The Blind Men and the Elephant

The First approached the Elephant,
And happening to fall
Against his broad and sturdy side,
At once began to bawl:
‘God bless me! but the Elephant
Is very like a wall!’

John Godfrey Saxe's (1816-1887)
version of the famous Indian legend.

CHAPTER 2
FRAMING THE PROBLEM

THE RATE OF CHANGE OF DIGITAL INFORMATION TECHNOLOGIES

Information Technologies are not recent. “For thousands of years, since the first cave paintings and the invention of writing, humans have used tools and techniques to collect, generate and record data” (Hall and Preston 1988, p. 30). Since then, information technologies have evolved from printing, to mechanical, to electromechanical, to electrical, and to microelectronic technologies to collect, generate and record data. What is recent is the digitization and convergence of information technologies. Digitization was made possible due to the existence of digital computers used to transform analog information to digital information. In 1945, the ENIAC, the first high-speed digital computer was built at the University of Pennsylvania for the U.S. Army’s Ballistics Research Laboratory. In 1976 Microsoft and Apple were founded, and by 1981 the first IBM personal computer was being released (NSF and NSB 2000). Convergence on the other hand, resulted as the fusion of a variety of complementary technological innovations "generated from a wide array of industries, including telecommunications, informatics, micro-processors, optoelectronics, and space industries" (Antonelli 1999, p. 59). Convergence of communication and processing information technologies also came as a result of two powerful forces known as the drivers of the information revolution: 1) the decline in the cost of transmitting information, and 2) the exponential increase in the power of computing and networking.

The decline in the cost of transmitting information was possible by the use of satellite communication and the installation of all-optical networks which increased bandwidths ten-thousandfold larger than existing fiber optics, which in turn decreased the cost of signal transmission (Bond 1997). The cost of a three-minute telephone call from New York to London fell from $245 in 1930 (in 1990 prices), to under $50 in 1960, to $3 in 1990, to 35 cents in 1999 (UN 1999). Predictions on further increases in bandwidth and decreases in costs include the possibility of having access to infinite bandwidth explained in books such as "Telecosm: How Infinite Bandwidth Will Revolutionize Our World" by George Gilder (Gilder 2000). Even though we may never have access to infinite bandwidth, we can safely predict that new solutions will asymptotically increase bandwidth capacity bringing it to huge numbers closer to infinity:

> Within a few years a combination of new technologies for compressing information (allowing you to get more done in a given capacity) with bigger capacity (fiber optic and cable) and entirely new approaches (such as satellite direct broadcast for the Internet) may move household access up to at least six million bits per second, and some believe we may reach the 110 million bits needed for uncompressed motion pictures. (NSF 2001b, p. 32).

On the other hand, exponential increases in the power of computing and networking are explained by a series of "laws" (Moore's, Gilder's, and Metcalfe's laws).

These laws explain why many of the exponentially improving trends in computer hardware capability have remained steady for the last years.

Moore's Law (1965) states that each new chip contains roughly twice as much capacity as its predecessor released within eighteen to twenty four months of the previous chip. This law has continued to hold true in the quarter century since it was first formulated: during the past 26 years, the number of transistors on a chip has increased more than 3,200 times.

Microprocessor	Year	Transistors (000s)	Clock Speed (Mhz)
4004	1971	2.30	0.1
8008	1972	3.50	0.2
8080	1974	6.00	2.0
8086	1978	29.00	10.0
80286	1982	134.00	12.5
Intel386TM	1985	275.00	16.0
Intel486TM	1989	1,200.00	25.0
Pentium®	1993	3,100.00	60.0
Pentium®Pro	1995	5,500.00	200.0
Pentium® II	1997	7,500.00	300.0
Pentium® III	1999	9,500.00	600.0

Table 2.1. Moore's Law: The trend in number of transistors per chip over time (NSF and NSB 2000).

Gilder's law, based on Moore's law, states that every increase in the number of transistors on a chip results in a square of the size increase in the chip's price-performance value; it has likewise been born out by subsequent experience. There is fairly widespread confidence that these trends are likely to continue for at least another ten years, in spite of reaching the fundamental limits of lithography[1]. To overcome this limit, research at molecular level in new post-lithographic manufacturing technology

[1] Lithography is a technique akin to photography used to design circuits on a computer chip.

known as "nanotechnology"[2] promises to meet or exceed Moore's law rate of progress for another 30 years. "By 2030, we are likely to be able to build machines, in quantity, a million times as powerful as the personal computers of today" (Joy 2000). So, even if the physical limits of lithography are reached, it is predicted that advances in nanotechnology will allow the production of computer chips in which the manufacturing costs will not greatly exceed the cost of the required raw materials and energy. Thus, it is predicted that by virtue of advances in nanotechnology, Moore's and Gilder's laws will continue to hold true in the near future (NSF 2001b).

