2010.[lvi] These expenditures dwarf that of major companies, which might spend about $5 billion in a year at the high end.

Some contend that government will be a significant driver in the current round of IT investments to consolidate datacenters and increase the efficiency of IT utilization.[lvii] In this vantage, initiatives such as the one launched in early 2010 by the US government for a sweeping consolidation of the government's datacenters are likely to affect the development of IT. It can accelerate the adoption of Cloud computing, which can offer increased efficiency in data center utilization, for example.[lviii] Others argue that the slow time scale of government spending will limit governments' effects on the development of industry.[lix]

Competitive markets throughout the value chain have been central to the development and rapid diffusion of the new ICT tools. For example, when the technology giants IBM and AT&T declined to enter the nascent semiconductor industry because of direct and indirect antitrust implications, a new array of companies pushing the use of the new digital technologies emerged. Similarly, the rapid development of the Internet grew from the competition unleashed by judicial deconstruction of the monopoly phone company. Policy makers should be on guard against monopolistic or oligopolistic control of emerging technology fields and take appropriate steps to encourage the emergence of multiple companies so as to encourage competition and drive innovation.

An important task for policy makers in this new economic era is to find ways to promote effective capacities that enable companies and communities to maintain a competitive advantage. Here we list three:

- First, they need the capacity to *develop new technologies*—the classic research and development function that has long been emphasized (correctly) as a vital tool for innovation.
- Second, they need the capacity to *recognize and harvest new technologies* from around the world and from diverse sectors.

- Third, they need the capacity to *combine, absorb, and apply diverse innovations and sources of knowledge* into whatever production processes they are engaged in.

Conclusion

We have argued that a fundamental transformation of services is underway. It is being driven by developments in ICT tools, and the uses to which they are being put. The application of rule-based information technology tools is transforming services activities, altering how activities are conducted and how value is created. Services sectors have transformed from a productivity sinkhole to a source of dynamism and productivity growth. The Algorithmic Revolution enables tasks underlying services to formalized, codified, and transformed, and firms are increasingly turning to services to add value. In-house business functions are available as services, firms are ever more comprised of bundles of services purchased on markets, and manufactured products are increasingly embedded and recast as services offerings. Traditional sectoral boundaries are breaking down as information and services offering bring previously unrelated firms into direct competition.

We have offered some analytical vantages to understand how the services transformation is unfolding. We introduced a spectrum of services activities, ranging from irreducible, to hybrid, to automated. While the latter offer the highest potential productivity gains, we contend that human judgment will continue to be critical. We also introduced a range of business model transformations made possible from the Algorithmic Revolution, ranging from enhancing the efficiency of traditional business models, to extending traditional business models with ICT, to creating completely new business models. We showed why the transformation is unfolding now, and so rapidly, by contextualizing it in the competitive pressures from a global, digital era and the evolution of computing technologies and platforms.

The challenge for firms and governments is in capturing the benefits of the services transformation. We call for recasting the policy debates by considering ICT-based services as "production." For firms, capturing the gains from the implementation of new technologies requires new business models, new organizational strategies, and cultivating new skills. For governments, this requires providing connectivity, an environment to foster the ability to continually learn new skills, and creating rules to facilitate experimentation and implementation. At the same time there must be attention to the classic market problems of assuring consumer rights, competition, and the like.

Services are deeply rooted in social rules, conventions, and regulations. Consequently, capturing the value possibilities in the algorithmic transformation inherently means recasting the rules, regulations, and conventions in which the services are embedded.

The present debates about Intellectual property, about the rights of Google to copy the world's libraries, of media companies to shape how mp3 files are shared, are all part of that basic debate about the new rules of market for a digital services age. Writing the new rules is not a matter of just saying, we have established principles. Those established principles about—for example, property and privacy, are in fact complex bargains often created and institutionalized over decades if not centuries. It is not enough to say apply those bargains in a digital age. New digital capabilities raise new issues. Who should manage the world's libraries? Or who should have the benefits from the genome of particular populations. As important, reopening the old bargains to deal with the new issues makes re-striking the bargain necessary and may change the original principles. There are implications both for the process of transformation, what it takes to accomplish the transformation, and for the kinds of services and tools that evolve.[9]

[9] Scholars on services innovation fail to make the comparative analysis of regions; for most authors, regions are flat and strategies are fungible across time and space. We counter that this is not true.

