

The Digital Economy: what is new and what is not?

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Abstract

There are many signs indicating that something new has happened in the United States economy during the last decade. While the surge in labor and total factor productivity growth rates in the latter half of the 1990s was impressive and widely interpreted as a sign of a ‘New Economy,’ it remains to be seen whether it was a fleeting phenomenon or the beginning of a new trend. But there are other indicators that are less cyclical in nature and that appear more likely to persist.

In this paper, I argue that the observed changes are at least consistent with the view that digitization of information, combined with the Internet, represents a form of general-purpose technology that is giving rise to a vast new array of possible combinations that we may refer to as the New Economy. The level of connectivity between actors and ideas is increasing dramatically. We have only begun to see the impact, and only part of it is measurable.

Interpreted in this way, the New or Digital Economy is about dynamics, not static efficiency. It is more about new activities and products than about higher productivity. What is really new in the New Economy is the proliferation of the use of the Internet, a new level and form of connectivity among multiple heterogeneous ideas and actors, giving rise to a vast new range of combinations. There are some measurable effects on productivity and efficiency, but the more important long-run effects are beyond measurement.

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1. Introduction

There are many signs indicating that something new has happened in the United States economy during the last decade. While the surge in labor and total factor productivity growth rates in the latter half of the 1990s was impressive and widely interpreted as a sign of a ‘New Economy,’ it remains to be seen whether it was a fleeting phenomenon or the beginning of a new trend. But there are other indicators that are less cyclical in nature and that appear more likely to persist. There is evidence of a wave of innovation. Census Bureau data show that the number of US patents issued to US corporations more than doubled between 1990 and 2001 and that R&D expenditures by industry surpassed government R&D expenditures in 1980 and more than doubled since 1990. Tobin’s Q ¹ more than doubled over the course of the 1990s, indicating a sharp rise in intangible capital (including knowledge capital) relative to tangible capital. There has also been a surge in production of IT, heightened competition in an increasingly deregulated economy facing strong international competition, a rising amount of R&D done in small companies, a rise in technology alliances and acquisitions, and new forms of financing (Baily and Lawrence, 2001). The ratio of inventories to shipments in the durable goods industries has declined by about 40% since the early 1980s, suggesting that shorter and more flexible manufacturing processes and just-in-time deliveries have reduced the need for inventories.

Regardless of whether one regards such data as convincing evidence of a New Economy or simply as indicators of some interesting and possibly new patterns, the question is: What is the cause of the different behavior of the US macro economy in the late 1990s compared to earlier periods? What is driving the observed changes?

In this paper, I argue that the observed changes are at least consistent with the view that digitization of information, combined with the Internet, represents a form of general-purpose technology that is giving rise to a vast new array of possible combinations that we may refer to as the New Economy. The level of connectivity between actors and ideas is increasing dramatically. We have only begun to see the impact, and only part of it is measurable.

Interpreted in this way, the New or Digital Economy is about dynamics, not static efficiency. It is more about new activities and products than about higher productivity. While economic growth can be described at the macro level, it can never be explained at that level. Economic growth results when a variety of actors create and use new technology. New technology is the result of new combinations of ideas. When connectivity increases, the number of possible new combinations increases also.

The paper is organized as follows. The theoretical background is presented in the next section. This is followed by a brief review of historical examples of general-purpose technologies and their economic impact. Next, the effects of digitization and the Internet are reviewed: the productivity enhancement in traditional industries, the restructuring of economic activity within industries, the market efficiency effects, and the potential arising from entirely new products and industries. The paper concludes with a brief summary.

¹ Tobin’s Q refers to the ratio between the market value of a firm’s assets and their replacement value.

2. Theory

Schumpeter (1911) argued that economic growth is a result of innovations, i.e., new combinations of products, processes, markets, sources of supply, and organizations. The number of potential innovations (i.e., the opportunity set or state space) is virtually unlimited. This means that at any moment only a small subset of all technical possibilities have been identified and only a yet smaller subset has been exploited commercially. New combinations are discovered through experimentation. In order to identify more technical possibilities, more attempts (experiments) are necessary. When technical possibilities are converted into economic opportunities, they become elements of the economy. The economy can be viewed as a system consisting of elements and connections. Greater connectivity among actors and ideas creates more possible combinations through identification of existing opportunities and discovery of new ones. “When connections change, so too does the structure of the system. When structure changes, the dynamic properties of the system change also. This changes the conditions under which connections exist; new ones may form, existing ones may fail or may even become strengthened” (Potts, 2001, p. 2).

Technological change occurs when the relationships among elements change or when new connections are established. The probability of discovering new combinations increases with the number of connections. Densely connected systems give rise to a large set of technical possibilities (a large state space), while more sparsely connected systems create fewer possibilities. “In essence, the defining characteristic of the modern economy is extremely rapid technological, organizational and institutional change, all embedded within broader patterns of social change” (Potts, 2001, p. 4). This understanding of the modern economy is imbedded in Eliasson’s concept of the experimentally organized economy which incorporates a virtually unlimited set of technical possibilities as well as bounded cognition and rationality on the part of each actor. This combination makes it impossible to identify *all* possibilities (optimization is not possible); mistakes are therefore common; and more experiments lead to a larger number of technical possibilities (Eliasson and Eliasson, 1996).