The same has been true for networking capacity. In 1982, the TCP/IP[3] was established as a network protocol for ARPANET, in 1986 a coalition of universities and the NSF established the NSFNet in five super computer centers (both the ARPANET and the NSFNet were precursors of the Internet). By 1987, the number of Internet hosts exceeded 10,000. By 1989, this number exceeded 100,000. By 1992, this number exceeded 1,000,000. Metcalfe's law states that the value of network groups grows by the square size of the network. This means that a network that is twice as large will be four times as valuable because there are four times as many things that can be done. This occurs due to the larger number of interconnections. The "network effect" is also explained in diffusion and economic growth models. "As more and more users commit to a standard, that standard becomes increasingly attractive to others; the commitment of others makes the standard even more attractive – and so on in a cumulative fashion that is often described as 'positive feedback'. These are called network effects because, in the

[2] Several types of research at this level are carried out where the characteristic dimensions are less than about 1,000 nanometers. New computer chips would be designed with mole quantities of logic elements that are molecular in both size and precision and are interconnected in complex and highly idiosyncratic patterns.

[3] Transmission Control Protocol and Internet Protocol

first instance, they arise in the case of physical connection networks like telephone systems. The value to me of a phone system increases with the number of other people who are on the system." (Langlois 2001, p. 88). Metcalfe's law on the value of network groups has been used to explain the diffusion of the Internet around the world[4]. Similarly, the social model of diffusion of innovations proposed by Everett Rogers originally used by rural sociologists to study the diffusion of agricultural technologies in social systems has also been successfully applied to predict the diffusion of innovations of digital information and communications technologies in social systems. (See Appendix A for more detail on Roger's social model of diffusion of innovations).

All of these laws and models are useful in illustrating the point that the rate of change of digital information and communication technologies over the last decade has been exponential, not arithmetic. Some would argue that digital information and communication technologies are like any other technology in the history of mankind, such as gun powder, the printing press, the railroad, the telegraph, the telephone, or electricity. Technologies which have always been linked to economic growth. What seems to be different of digital information and communication technologies is the *rate* of change. So even though comparisons have been made between the information revolution and the industrial revolution in terms of potential scope and impact on society

[4] Another example of Metcalfe's Law and the network effect was the French network created in the 1970s using videotex terminals connected to the telephone network called the "Minitels". The creation of online services based on Minitels was an effort of the French policy elites to upgrade the French telephone network in response to the "American Challenge" described by Jean Jacques Servain-Schreiber's description of U.S. hegemony in the global information economy Servain-Schreiber, Jean Jacques. 1968. *The American Challenge*. New York: Atheneum.. By the late 1980s, Minitel was available in approximately 25% of the French households, almost every French office, and most large businesses OECD. 1998. "France's experience with the Minitel: lessons for electronic commerce over the Internet." Paris: OECD.

(Alberts and Papp 1997; Castells 1996; Kranzberg 1989), the rate of change produced by digital information technologies appears to have no equivalent in human history (Forester 1987). According to the NSF "the rate of technological change since the early 1980s has often outpaced the ability to define what it is we want to know and what data should be collected." (NSF and NSB 2000).

Technological change has always been a contributing factor to economic growth and development (Freeman and Perez 1988; Kuznets 1955; Rosenberg 1982; Schumpeter 1943). However, in the 1980s, the contribution of technological progress to productivity, and ultimately economic growth was still under discussion:

> In the past twenty years, economists and economic historians have attempted to develop serious quantitative measures of the contribution of technological progress to economic growth. This research is fraught with difficulties, both methodological and conceptual. Not only is it difficult to sort out the contribution of technological progress from other related contributions -capital formation, education, resource allocation- but there are no unambiguous measures of output over time periods long enough to permit changes in both prices and the relative importance of each component of the output. (Rosenberg 1982, p. 23)

Despite the elusive link between technological progress and economic growth[5], a number of economic historians[6] agreed with Rosenberg's characterization of technological change in the twentieth century. Unlike technological progress in other periods of time, technological progress in the twentieth century was characterized by: 1)

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[5] See Appendix D for detail on the *productivity paradox*.

[6] For an excellent discussion on the contribution of other technologies such as electricity to economic progress compared to the computer chip see David, Paul A. 1990. "The Dynamo and the Computer and Dynamo: A Historical perspective on the Productivity Paradox." *American Economic Review Papers and Proceedings* 80:355-361.

the structural changes it created, 2) an increasing reliance on science, and 3) the technological uncertainty produced by new emerging technologies (Rosenberg 1982).