Managing Transitions: Recasting Rules, Regulations, and Conventions

The implementation of new technologies, and the adoption of new business models and strategies, involve complex transitions. These transitions are not just about adopting a new technology, or about a shift from one market equilibrium to another, but rather a broader shift from one policy regime and set of market signals to alternate policy regimes and sets of market signals. Social and economic transformations always involve winners and losers, and hence are, in both a large and small sense, political. It is a tumultuous process as economic wellbeing and social positions are recast and reinvented.

In a small political sense there will be the struggles around and within the organization of companies, about shifts in required work skills, the relocation of work and displacements of workers. Again, even these smaller stories are never just technical, but, involving shifts in position and roles, they are always fraught with conflict.

In a larger political sense there will be battles about the rules of providing services, who can be providers, how quality is maintained, who gets to use what information, as well as about how losers are compensated and potential winners supported. Those who would implement the new tools, reorganize services and service delivery, must understand, almost begin with, the entrenched social character of services, of market regulation and labor market dynamics. That will apply to the end user, a health care company or a bank, to the ICT services company, or to the regulator.

As the political debates and battles unfold across the world, policymakers, analysts, and scholars may be tempted to see a narrower set of issues and problems with a smaller set of solutions. Our view is that only by understanding the fundamental transformation of services, which are driving the emergence of these issues and debates, can we see the disparate issues as part of a larger complex, systemic transition—a transition entailing different sets of bargains and solutions that will unfold differently across the globe.

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Zysman, John, and Abraham Newman, eds. *How Revolutionary Was the Digital Revolution? National Responses, Market Transitions, and Global Technology in a Digital Era*. Stanford, CA: Stanford Business Press, 2006.

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[i] William Baumol wrote in the 1960s that it still takes the same amount of labor to play a Beethoven quintet. William J. Baumol and William G. Bowen, *Performing Arts, the Economic Dilemma; a Study of Problems Common to Theater, Opera, Music, and Dance* (New York,: Twentieth Century Fund, 1966), William J. Baumol, "Macroeconomics Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis," *American Economic Review* 57 (1967), ———, "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis," *American Economic Review* 57 (1967). In the past years he has come to recognize the power of the ICT transformation of services. ——, "On Mechanisms Underlying the Growing Share of Service Employment in the Industrialized Economies," in *Services and Employment: Explaining the U.S.-European Gap*, ed. Mary Gregory, Wiemer Salverda, and Ronald Schettkat (Princeton, NJ: Princeton University Press, 2007).

[ii] Jack E. Triplett and Barry Bosworth, *Productivity in the U.S. Services Sector New Sources of Economic Growth* (Washington, D.C.: Brookings Institution Press, 2004). - check

[iii] John Zysman, "The 4th Service Transformation: The Algorithmic Revolution.," *Communications of the ACM* 49, no. 7 (2006).

[iv] For more on the first round of market and policy transformations in a digital, global, era see John Zysman and Abraham Newman, eds., *How Revolutionary Was the Digital Revolution? National Responses, Market Transitions, and Global Technology in a Digital Era* (Stanford, CA: Stanford Business Press,2006).

v William D. Nordhaus, "The Progress of Computing Ver 5.2.2," Yale and NBER, http://nordhaus.econ.yale.edu/prog_030402_all.pdf.

[vi] François, and Michael Borrus, Telecommunications Development in Comparative Prospective: The New Telecommunications in Europe, Japan, and the U.S., BRIE working Paper # 14, Berkeley, March 1985.

[vii] "Outsourcing: External Affairs," *The Economist,* July 28 2007.

[viii] Firms usually installed IT systems by adding new systems to existing legacy ones. By the late 1990s, most large enterprises were running several different legacy systems that were not always compatible with each other. Waves of M&A activity exacerbated the situation. However, increases in the sheer number-crunching ability, combined with "glue-code"—pieces of code that bridged heterogeneous system, increasingly enabled heterogeneous IT systems to be connected. Within companies, this increased efficiency, but more importantly, this facilitated the connections of IT systems across company borders, facilitating the outsourcing of an increasing array of activities.

[ix] Michael Borrus, Dieter Ernst, and Stephan Haggard, *International Production Networks in Asia Rivalry or Riches?*, Routledge Advances in Asia-Pacific Business ; 11 (London New York: Routledge, 2000), Carliss Y. Baldwin and Kim B. Clark, *Design Rules* (Cambridge, Mass.: MIT Press, 2000).