Certain environments are more supportive of experimentation than others. It is useful to think of the business environment as an innovation system. While several types of innovation systems have been examined in the literature, the notion of a technological innovation system (Carlsson and Stankiewicz, 1991; Carlsson, 1995, 1997, 2002) has the advantage that it focuses on a particular technology or set of technologies and incorporates all the actors (not just those in the market), the networks through which they interact, and the institutional infrastructure. Thus, technological innovation systems constitute frameworks that support the supply of innovations that give rise to new business opportunities. One of the functions of a technological innovation system is to provide connections among various elements of the system.

There are three dimensions to technological innovation systems: (1) a *cognitive dimension* defining the clustering of technologies resulting in a new set of technological possibilities; this identifies the relevant knowledge base or ‘design space’ (see below) of the system; (2) an *organizational and institutional dimension* capturing the interactions in the network of actors engaged in the creation of these technologies; and (3) an *economic dimension* consisting of the set of actors who convert technical possibilities into business opportunities.

Technology can be interpreted as a set of combinatorial *design spaces* formed by *clusters of complementary technical capabilities* (Stankiewicz, 2002). A design space represents a small part of the opportunity set (the sum total of all technical possibilities). It may be thought of as a convenient way to group together the technical capabilities required for a particular type of economic activity. Design spaces undergo constant evolution.

There are three modes of technological growth (accumulation) in the design spaces: (1) expansion of the space through the *addition of new capabilities*; (2) *progressive integration and structuring* of the design spaces through the co-evolution of its various elements; and (3) accumulation of application-specific know-how linked to the evolutionary trajectories of particular artifacts, such as, for instance, aircraft. Design spaces are potentially influenced by academic research (concepts, theories, research methods, and tools) and industrial R&D (increasing the absorptive capacity within the system).

If we apply the design space concept to economic activities involving digitization and the Internet, it is not hard to imagine that the Internet makes it easier than before to connect people, ideas, and bodies of knowledge. This makes it more likely that new capabilities will emerge and that previously separate activities will be connected, integrated, and restructured. The search for information and knowledge is facilitated and thereby their accumulation. This will be illustrated later in this paper.

When the design space changes, the elements of the organizational and institutional dimension also change: individual actors, networks, organizations such as universities, research institutes, and public agencies, and institutions in the form of regulations, standards, etc. For example, with the emergence of biotechnology, the knowledge base of the pharmaceutical industry has shifted from chemistry and chemical engineering towards biotechnology. The carriers of this knowledge, their research tools and methods, and the organizations with which they are associated are different from those in the conventional pharmaceutical industry.

The greater the connectivity (density) of the design space (in both the cognitive and organizational dimension), the greater the possibility of identification of technical possibilities (innovation) that can be converted into business opportunities. The role of entrepreneurs is to identify profitable innovations among all the technical possibilities and convert them into business opportunities. In order to do so, entrepreneurs need support in the form of venture capital (not just risk capital but also the business competence required to develop suitable strategies as well as identify and acquire key resources, including personnel). To facilitate redeployment of resources and ownership changes, well-functioning exit markets (such as an IPO market and an acquisition-friendly business climate) are needed. Collectively, competent customers, innovators, entrepreneurs, venture capitalists, exit markets, and industrialists who take successful innovations to large-scale production may be referred to as a competence bloc (Eliasson and Eliasson, 1996). Whereas the technological innovation system is defined from the technology supply side, the competence bloc constitutes the demand or market side.

In summary, then, the new connectivity through the Internet gives rise to a massive increase in the number of new possible technical combinations. The more people are connected and the greater the variety of ideas, the greater is the number of new combinations. But the conversion of new possibilities into profitable business opportunities is by no means automatic. Only when the actors in the innovation systems and competence blocs interact

with each other closely and frequently enough do the new technical possibilities result in economic growth. The greater the number and variety of actors with different beliefs and expectations, the greater are the chances that new ideas will result in economic growth. Institutions (such as markets and technological innovation systems) reduce the costs of making certain transactions by establishing powerful connections (Loasby, 2001, p. 407). Densely connected systems are more likely to absorb and exploit new ideas than are more sparsely connected systems. For example, a large and sophisticated stock exchange such as the New York Stock Exchange is more likely to support new ideas than a small, less well established stock market.

While densely connected systems give rise to economies of both scale and scope, it is the latter that are of primary concern in this paper. In other words, connectivity has more to do with new products than with larger markets.

3. Historical examples of general-purpose technologies

What historical evidence is there that new connections lead to economic growth? In this section I will discuss three examples of new technologies in the past that gave rise to new combinations, resulting in new business opportunities that were exploited by entrepreneurs and contributed to economic growth. Obviously, general-purpose technologies (GPTs) open up more new possibilities than more specific technologies. The more generally applicable are the technologies, the greater the economic growth potential. While the cost-saving potential of a GPT may be substantial, that is only a part, and not necessarily the most important part, of the contribution to economic growth:

In our view a methodology that focuses on cost comparisons, and the concomitant cost-savings calculations, by and large misses the deeper point . . . [T]he impact of a general purpose technology on growth operates primarily through innovational complementarities and the positive loop that these set in motion, and not just through cost advantages. Regardless of the size of the cost savings that a new technology might bring about, if it does not prompt down-the-line innovations and related complementary investments across a wide range of user sectors, it will not propel long-term growth, and hence it will not qualify as a GPT. Conversely, a technology that does exhibit pervasive innovational complementarities may not result in significant cost savings vis a vis its closest substitute, but this latter fact would not necessarily hinder its role as a GPT. (Rosenberg and Trajtenberg, 2002, p. 9)

On the other hand, the very fact that GPTs do generate new combinations, sometimes with considerable delays, makes it difficult to identify and measure their contributions to economic growth, as will be apparent below.