In the late 1980s technological change was classified as a process of change occurring through: 1) *incremental* innovations, 2) *radical* innovations, 3) changes in the *'technology systems'*, and 4) changes in the *techno-economic paradigm* (Freeman 1988). *Incremental* innovations are produced by a progressive modification of existing products and processes. *Radical* innovations are discontinuous events, that even though do not have widespread effects on the economic system, may radically change existing products or processes. A combination of incremental and radical changes will in turn, produce changes in the *technology system*, reflected by changes in several sectors of the economy, including the creation of new economic sectors. Finally, changes in the *techno-economic paradigm* were characterized as large-scale revolutionary changes that affected the whole system. In the late 1980s, digital information and communication technologies were considered as one of the five generic technologies[7] to have produced both *incremental* and *radical* changes in *technological systems*. Furthermore, information technologies were predicted to be "the new techno-economic paradigm around which the new wave of technological and economic changes will cluster" (Freeman and Perez 1988, p. 10).

Technology is crucial for economic growth, as well as for competition. In the 1980s technological change due to the use of digital information and communication technologies was considered perhaps as the single most important source of major market share changes among competing countries or firms (Porter 1983). The power of technology as a competitive variable lies in its ability to alter competition through

[7] Besides biotechnology, materials technology, energy technology and space technology.

changing industry structure. By the end of the decade, comparative cross-country findings published in the World Competitiveness Report (Forum 1999) highlighted the importance on focusing on information technology as a new source of competitiveness. Three reasons were stated:

> First, email has greatly expanded the possibilities of interpersonal, inter-firm, and international communication. Second, the Internet has allowed for much more extensive and rapid dissemination of information. Third, the emerging area of e-commerce offers a potentially huge increase in the customer base for companies and huge savings in marketing costs in finding low-cost suppliers. Competitiveness in all of these areas is closely linked with the competitiveness of the local telephone infrastructure and with the penetration of the computer in the local economy (Forum 1999, p. 21).

The broader ramifications of digital information technologies on the global economic system are still unfolding and go well beyond the scope of this study. More recently, the host of dot-coms failures would lead us to reconsider earlier optimism. However, for the purpose of this study, it is important to acknowledge that during the last decade (1990-2000) the computing and networking capacity around the globe was growing at exponential rate, at least for post-industrial countries.

The perspective from the developing world

Even though the information revolution can be traced back to the 1960s in the U.S. with the convergence of information and communication technologies, it was only in the last two decades that these technologies diffused to most developing societies around the globe allowing interactive and simultaneous transfer of information in real time. And it wasn’t until the mid 1990s that Internet became a worldwide phenomenon.

Despite fast technological changes, in the early 1990s more than 1 billion people, one fifth of the world's population, lived on less than one dollar a day – a standard that Western Europe and the U.S. attained two hounded years ago (World Bank 1991). Technological progress and social progress had not been a reality for the majority of the population in the developing world. The rate of progress in technological development was in sharp contrast to the rate of progress of social development. By 1999, nearly 1.3 billion people still lived on less than a dollar a day, and close to 1 billion could not meet their basic consumption requirements (UN 1999). Three decades after the "widening gap between developed and the developing countries" was recognized by the United Nations as the "central problem of our times", the income gap between the world's richest fifth and poorest fifth had more than doubled, to 74 to 1 (UN 1999).

In the early 1990s digital information technologies were being hailed as the technologies that would transform developing economies. On the production side it seemed like the developing world could be a player: software was being developed in places like Bangalore in India, and computer chips were manufactured by Costa Rica for Intel. As barriers to connectivity diminished, the prospectus that information technologies would assist in fighting poverty were bright. By the end of the decade, revenue generated by the production of information and communication technology goods (like office equipment, telecommunications and consumer audiovisuals) showed the U.S. as absolute leader in the world, but with many Asian countries as close rivals, including Japan (2nd), Korea (3rd), Singapore (4th) and Taiwan (7th) and Malaysia (8th) (OECD 2000a).

In 1997, the OECD reported that even though industrialized countries accounted for more than 80% of the world market for information and communication technologies, expenditures in non-OECD countries such as Brazil and China had been growing at more than a double the OECD average (OECD 1997).

In 1996, a third of new phone lines worldwide were laid in China, and more cellular users were added than in any other country except the U.S. (ITU 1999). Many South East Asian countries like Singapore, Taiwan and Malaysia were seeking to emulate the Japanese model of development via the use of information and communication technologies. In the mid 1990s just outside Kuala Lumpur in Malaysia, Cyberjava was being designed to become a “model intelligent city” for the world. As the nucleus of the Multimedia Super Corridor (MSC), the Malaysian government expected within the next decade to use the MSC initiative as Malaysia's second engine of growth, catalyzing the transformation of Malaysia's economy from an industrial based economy to a knowledge based economy. In 2000 in Singapore, a small city-state with no natural resources was manufacturing about half of the world hard disk’s. Every other home in Singapore had a personal computer and the majority had access to the Internet via Singapore One, the world’s only nationwide high speed broadband network (Wired 2000).