[x] For example, see Frances X. Frei, "The Four Things a Service Business Must Get Right," *Harvard Business Review* (2008), Venkatesh Shankar, Leonard L. Berry, and Thomas Dotzel, "A Practical Guide to Combining Products and Services," *Harvard Business Review* (2009).

[xi] Until Apple's music store became hugely popular, it was not obvious that consumers were willing to pay for music downloads. The rise of Napster, which allowed users to freely share mp3 music files of copyrighted music, was sometimes argued to have had such a pervasive cultural effect that people would be unwilling to pay for any content downloaded from online.

[xii] The company can also use data from the levels of usage of its machines to generate supply-demand predictions for countries or regions in which statistics about economic trends are unreliable.

[xiii]

[xiv] IBM mainframes were leased to major enterprises and manned by specialists.

[xv] Kenji Kushida, Dan Breznitz, and John Zysman, "Cutting through the Fog: Understanding the Competitive Dynamics in Cloud Computing," *BRIE Working Paper* (forthcoming). See also Michael Armbrust et al., "Above the Clouds: A Berkeley View of Cloud Computing," www.eecs.berkeley.edu/Pubs/TechRpts/2009/EECS-2009-28.pdf.

[xvi] Amazon's online Kindle offerings were initially only available on Amazon's Kindle device. Amazon subsequently introduced Kindle reader software for PCs, iPhones, and Blackberry smartphones. Kindle offerings can be read on a variety of platforms, but only using Kindle software, which is not (as of this writing) offered for any other electronic reading device competing directly with the Kindle reader device. As long as this continues, the Kindle device will not be commoditized as quickly as if content interfaces were open. Therefore, product cycles do not have to be as fast, such as every three months, to stay ahead—a contrast with cellular handsets, especially before the introduction of smartphones such as Apple's iPhone. Apple's book reader application for the iPad is also initially offered only for that particular device.

[xvii] Many thanks to Erkki Ormala of Nokia who first made this argument at a lunch in Helsinki.

[xviii] The attributes over competition shifted too. While traditional digital cameras may take higher quality images, observing the behavior of crowds at any noteworthy event captured by camera will show a large proportion of people holding up their cell phone. Even more so in markets where cell phone camera quality was an attribute of competition, such as Japan and South Korea.

[xix] The success of carriers differed widely across markets. Japan's KDDI, for example, commercialized downloadable songs, "chaku-uta" in late 2004. It logged 5 million downloads in the following 16 months, closing in on the number of CD singles sold in early to mid-2006Daisuke Masuno, *Gyoukai Kenkyu Shiriizu: Tsushin [Industry Analysis Series: Telecom]* (Tokyo, Japan: Nihon Keizai Shimbun Sha, 2006), 34. The music download services of major US carriers such as Verizon's V Cast Music, however, have not made headlines with their subscription levels or download volume after it was introduced in 2006.

[xx] The most famous mobile internet connection services in Japan, NTT DoCoMo's i-mode, pioneered in 1998, helped launch a mobile content market in Japan with revenues of approximately 1 billion dollars by 2002, reaching 7 billion by 2007. However, the entire ecosystem, consisting of content, handsets, and carriers' business models, was trapped in the domestic market. For details, see Kenji E. Kushida, "Leading without Followers: Innovation, Competition, and the Political Economy of Japan's Telecommunications Sector," *BRIE Working Paper* 184 (2008).

[xxi] Stephen S. Cohen and John Zysman, *Manufacturing Matters : The Myth of the Post-Industrial Economy* (New York: Basic Books, 1987).

[xxii] The dot-com bubble and crash of 2000 was the result of misplaced investments and optimism, but it was a classic bubble; the dot-com bubble was not about the underlying IT tools and how they were deployed and used.

[xxiii] Niels Christian Nielsen and Maj Cecilie Nielsen, "Spoken-About Knowledge: Why It Takes Much More Than Knowledge Management to Manage Knowledge," in *How Revolutionary Was the Digital Revolution? National Responses, Market Transitions, and Global Technology in a Digital Era*, ed. John Zysman and Abraham Newman (Stanford, CA: Stanford Business Press, 2006).

[xxiv] For one of the most readable tales of the limited financial modeling, see Michael Lewis, *The Big Short: Inside the Doomsday Machine* (W. W. Norton & Company, 2010).