3.1. *Transportation and communication technologies in the 19th century*

In *Scale and Scope*, Chandler (1990) argues that the emergence of steamships, the cable and the telegraph, and railroads raised the speed and dependability and significantly lowered the costs of transportation and communication. This created a vast new national market in

the United States, making it possible in capital-intensive, process-oriented industries to take advantage of new and improved processes of production that for the first time in history enjoyed substantial economies of scale and scope. Large manufacturing units applying the new technologies could produce at much lower unit costs than could smaller units.

However, the conversion of the new opportunities into economic growth was by no means trivial or automatic:

In order to benefit from the cost advantages of these new, high-volume technologies of production, entrepreneurs had to make three sets of interrelated investments. The first was an investment in production facilities large enough to exploit a technology's potential economies of scale or scope. The second was an investment in a national and international marketing and distributing network, so that the volume of sales might keep pace with the new volume of production. Finally, to benefit fully from these two kinds of investment the entrepreneurs also had to invest in management: they had to recruit and train managers not only to administer the enlarged facilities and increased personnel in both production and distribution, but also to monitor and coordinate those two basic functional activities and to plan and allocate resources for future production and distribution. It was this three-pronged investment in production, distribution, and management that brought the modern industrial enterprise into being. (Chandler, 1990, p. 8)

These large new industrial enterprises, particularly in the United States but also in other countries such as Britain and Germany, ushered in the industrial era and spearheaded economic growth for more than a century.

Chandler focuses on the large firms in capital-intensive, process-oriented industries, since they were the ones that made the three-pronged investment in production, marketing and distribution, and organization and management, thereby taking advantage of economies of scale and scope offered by technological change in production. While these firms were also among the main beneficiaries of the new and improved transportation and communication technologies, they were not the only beneficiaries. The railroads, the steamships, and the cable and telegraph influenced the nature and location of virtually all kinds of economic activity.

Thus, the innovations in transportation and communication involved general-purpose (enabling) technologies that made it possible for new combinations to be made throughout the economy, especially in certain capital-intensive industries. The new transportation and communication technologies made it possible to join together previously small regional markets into a single national market. The United States quickly became the largest national economy in the world. Rapid population growth (partly as a result of immigration) led to large investments in both infrastructure and manufacturing, enabling US firms in scale- and capital-intensive industries to take advantage of new technologies more rapidly than their European counterparts. All these factors created a more fertile environment for economic growth in the United States than elsewhere. As a result, the US benefited more than Britain and Germany from these innovations, even though Britain was more advanced and had a larger market until the late 19th century. The new technologies had a more transforming effect in America than in more densely populated Europe.

By combining fast, dependable transportation with economies of scale in production, first movers created larger markets. But as they expanded the scale of operation, they also

created new combinations in the form of new products. While Chandler does not address this directly, he does point out some of the new opportunities in byproducts and related products as output expanded. For example, in the production of aluminum and synthetic ammonia, the scale economies were so large that the companies involved had to search for new products that could take some of the output of the most efficient plants. And the expansion of meatpacking activities gave rise to byproducts such as fertilizer, soap, and glue, while oil refining generated new petrochemical products. When the volume was large enough, as it was in the case of fertilizer and leather for the largest meatpackers, nationwide sales organizations were established, managers hired, and integrated divisions were formed to market such products (Chandler, 1990, pp. 40–41). A systematic search for new combinations arising from businesses taking advantage of economies of scale and scope would likely yield impressive results.

3.2. *Corliss steam engine*

The steam engine is widely regarded as the icon of the Industrial Revolution and a prime example of a general-purpose technology. Prior to steam engines, waterpower was the main source of energy for industrial activity, but it restricted the location of manufacturing to areas with suitable topography and climate. Steam engines offered the possibility of relaxing this constraint, allowing industry to locate where key considerations such as access to markets for inputs and outputs directed. But even as late as 1870, the vast majority of steam engines used in the United States were quite small, with a capacity of only 5–25 hp (Rosenberg and Trajtenberg, 2002, p. 16). In the early 1850s, George Corliss of Providence, Rhode Island, invented a new type of steam engine that had much greater capacity than other engines and that also had an automatic variable cut-off mechanism. This meant that the speed of the engine was much more precisely controllable than in previous designs and led to substantial fuel savings.

The enhanced performance of the Corliss engine as well as its fuel efficiency helped tip the balance in favor of steam in its contest with waterpower. Through analysis of detailed data, Rosenberg and Trajtenberg (2002) show that the deployment of Corliss engines served as a catalyst for the massive relocation of industry away from rural areas and into large urban centers (especially in the northeastern US), thus fueling agglomeration economies by attracting further population growth to the cities, giving rise to larger markets and directly stimulating economic growth. But the relocation of industry may also have provided an indirect stimulus to growth. One of the advantages of being able to locate plants in large urban centers was to considerably increase the connectivity. This led to higher density of people and ideas, increasing the probability of new combinations and new connections. In particular, knowledge-intensive activities that tend to cluster geographically were likely to benefit more than others.

3.3. *The dynamo (electric motor)*

A third historical example of a general-purpose technology is the dynamo (electric motor) that has been studied in a series of papers by Paul David. Focusing primarily on the effects in manufacturing, David (1990) shows that the electric motor, in comparison with steam

engines, provided savings in fuel input and greater efficiency (partly through more precise controllability). It also facilitated an improved plant layout in that individually powered machines could be placed within the factory to facilitate work and material flows rather than in the sequence dictated by a single power source. This led to savings in fixed capital (single-story, lighter weight buildings); savings in operating capital due to better materials handling, flexible reconfiguration of machine placement; as well as more flexibility, more up time, and less power consumption.