By 1998, the Cayman Islands (pop. 36,000) had more cell phones per person than Germany, or more Internet hosts per capita than the US. The Cayman Island’s tradition of acting as offshore banking center and tax free business had dated from the 1960s. But by 1998, companies registered in the island outnumbered citizens and the small country hosted more than 568 banks producing a number of banking transactions placed through Cayman institutions exceeded only in the US, the UK, Japan and France (Wired 1998).

In 1999, Tunisia’s government launched the Communications Technology Park in a suburb in the capital Tunis, housing software startups, consulting and system companies. By 2000, the Internet could be accessed for the price of a local phone call even from remote parts of Tunisia. Likewise in 1999, in the northeastern South African province of Gauteng a technological corridor from Johannesburg to Pretoria was being set up by the University of Pretoria and a local research and development center linked by a cross continental fiber optic cable project called Africa One system, designed to accommodate all the traffic demand for the African continent for the next decade.

Furthermore, 1998/9 World Bank Report included many examples of how information and communication technologies were making a difference in the developing world:

> In rural Costa Rica small coffee growers use telecommunications to get marketing information from central cooperatives in the capital, which have computers linked to sources of information on national and international process.
>
> Farmers in Cote d'Ivoire use cellular phone to get international cocoa price quotations from Abidjan
>
> Farmer associations in Mexico use computers to monitor the government's rural credit program; armed with that information, they can negotiate to make the program fairer and more effective.
>
> The introduction of telephone service to several rural towns and villages in Sri Lanka allowed farmers to obtain current, firsthand information on other produce in Colombo, the capital. Before they obtained a telephone service, they used to sell their crops at prices averaging 50 to 60 percent of the Colombo price. Now they regularly get 80 to 90 percent of that price. (World Bank 1998, p. 60)

In spite of these trends and many more examples, both the United Nations and the World Bank acknowledged the existence of a "divide":

> Geographic barriers may have fallen for communications, but a new barrier has emerged, an invisible barrier that is like the world wide web, embracing the connected and silently – almost imperceptibly – excluding the rest. (UN 1999, p. 1)
>
> If knowledge gaps widen, the world will be split even further, not just by disparities in capital and other resources, but by the disparity of knowledge. Increasingly, capital and other resources will flow to those

> countries with the stronger knowledge bases, reinforcing inequality. There is also the danger of widening knowledge gaps within countries, especially developing ones, where a few fortunate surf the World Wide Web while others remain illiterate. (World Bank 1998, p. 14)

Had the exponential pace of information and communications technologies mainly served to benefit the post-industrial countries? Or had it created opportunities for "leapfrogging" development stages for developing countries? If there was such thing as a "digital divide", was it expanding or was closing?

The term "digital divide" was coined due to discussions raised by the U.S. Telecommunications Act of 1996 which was designed to ensure every American eventual access to advanced telecommunications networks and services, and more immediate access to basic telephone networks and services. Since then, the term has broadened and defined as differences in access to all digital information and telecommunications technologies, including the Internet. "Those with income, education and –literally- connections have cheap and instantaneous access to information. The rest are left with uncertain, slow and costly access. When people in these two worlds compete side by side, the advantage of being connected will overpower the marginal and impoverished" (UN 1999, p. 63). This means that even though the traditional geographic barriers to communications had fallen, new ones had emerged as illustrated in Figure 2.1. For example, during 1998 and until 2001 the "integration" of communications was concentrated among high income economies containing 19% of the world population, accounting for 91% of IT infrastructure and production in 1999. More than three quarters of Internet users in 2000 lived in countries that accounted for 14% of the world's population. (See Figure 2.1.).

By the end of the year 2000, the “digital divide” had attracted the interest of policy makers and scholars (Analysys 2000; Aspen Institute 1999; Baker 2001; Crenshaw and Robison 2000; Gage 2000; ITU 1999; Kirkman 1999; Mody and Dahlman 1992; Norris in press; NSF 2001a; NTIA 1999; NTIA 2000; Quaynor 2000; SIQSS 2000; Sirimanne 1996; U.S. Census Bureau 1999; Warschauer unpublished manuscript; Wilson 1999; Wilson and Rodriguez 2000). Initial research explored whether there was an information and communication technology gap between rich and poor countries, whether that gap was diverging or converging, and whether a link between the digital divide and gaps in income could be established both *within* countries, and *among* them. On the other hand, policy makers in international organizations, multilateral banks, and NGOs had started to implement programs to bridge the “divide” and programs to convert digital obstacles into “digital dividends”.