[xxv] Lewis, Michael The Big Short: Inside the Doomsday Machine

[xxvi] "In Modeling Risk, the Human Factor Was Left Out." *New York Times,* November 5, 2008.

[xxvii] Mark Walsh, "Virtual Goods to Reach $1 Billion in 2009," http://www.mediapost.com/publications/?fa=Articles.showArticle&art_aid=115398.

[xxviii] McKinsey cite

[xxix] Thomas L. Friedman, *The World Is Flat : A Brief History of the Twenty-First Century*, 1st ed. (New York: Farrar Straus and Giroux, 2005), Suzanne Berger and MIT Industrial Performance Center., *How We Compete : What Companies around the World Are Doing to Make It in Today's Global Economy*, 1st ed. (New York: Currency Doubleday, 2006).

[xxx] Quote from Niels Christian Nielsen. Susan Strange, *The Retreat of the State : The Diffusion of Power in the World Economy* (Cambridge, England New York: Cambridge University Press, 1996), Ken ichi Omae, *The Borderless World : Power and Strategy in the Interlinked Economy*, Rev. ed. (New York: HarperBusiness, 1999).

[xxxi] Kenji E. Kushida and John Zysman, "The Services Transformation and Network Policy: The New Logic of Value Creation," *Review of Policy Research* 26, no. 1-2 (2009).

[xxxii] Finland's concerted efforts toward attaining mobile prominence occurred in the context of a broader Finnish move away from supplying the Soviet Empire to become a technology-based innovator. See Ari Hyytienen et al., "Finland's Emergence as a Global Information and Communications Technology Player: Lessons from the Finnish Wireless Cluster," in *How Revolutionary Was the Digital Revolution? : National Responses, Market Transitions, and Global Technology*, ed. John Zysman and Abraham Newman (Stanford, Calif.: Stanford Business Books, 2006).

[xxxiii] The software engineer shortage was acute as the Y2K problem demanded a massive quantity of relatively basic mechanical coding. After the dot-com bubble burst, transpacific fiber became cheaper, and intense pressures on major firms to cut costs led to a deluge of outsourcing to India.

See Friedman, *The World Is Flat : A Brief History of the Twenty-First Century*, Rafiq Dossani and Martin Kenney, "Service Provision for the Global Economy: The Evolving Indian Experience," *Review of Policy Research* 26, no. 1-2 (2009).

[xxxiv] Computing power has increased exponentially, following the principle known as Moore's Law. Derived from the prediction made by Gordon Moore, founder of Intel, in 1965, Moore's Law states that the number of transistors that can be placed inexpensively on an integrated circuit would continue to double approximately every twelve to twenty-four months. This principle has held until now, leading to exponential rises in computing power and decreasing cost (A typical laptop today has as much computing capacity as the *world* did in 1960).

Networking has also speeded up radically. In the 1970s, the fastest links between computers were about 1.5 megabits per second; today 10 gigabits (10,000 as fast) is typical. The transatlantic cables of the 1950s carried an equivalent bandwidth of a few megabits, while the most recent international cables have a theoretical capacity in the terabits (one million times as much). Transmission costs have fallen by comparable amounts, partly since cables' carrying capacities can be improved with new equipment at the end, without replacing the installed fibers. Thanks to the resulting proliferation of high-speed networking, computing power can be dispersed rather than having to be concentrated in or near corporate headquarters—and when knowledge is dispersed, so, to a significant extent, is power.

Software, too, has undergone a series of dramatic evolutionary steps. In the early days of computing, programs closely mimicked what people were already doing. The earliest scientific programs implemented formulas already in use, and the first payroll systems simply did elementary calculations on time cards and printed checks. With growing experience and increasing technological power, new algorithms were designed to do ever-larger numeric computations and to perform them more quickly than ever.

[xxxv] Let us go into more detail about the evolution of *computing platforms*—combinations of hardware, software, and usage patterns that fit together in a particularly useful fashion. Although the history of modern information technology involves several different platforms, it also exhibits a single major divide—that between I.T. systems that are fundamentally independent and systems that are highly interconnected.

The *stand-alone era* began with the platform of mainframe computers in the early post-World War II years**.** Database systems were first designed for mainframes, and the maintenance of such databases (along with the processing of transactions and reports) is still a dominant function of the mainframe platform. The original uses were all batch-oriented and off-line due to hardware limitations. The mainframe platform entailed centralized management, control by a highly-trained priesthood of experts, and utter dependability purchased at a high price.