David found that “approximately half of the 5 percentage point acceleration recorded in the aggregate TFP growth rate of the US manufacturing sector during 1919–1929 (compared with 1909–1919) is accounted for statistically simply by the growth in manufacturing secondary electric motor capacity during that decade” (David, 1990, p. 359). In a subsequent paper, a similar productivity increase, attributable to the diffusion of electric motors, was found for the United Kingdom (David and Wright, 1999).

While this is impressive enough, David also notes that the measured productivity improvement is only a part of the total contribution to the economy. Conventional productivity measures are especially problematic in accounting for new kinds of products. Better, more powerful machines with better controls facilitated both improved products (better quality, more standardized output) and entirely new manufactured products. As explored in more detail in Carlsson (1984), electrification and single unit drive were essential for the development of larger and more powerful machine tools and the efficient use of improved high-speed tool steels. These included more automatic and specialized machine tools as well as machine tools capable of greater precision. These, in turn, were critical for mass manufacture of interchangeable parts. Without that, it is unlikely that the moving assembly line, introduced by Henry Ford in 1913, would have been possible. When the typical assembly time for cars was reduced from 12 h to 30 min, it was necessary for suppliers of components to operate at much higher rates. This required machine tools of all kinds to operate much faster, with more automatic feed devices and substantially increased accuracy in order to avoid problems further down the production line and in the quality and performance of the product. With improved machine tools, it became possible to produce a vast array of new or greatly improved mechanical products. It is hard to imagine this development without electrification and single unit drive—but it is even harder to measure.

If we extend the analysis to include not only manufacturing but also the total improvement in human well-being and economic welfare caused by electrification more generally, conventional measurement tools are even more deficient. The introduction of electric lighting and electric domestic appliances (e.g., refrigeration) permitted changes in lifestyle, improved the environment, and influenced how human beings spend their time and build their homes and cities. This created many new combinations in the form of new goods and services and increased variety. Almost none of this is captured in the productivity statistics.

It is also worth noting that it took several decades for the productivity improvements (as conventionally measured) to show up in the statistics. The reasons for this delay have to do with network externality effects (the building of transmission networks—power grid—was necessary). This required compatibility standards (e.g., the choice between ac and dc, and a common voltage) and the building of public infrastructure (including regulation). Another reason for the delay was the slow pace of factory electrification: the unprofitability of replacing still serviceable manufacturing plants and the resulting necessity of operating

parallel systems for extended periods. As a result, the most rapid diffusion of the new technology occurred in the industries that happened to grow the most rapidly at the time (i.e., that were the least encumbered by previous investments): tobacco, fabricated metals, transportation equipment, and electrical machinery. A third factor may have been the need to develop appropriate management competencies and worker skills (different from skills acquired in traditional craft apprenticeships) (David and Wright, 1999, p. 15).

3.4. *Lessons from history: the economic impact of general-purpose technologies*

This brief review of a few general-purpose technologies suggests that they have all led to higher efficiency and productivity in the economy as conventionally measured but also that the measured effects are only a part, and perhaps not even the most important part, of the contribution to economic well-being and long-run economic growth. The more generally applicable the technology, the greater are the systemic effects, and the greater is the number of possible new combinations it generates. The greater the connectivity, the greater are the dynamic effects.

In Chandler's *Scale and Scope* the main focus is on the creation of large enterprises in capital- and scale-intensive industries, even though the innovations that generated the process were general-purpose technologies (transportation and communication) with applications far beyond a subset of manufacturing industries. Rosenberg and Trajtenberg's study of the Corliss steam engine has a broader focus, as does David's study of the electric motor. In all three cases the immediate effects in manufacturing were substantial; as I have suggested above, the broader impact on society—particularly via new combinations—was probably even larger but was not directly studied and certainly not measured. In the next section it will be argued that one of the most important current general-purpose technologies—digitization in combination with the Internet—has an even broader impact, though not any easier to measure.

4. The New (Digital) Economy

In discussing the New (Digital) Economy, it is necessary to distinguish between information and knowledge. Information may be defined as a collection of data, whereas knowledge can be defined as a structure (theory or hypothesis) that makes it possible to organize and interpret information. Thus,

In the *old economy*, information flow was physical: cash, checks, invoices, bills of lading, reports, face-to-face meetings, analog telephone calls or radio and television transmissions, blueprints, maps, photographs, musical scores, and direct mail advertisements.

In the *new [digital] economy*, information in all its forms becomes digital—reduced to bits stored in computers and racing at the speed of light across networks . . . The new world of possibilities thereby created is as significant as the invention of language itself, the old paradigm on which all the physically based interactions occurred. (Tapscott, 1995, p. 6)

Certainly information is not new, only the form in which it is gathered, manipulated, stored, and transferred. Nor is knowledge new. In *Post-Capitalist Society* (1993), Peter Drucker argues that knowledge has been at the core of economic activity since the industrial revolution: the essence of the change in economic activity during the period 1700–1850 was to convert practical experience into systematic, codified knowledge. Drucker argues further that the period 1850–1950 (the “Productivity revolution”) involved the application of knowledge to work (Taylorism), whereas he refers to the period from 1950 forward as the management revolution, characterized by the application of knowledge to knowledge. He concludes that:

[k]nowledge is the only meaningful resource today. The traditional ‘factors of production’—land (i.e., natural resources), labor and capital—have not disappeared. But they have become secondary. They can be obtained, and obtained easily, provided there is knowledge. And knowledge in this new meaning is knowledge as a utility, knowledge as the means to obtain social and economic results. (Drucker, 1993, republished in Neef, 1998, pp. 29–30)

Therefore,

knowledge work—activities that involve complex problem identification, problem solution, or high-technology design and that result in innovative new products or services or create new ways of exploiting markets—has quickly become the focus for economic growth and individual and organizational prosperity. (Neef, 1998, p. 3)

In the long run, therefore, one would expect knowledge-intensive industries such as financial services, entertainment, health care, education, and government to be those most transformed and benefiting the most from digitization and the Internet. In the medium term, the most visible effects may be seen in retailing, manufacturing, and travel.

In order to examine the effects of digitization and the Internet, let us consider some examples of new combinations in the following four categories of economic activity: (1) productivity enhancement in traditional industries, (2) restructuring at the industry level, (3) the creation of more efficient markets, and (4) the creation of new combinations that give rise to new products and new industries. The main thrust of the analysis is to show the pervasiveness and transformative nature of the Digital Economy.

4.1. Effects of digitization and the Internet on productivity in existing activities

4.1.1. The oil industry

The world has burned about 820 billion barrels of oil since the first strike at Oil Creek, Pennsylvania, in 1859, and 600 billion of those barrels—almost three fourths of the total—have been burned since 1973. Yet the world’s proven oil reserves are about half again as large today as they were in the 1970s, and more than 10 times as large as in 1950. Also, the average cost of finding new oil has fallen from US\$ 12–16 a barrel in the 1970s and 1980s to US\$4–8 today (Rauch, 2001).

What were the factors that made this possible? There are essentially six major developments:

- (1) *Computers*. The power of microprocessors increased by a factor of 7000 between 1970 and 2000. Computing chores that took a week in the early 1970s now take a minute. The cost of storing one megabit of information, or enough for a 320-page book, fell from more than US\$ 5000 in 1975 to 17 cents in 1999.
- (2) *Seismic imaging*. Knowing how fast sound travels, geologists can set off booms or pings and then analyze the returning echoes to infer the nature and location of the surface that has reflected them. For many years, the most that computers could handle was two-dimensional imaging that showed vertical cross sections of rock. Three-dimensional imaging was first used commercially in 1975. It required enormous computer capability. Even a small 3-D survey might generate 200 gigabytes of data.
- (3) *Combination of computers and 3-D seismic imaging*. Between 1985 and 1995, the computing time needed to process a square kilometer's worth of data fell from 800 to 10 min. From 1980 to 1990 the cost of analyzing a 50-square-mile survey fell from US\$ 8 million to US\$ 1 million. Now it is more like US\$ 90,000.
- (4) *Directional drilling*. A directional well can run in any direction, approaching a reservoir from whichever angle geologists deem most promising. It can twist and turn to cut through any number of reservoirs. The effect was to bring all kinds of previously inaccessible or uneconomical reserves within reach. By the late 1980s, 3-D seismic imaging was revealing targets accurately enough to make directional drilling worth considering. The cost of horizontal drilling fell from 4 to 8 times that of vertical drilling in 1989 to less than double in 1993, while the productivity advantage of horizontal wells stayed constant at 2–5 times that of vertical wells.
- (5) *Measurement-while-drilling*. Before 1980, a driller would point his bit in the indicated direction, bore a few hundred feet, and stop. Then he would push an instrument down, take a picture of a compass, pull the instrument out, and check the location. Each survey could mean halting drilling for hours at a stretch (at a cost of around US\$ 4000/h), and the results were approximate. In measurement-while-drilling, an instrument rides behind the drill bit, continually records the bit's location, and reports it back to the surface.
- (6) *The Internet*. Geologists and executives in the home office can now click on their Web browsers and see what the driller is seeing somewhere in the Gulf of Mexico, or in Prudhoe Bay, or in the North Sea. They can plug into the rig from laptops at the airport. They can instruct the rig to let them know by e-mail or pager when the hole reaches 20,000 feet, or when resistivity suggests oil, or when anything else of interest happens. Rigs can now talk to Palm Pilots. This makes it possible even in this capital-intensive industry to take advantage of short-run market changes and to reduce costs.

So, what's new in the oil industry? Higher-resolution (3-D) imaging increased the payoff for accurate drilling. This induced companies to invest in high-tech down-hole sensors. Powerful sensors increased the yields of directional drilling (i.e., resulted in faster, cheaper directional drilling), which led to higher payoffs to even higher resolution 3-D seismic imaging. None of these technologies were truly new, but they had co-evolved technologically to the point where they could be called new when they intersected with the proliferation of the Internet. They all involve digitization of information and the use of computers. What was *really* new was the way in which they developed simultaneously, energizing and reinforcing

one another. The result is that even more than earlier, knowledge, not petroleum, is becoming the critical resource in the oil business. Though the supply of oil is “fixed,” the supply of knowledge is boundless (Rauch, 2001). Digitization of information that had occurred over decades made it possible to take advantage of the Internet. And the Internet made it possible to integrate decisions on where and when to drill into the overall management of the oil business, reducing costs and raising productivity.