After a series of transitional standalone computers, Personal Computers (PC) became the new paradigm from the 1980s. The so-called Wintel PC, using Intel-based processors and Microsoft-based operating systems and software (with Apple's Macintosh computers and the Linux operating system providing an alternative). The key technology breakthrough was the development of the computer whose processing capability was contained on a single chip. Thanks to Moore's Law, what began as a toy quickly became a powerhouse. Although the operating system and hardware change every year significant backward compatibility was retained, and over time, the existence of this long-lasting *de facto* standard has encouraged the growth of a major ecosystem of software and hardware producers.

The low cost, simplicity, and ease of use of the PC revolutionized the role of I.T. in business. Individuals became direct users of information technology, no longer reliant on a priesthood of experts. They were free to create their own data, manipulate it as they liked, load new applications or create their own. Inside corporations, work groups equipped with PCs could operate almost independently in providing services to themselves and to others. Freelancers and small business could create applications and manage information as easily as large corporations. And all the while, costs were plummeting. In companies based on the mainframe model, the I.T. budget was typically 15 percent of revenues; in companies based on PCs, the figure was just two percent.

The connected era had roots in the 1960s or earlier, but it came of age with the advent of the World Wide Web and the Internet. Even predating the Web and the Internet, increasing standardization, openness, and bandwidth enabled IT to attain *locational independence* (the data could reside and computations could be performed anywhere), *distributed processing* (the ability to combine information and calculations without physical relocation or permission), and *federation* (the ability to combine data and processes across organizational boundaries and ownership domains).

The Internet, in its essence, is a system for easy networking, a universally accepted way of communicating among machines (whether mainframes, microcomputers, or terminals) using open protocols—that is, the way different machines are accessed is the same everywhere.[xxxv] These open protocols, designed for the U.S. government and supported by a volunteer standards body, together with an underlying philosophy of end-to-end communication, have led to a huge and rapid growth in networked computing by making it possible to add data sources, services, and human users quickly, easily, and cheaply.

The new communication and information formats created for the Internet had enormous impact, becoming the key standards for the 1995-2010 era. As processing and software capabilities are extended, the interactions between systems over the Internet are extended. While the Internet is basically a message-based model, with simple interactions, systems can now interact is through a service model. With a service model, the basic unit is a request from one system to another for a service to be performed. A service is characterized not only by what is wanted, but also by the expectations of service level (such as promptness and reliability) and by business-like attributes (such as cost and ownership of information).

There are a variety of competing protocols for services, but the underlying Internet and Web mechanisms enable interoperability while details are being agreed. Since services have defined interfaces of various sorts, it is possible to build services that use other services as components, held together by what programmers call *glue code*. The work can be done at various levels of software engineering rigor, from quickly written mash-ups (web applications that combine data from more than one source into a single integrated tool assembled on a rapid, *ad hoc* basis) to carefully-built service frameworks.

[xxxvi] The combination of today's computer hardware, vast interconnected networks, and enormous databases has enabled the development of entirely novel sets of algorithms that mine data and draw inferences using statistical techniques from large data sets. They have started to replicate many of the analytical tasks previously done by skilled knowledge workers; the resulting change, which is as much qualitative as quantitative, is radical.

The analytic powers thus liberated made possible such remarkable applications as the creation of useful, real-time weather forecasts, enormous improvements in the accuracy and detail of demographic projections for use by insurance companies, and the expansion of basic payroll programs into full-scale H.R. systems that maintain records of employee compensation, roles, training, skills, and so on.

[xxxvii] Since Cloud Computing is still new, there is still disagreement and confusion over definitions. The characteristics here are from Armbrust et al., "Above the Clouds: A Berkeley View of Cloud Computing."

[xxxviii] See Kenji E. Kushida, Dan Breznitz, and John Zysman, "Cutting through the Fog: Understanding the Competitive Dynamics in Cloud Computing," *Forthcoming* (2010).

[xxxix] Stephen Cohen, J. Bradford DeLong, John Zysman, *Tools for Thought: What Is New and Important About The "E-Conomy"* (Berkeley, CA: Berkeley Roundtable on the International Economy, University of California at Berkeley, 2000), 15.

[xl] Baumol and Bowen, *Performing Arts, the Economic Dilemma; a Study of Problems Common to Theater, Opera, Music, and Dance*.