4.1.2. Productivity enhancement through collaboration

Digitization and the Internet, in combination with new software, enable companies to collaborate with suppliers and customers in new ways and thereby to raise productivity. For example,

In a March, 2002 poll conducted by the online newsletter of the National Association of Wholesaler-Distributors, readers were asked which of the following business strategies would have the biggest impact on them in the next three years: collaboration with supply chain partners (38 percent); new information technologies (26 percent); or network restructuring (five percent). Twenty-eight percent of respondents said that all three would impact their businesses. (Tuttle, 2002, p. 59)

Accessing information and responding quickly to customers’ needs are what drive the demand for Internet collaboration in the distribution industry. Using collaborative Web technology, distributors can become involved in designing and developing products more easily than in the past. Also, a distributor with direct supplier connections with a number of vendors can enable customers to check availability of needed items at these vendors and fill their orders immediately rather than having to wait while a salesperson calls each factory and then places an order. This can reduce the order cycle from days to minutes, and the software makes it possible to store information about the transactions that can be used later (Tuttle, 2002).

Similarly, web technology makes it possible to bring together design engineers in collaborative systems to develop new products. An example is DaimlerChrysler’s FastCar project. The company expects to develop the new car 40% faster through its new web-based system than in a traditional system in which geographically dispersed engineers communicate via phone, fax and e-mail and where each proposed design change might require days or weeks. As a result, DaimlerChrysler expects to save billions of dollars off the cost of car development over the next few years (Moozakis, 2000). For similar reasons, General Motors can get a car into production in 18 months rather than the 42 months it took in the mid-1990s (Keenan et al., 2002).

Thus, digitization of information in conjunction with the Internet can reduce costs, increase productivity, and help producers respond more quickly to changing consumer demand. Through better connectivity, the design space becomes denser: more ideas are created, new ideas can be tried and implemented (or rejected) more quickly, and the knowledge base can expand through more experimentation. This reflects the supply side (the innovation system) of the market for innovations. If the demand side responds appropriately—i.e., if the competence bloc succeeds in selecting and supporting viable new products—economic growth results.

4.2. Restructuring of economic activities within industries

Many industries are beginning to confront the challenges and opportunities presented by the Internet. A few illustrative industry studies are now emerging. This section provides some examples from the banking, airline, and automobile industries.

4.2.1. The banking industry

A recent development in banking is the growth of vendors providing web-based self-service technology. This changes the interaction between banks and their customers from bank customer facing staff (in particular, call center agents) towards automated Internet-based channels, while maintaining a high level of service to the customer. This offers potential cost savings and efficiencies while theoretically improving customer service, with bank staff able to focus on higher-value and more customer-specific enquiries (Datamonitor, 2001).

On-line banking customers reduce costs for the banks because the majority of transactions by those customers are of the self-service type. Nevertheless, while it is likely that the Internet will continue to have a profound effect on the way banks do business in the future, it is much less clear whether the Net will create or destroy value for the banks, and what its overall impact on banking revenues is likely to be. As on-line banking becomes more common, it is likely to provide less strategic (competitive) advantage to individual banks, and the customers are likely to be the main beneficiaries.

The mortgage industry provides an example of restructuring of the financial services industry as a result of the Internet. The industry is changing as new Internet-based entrants identify niches and supply special services, bringing new value to customers, while outmoded traditional business models have disappeared. Among the reasons are:

1. *The Internet aids cost reconfiguration:* It facilitates cost control and process reconfiguration by work elimination, work shifting, work avoidance, and work sharing. Web-centric mortgage systems reduce employee training costs, are easier to navigate, and provide easier access to databases than conventional systems.
2. *The Internet facilitates self-service:* Ubiquitous Internet access, coupled with real-time technologies, provides consumers an opportunity to access and/or update information at any time, from anywhere. This reduces the demand for customer service departments. Consumers can also perform more complex interactions, such as calculating loan payoffs and determining how much additional payment to principal is required to qualify for mortgage insurance cancellation.
3. The Internet can enhance revenue by allowing service providers to cross-sell, refinance, and pursue other revenue-generating opportunities.
4. Asset/risk management is improved through Internet connectivity as information can be communicated, viewed, and shared on an immediate, real-time basis (Thinakal, 2001).

In a recent paper, Autor et al. (2000) describe how a single technological innovation, the introduction of image processing of checks, led to distinctly different changes in the structure of jobs in two departments of a large bank. In the deposit processing department, image processing led to the substitution of computers for high school educated labor in

accomplishing core tasks and in greater specialization in the jobs that remained, raising the possibility of outsourcing and changes in the location of certain parts of the operation. In another department (exceptions processing), image processing led to the integration of tasks, with an associated increase in the demand for particular skills, and with an overall 28% reduction in labor input.²

These examples from the banking industry suggest that digitization and the Internet are changing the locus and organization of banking services. They also suggest that the main beneficiaries are more likely to be the customers, not the banks.

4.2.2. *The airline industry*

Another industry undergoing structural change, due in part to the Internet, is the airline industry. As a result of increased use of the Internet in searching and booking airline travel, the business model used by US network carriers is being challenged. This business model is based on sharp price discrimination between economy class passengers using tickets with restrictions on use and refundability and business and first class passengers traveling on unrestricted tickets. Unrestricted ticket fares are typically 2–4 times higher than the restricted fares and historically have generated the large bulk of profits in the industry. The transparency of fares on the Internet and the ease of use of the Internet have made it difficult, if not impossible, for the airlines to sustain their price discrimination policies. As shown in a recent study, the share of restricted coach tickets as a percentage of total tickets sold increased from 80% in early 1998 to 94% in early 2002 (Lane, 2003). The study also found a strong correlation between increasing Internet usage and a decrease in restricted coach fares. When added to the problems facing the airline industry from other sources (the business downturn since 2001, the reduction in traffic resulting from the terrorist activities after September 11, 2001, and the pre-existing overcapacity and low profitability in the global airline industry), the Internet contributes to forcing the airlines to rethink their whole strategy (including both the hub and spoke system, the price discrimination model, and various other business practices) and restructure in order to survive.

4.2.3. *The automobile industry*

The automobile industry provides additional examples of new combinations, primarily organizational in nature, resulting from the Internet. For instance, the major producers in the US automobile industry have joined together in Covisint, a business-to-business supply system, as well as other manufacturing systems and supply exchanges. Together with business-to-consumer ordering and purchase systems, such systems have the potential to improve efficiency in this otherwise traditional industry. Internet ordering by customers would greatly diminish the role of conventional dealers, who have thus far blunted its impact (Kwoka, 2001).

The E-business effects on consumer and supplier relationships in the US auto industry have also been studied by Helper and MacDuffie (2001). They find that although the impact

² For further information on the relationship between technological and organizational changes associated with the new digital technologies, see some recent papers by Bresnahan et al. (2002), Caroli and Van Reenen (2001), and Caroli et al. (2001).

of the Internet may be profound, it is by no means technically determined. It will depend on the extent to which complementary changes occur in the retail strategies of the auto producers (build-to-order, factory direct, and dealer direct), design strategy (modular or not, standardization or not), procurement strategy (voice versus exit), technology strategy (incremental versus radical technical change), and public policy (especially with respect to regulation).

4.2.4. *The defense industry*

The design and production of military aircraft provide another example of restructuring of economic activity due to collaboration via the Internet. While management experts have long talked about so-called virtual corporations (companies that focus on what they do best and farm out the rest to specialists), a new generation of web-based collaboration technologies is making it easier for companies to work hand-in-hand with their partners to bring new products to the market much faster and cheaper than previously. In designing and manufacturing the supersonic stealth fighter planes in the largest defense contract ever, Lockheed Martin Aeronautics Co. will engage in some intricate teamwork:

More than 80 suppliers will be working at 187 locations to design and build components of the Joint Strike Fighter. It's up to the 75-member tech group at Lockheed's Aeronautics division to link them all together, as well as let the U.S. Air Force, Navy, and Marines, Britain's Defense Ministry, and eight other U.S. allies track progress and make changes midstream if necessary. All told, people sitting at more than 40,000 computers will be collaborating with each other to get the first plane in the air in just four years—the same amount of time it took to get the much simpler F-16 from contract to delivery in the 1970s . . . Lockheed and its partners will be using a system of 90 Web software tools to share designs, track the exchange of documents, and keep an eye on progress against goals. (Keenan et al., 2002)

The examples provided here are meant simply to illustrate the kinds of restructuring of economic activity that are likely to result from digitization and the Internet. There are not yet many studies on this topic—thus providing ample opportunities for further research. But there are many previous studies on structural change (reconfiguration of companies, restructuring of industries, increased role of small business, outsourcing, and alliances) that are suggestive and that could be reviewed from the standpoint of the role of digitization and the Internet. Another potentially fruitful avenue of research would be to examine the rapidly growing number of studies of innovation systems and industry clusters from a similar standpoint (such as the biotechnology-focused studies of Cooke (2001) and Carlsson (2002)).

4.3. *The market efficiency effects of the Internet*

The market efficiency impact is the most heavily studied aspect of the Internet. Several studies of the efficiency effects of the Internet (see, e.g., Smith et al., 2000) show that the main effects in the markets are to make it easier for buyers and sellers to compare prices, to cut out the middlemen between firms and customers, and to reduce transaction costs and

barriers to entry. Thus, as illustrated in the airline example above, the Internet increases competition and improves the functioning of the price mechanism. In this sense, the most important immediate (and measurable) effect of the ‘new’ economy may be to make the ‘old’ economy more efficient. There is at least some evidence to bear out these claims. For example, Lehman Brothers (a financial services firm) reports that a transfer between bank accounts costs US\$ 1.27 if done by a bank teller, 27 cents via a cash machine (ATM), but only 1 cent over the Internet. Similarly, it was reported in 1996 that the average cost to issue a ticket was US\$ 35–45 through traditional travel agents, less than US\$ 20 if the ticket was purchased directly through the airlines, US\$ 5–10 if the ticket was electronic, and only US\$ 2–5 if purchased on-line (Grant, 1996). These cost differentials are likely to have become even greater since then but are still illustrative. Recent actions by US airlines to stop paying commissions to independent travel agents and to encourage customers to use the Internet when purchasing tickets confirm these findings.

Litan and Rivlin (2001) have attempted to extrapolate judgmental estimates of the likely impact of the Internet at the industry level based on estimates by individual firms and analysts and then adding up the results to see what they imply for the overall economy. Their estimate shows a total annual cost saving of US\$ 100–230 billion. This implies a total cost saving of about 1–2% which over 5 years translates into an annual contribution to productivity growth of 0.2–0.4%.

The sources of potential cost savings that they identify are reduced transaction costs, increased management efficiency, and increased competition leading to more transparent prices and broader markets. They conclude that the greatest impact may not be felt in e-commerce, but rather in a wide range of ‘old economy’ arenas, including health care and government, because of changes to the way information flows. Further, as a result of the Internet, there is considerable scope for management efficiencies in product development, supply-chain management, and a variety of other aspects of business performance, encouraged by enhanced competition. Finally, they conclude that much of the benefit from the Internet is likely to show up in improved consumer convenience and expanded choices, rather than in higher productivity and lower prices.