[xli] The logic was that while the productivity of a large portion of services did not increase, wages increased, pulled up by the sectors in which productivity did grow, such as manufacturing Baumol, "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis."

[xlii] Gordon Moore, "Cramming More Components onto Integrated Circuits," *Electronics* 38, no. 8 (1965).

[xliii] Baumol, "On Mechanisms Underlying the Growing Share of Service Employment in the Industrialized Economies."

[xliv] Jack E. Triplett and Barry P. Bosworth, ""Baumol's Disease" Has Been Cured: It and Multifactor Productivity in Us Services Industries," in *The New Economy and Beyond: Past, Present and Future*, ed. Dennis W. Jansen (Cheltenham, UK ; Northampton, MA: Edward Elgar, 2006), Triplett and Bosworth, *Productivity in the U.S. Services Sector New Sources of Economic Growth*.Until the surge from 1995, observed in the early 2000s, the lack of productivity gains from ICT observable in economic data had been puzzling economists – it was referred to as the "productivity paradox."

[xlv] Zvi Griliches et al., *Output Measurement in the Service Sectors* (Chicago: University of Chicago Press, 1992).

[xlvi] Jack E. Triplett and Barry P. Bosworth, "Productivity in the Services Sector," (2000).

[xlvii] It is possible that the previous slow growth of productivity in services despite heavy ICT investments was due to measurement and data problems. As Triplett and Bosworth have noted, a large proportion of ICT investment in the US goes into the particular service industries with the most serious measurement problems, such as finance, wholesale trade, business services, communications, and medical care. Ibid, Triplett and Bosworth, *Productivity in the U.S. Services Sector New Sources of Economic Growth*.

[xlviii] Triplett and Bosworth, "Productivity in the Services Sector."

[xlix] Dale W. Jorgenson, Mun S. Ho, and Kevin J. Stiroh, "A Retrospective Look at the U.S. Productivity Growth Resurgence," *Journal of Economic Perspectives* 22, no. 1 (2008), ———, *Productivity Volume 3: Information Technology and the American Growth Resurgence* (Cambridge, Mass. ; London: MIT Press, 2005).

[l] "ICT in services industries accounted for 80 percent of the total ICT contribution to U.S. labor productivity growth between 1995 and 2001." Triplett and Bosworth, *Productivity in the U.S. Services Sector New Sources of Economic Growth*, 2.

[li] In the evolving ICT world, other aspects of connectivity in addition to raw connectivity to the networks become important. For example, access to data, collaborative activities, and the

availability of digital tools should be included. We will expand upon this point in subsequent versions of this paper.

[lii] C. Labovitz et al., "Atlas Internet Observatory 2009 Annual Report," http://www.nanog.org/meetings/nanog47/presentations/Monday/Labovitz_ObserveReport_N47_Mon.pdf.

[liii] Alvin Toeffler, *Rethinking the Future: Rethinking Business Principles, Competition, Control and Complexity, Leadership, Markets and the World* (Nicholas Brealey Publishing, 1998).

[liv] Gartner, "Gartner Says Worldwide Vertical Market It Spending Will Be Flat in 2009," http://www.gartner.com/it/page.jsp?id=893512. The top 10 worldwide IT spenders in 2008 according to Gartner were (billions of dollars: 1) Financial Services, 559; 2) Manufacturing 483; 3) Government 420; 4) Communications 368; 5) Services 190; 6) Retail Trade 153; 7) Utilities 128; 8) Transportation 106; 9) Healthcare 86; 10) Wholesale Trade 81.

[lv] ComputerWorld estimate. Patrick Thibodeau, "White House Appoints Its First Federal Cio," http://www.cio.com/article/483180/White_House_Appoints_Its_First_Federal_CIO.

[lvi] IDC, "Idc Government Insights Says Government It Spending in Western Europe Will Reach $68.6 Billion by 2013," http://www.idc-gi.com/getdoc.jsp?containerId=prIT22198510.

[lvii] The current round of IT rationalization by governments is in response to the financial crisis that has increased pressure on governments to cut IT expenditures. After the dot-com bubble burst in 2000-2001, firms rationalized their IT systems in response to pressures to increase efficiency, but governments did not undertake similar measures until now.

[lviii] The program, the “Federal Data Center Consolidation Initiative” was announced in February 2010 by the Federal Chief Information Officer’s Council, a new position created by the Obama administration.

[lix] This is a point of contention among the authors.