4.4. New combinations in the form of new products and industries

As has already been indicated, increased production and market efficiency and restructuring of economic activity are only the beginning; in the long term, the most important effects of digitization and the Internet are likely to come through entirely new products (goods and services). By definition, we do not know what these are. But the following list is at least suggestive of some of the ways in which digitization and the Internet have already transformed existing products and activities in a number of areas.

E-mail is changing the ways in which people communicate with each other, replacing regular mail, and to some extent also voice communication. The availability of on-line financial services is transforming the way we manage our accounts, pay bills, etc. On-line applications to universities and various other institutions and e-filing of tax returns are other examples. As already indicated, on-line travel agents have changed the way we obtain information and book our travel (including an arguably new product, e-tickets). Electronic games, electronic greeting cards, and downloadable music are examples of

consumer products that are both complements to and substitutes for existing products. On-line searchable databases and electronic journals are changing the ways in which research is done.

Common to all these examples is that they involve changes in delivery (electronic rather than some other way) of existing products, digitization being a prerequisite. Are there also examples of genuinely new products that were not available prior to the Internet? Our knowledge here is necessarily even sketchier, but the following Internet-based products are at least suggestive.³ One example is so-called open innovation: helping customers find solutions to technical problems via the Internet. Assisting customers in sourcing specialized products and materials over the Internet is another. Providing services to enable national advertisers to adapt their advertisements to each local market, providing outsourced staffing to support billing and collection of medical insurance, helping startup companies find alternative sources of funding to conventional venture capital, and employment portals to help employers and recruiters find and match suitable job candidates are other examples. As it turns out, they all involve some type of brokerage function that requires real-time connectivity, i.e., timeliness is one of the distinctive features of the product. Besides connectivity, these services involve the collection, use, and distribution of information of one sort or another. Sometimes the databases are massive. But even more fundamentally, these services involve not just information but also knowledge in the form of software to organize data and information. This knowledge is proprietary and quite specialized; it is the core competence of the business. As these examples suggest, this core competence can be quite narrow. The important point is that this type of knowledge is ubiquitous; it can be applied to all sorts of activities and give rise to a multitude of new businesses. To what extent this generates ‘net new’ business at the macro level or whether it simply substitutes for some existing products is difficult to say—but it would be surprising if increased specialization, over time, did not lead to new products.

Inherent in the term ‘new combination’ is the idea that the result of the activity contains some new element, even though all the components being combined may have existed previously. And what is ‘genuinely new’ may be far less important than the cumulative effect of a multitude of minor, perhaps imperceptible, changes. As the review of general-purpose technologies has suggested, these numerous small changes are difficult to identify and measure—they become obvious only with hindsight, and the timeframe is counted in decades rather than years.

Nevertheless,

... a new economic theory is beginning to emerge, which suggests that the ability to exploit markets and to innovate ... has replaced production efficiency (and therefore the concept of cost-reduction productivity) as the major driver of growth ...

... there are indications that domestic growth arises not through expansion or replenishment of market share (particularly in the near-saturation domestic market of developed

³ These examples are based on preliminary results of an ongoing study by the author of Internet-based companies in Ohio and Sweden.

economies), but through the introduction of entirely new technologies or problem-solving services that create new markets. (Neef, 1998, p. 4)

5. Conclusion

So what is really new in the New (Digital) Economy? In a nutshell: the Internet, a new level and form of connectivity among multiple heterogeneous ideas and actors, giving rise to a vast range of new combinations.

I have argued that the combination of digitization and the Internet can be viewed as a general-purpose technology with features similar to GPTs in the past. The technological changes in transportation and communication in the 19th century gave rise to a large national market, offering great opportunities for businesses to take advantage of scale and scope in production and distribution of certain capital-intensive goods. The Internet has less to do with transportation than with communication and therefore has less impact on production and distribution of goods than it does on handling of information. The Internet makes it possible to collect, package, and distribute information quickly and efficiently.

The Corliss steam engine removed a constraint on the location of certain heavy industrial activities and made it possible for them to locate wherever the market conditions were favorable. This fueled urbanization and agglomeration, leading to further economies of scale and scope.

Electrification and single unit drive generated improvements in manufacturing technology that led to both improved existing products and new industrial products.

Each of these GPTs arguably led to lower costs and higher productivity in the activities directly affected, but even these effects are difficult to measure. The fact that the effects of GPTs were spread over many activities and several decades makes the measurement task even more difficult. Their broader impact in terms of new economic activities is even harder to identify, let alone measure.

A more thorough review of historical general-purpose technologies than that above, with particular attention to their broader impact on economic activity (not just productivity enhancement) would likely yield insight as to the types of new economic activities generated in the past. Electrification, the automobile, commercial aviation, and television are examples of such technologies that have changed the way we live and organize our daily activities. It is hard to even imagine what life would be like without them. Digitization in combination with the Internet seems to have even broader applicability than previous general-purpose technologies, since it is more pervasive: It affects the service industries (e.g., health care, government, and financial services) even more profoundly than the goods-producing industries, and these service sectors represent over 75% of GDP.⁴ In addition, we may never be able to measure the direct impact on consumers in the form of new products. Thus, there are some measurable effects on productivity and efficiency, but the more important long-run effects are beyond measurement.

⁴ In 1999, transportation and public utilities, wholesale and retail trade, finance, insurance and real estate, services, and government represented 77% of US GDP (US Census Bureau, *Statistical Abstract of the United States*, 2001, p. 418).

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