# Trends in Information and Communication Technologies

by

Marc BOURREAU

ENST, Département EGSH and CREST-LEI[#]

and

Michel GENSOLLEN

ENST, Département EGSH[##]

[#] ENST, Département EGSH, 46 rue Barrault, 75634 Paris Cedex 13, France. Tél: +33 1 45 81 72 46. Fax: +33 1 45 65 95 15. E-mail: marc.bourreau@enst.fr

[##] E-mail: michel.gensollen@enst.fr

# Trends in Information and Communication Technologies


## Abstract

In this article, we analyse current trends in information and communication technologies and services. We identify three main technological uncertainties. First, progress made in quantum computing could soon allow to crack current security systems, before the availability of quantum cryptography; hence, there may be a period with a lack of security. Second, open source software could be the first sign of a revolution in the way contents are produced or could be limited to very specific software. Third, human to machine interfaces and artificial intelligence appear as lasting bottlenecks for the development of the information society, and the possibility of breakthroughs is uncertain. Finally, we conclude with a discussion of policy implications.



**Keywords:** Information and Communication Technologies; Trends; Market development.

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## 1. Introduction

Between 1995 and 2000, U.S. productivity growth experienced a surge and achieved growth rates far beyond those of the 1950-95 period. This suggests that we could be at the beginning of a new technological revolution propelled by digital processing, pervasive networking and biotechnologies that will change how people communicate, work and consume. Some economists (e.g., Oliner and Sichel [2000] and Jorgenson and Stiroh [2000]) relate the observed productivity growth to the rate of technological progress in information and communication technologies (ICTs). Others (e.g., Gordon [2000]) compare this new "revolution" to the Second Industrial Revolution that took place between 1860 and 1900 and conclude that the marked acceleration of total factor productivity (TFP) growth in the last five years may not be due to ICTs.

Actually, the ICT revolution may take time to develop as the development of electrification took time in the 1920s (David and Wright [1999]). As long as the progress of factory electrification did not instigate any reorganization of the firms, there were no visible gains in productivity; but when the dynamo finally triggered thorough factory redesign, multi-factor productivity growth was rapidly achieved.

Since ICTs developed today will, to some extent, influence the pace of economic growth in the years to come, it is interesting to survey current trends in ICTs. In this article, we aim at providing such a survey.

For this survey, we interviewed ten experts in various technological fields between January and March 2001. In addition, two workshops were conducted in January and March 2001, the first one to evaluate trends and potential disruptions in ICTs, and the second one to determine factors that could influence the market success of innovations. A total of nineteen experts in different technical fields and in economics and management science participated to the research.[1] Using our interviews with technological experts, we surveyed the following fields: transmission, signal compression, networks, computer hardware, human-computer interaction, artificial intelligence, security and software. We focused our analysis on technological trends with social or economic impact.

In the following, we make a distinction between “hardware” technologies and “software” technologies. “Hardware” technologies are low-level technologies and include network and transmission technologies. “Software” technologies are “high-level” technologies and include software, compression, artificial intelligence and human-to-computer interfaces. For each technology, we provide a description of current trends, possible breakthroughs and lasting uncertainties.

This paper is related to other foresight exercises, which have been made on ICTs. Among these, the European FISTERA project is of particular interest. This project, which started in 2003, analyses the potential development of key ICTs. It aims at providing a synthesis of different national foresight exercises on the future of information society technologies by 2005.[2]

The rest of this article is organized as follows. In Section 2, we provide a description of “hardware” technologies. In Section 3, we describe “software” technologies. Finally, we devote Section 4 to some concluding remarks.

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[1] In Bourreau, Gensollen and Gille [2001], we provide the names and affiliations of the experts, as well as more details on the methodology.

[2] See the FISTERA web page, http://fistera.jrc.es/.

## 2. Trends in “hardware” (process) technologies

### 2.1 Security

Security is a major area of research that will probably shape the development of the information society. Reliable security solutions are expected to make interactions more secure (e.g., for electronic commerce) and to enable to convey information with perfect privacy.

Security systems provide today a good quality of service. Besides, it is expected that quantum cryptology, when it is implemented, will substantially increase piracy costs and perhaps provide perfect security. Commercial solutions based on quantum cryptography could be available in the next decade.

Quantum cryptography was developed in the early seventies. While classical cryptography uses various mathematical techniques to protect information, with quantum cryptography information is protected by the laws of physics. Quantum cryptography uses the Heisenberg principle and quantum entanglement; in this context, the act of detection destroys information. The basic idea is as follows. A sequence of correlated particle pairs is generated. One member of each pair is detected by each party. To intercept information, a third party would have to detect a particle, but this would destroy the quantum correlation with the other particle. The two parties could easily detect this.

However, due to large computing speed, quantum computers will be able to crack current security systems. As prototype quantum computers could be available before quantum cryptography, there might be a period with a lack of security, until quantum cryptography is available.

## 2.2. Transmission

"Transmission" refers to any network technology used to convey information, either in the local loop or in core networks. Transmission technologies include: access technologies, transmission technologies, switching technologies, etc. Current trends in transmission technologies are characterized by the following four factors:

- Bandwidth provided by transmission technologies is rapidly increasing.
- In terms of cost, there are two bottlenecks: transmission and switching. Currently, transmission costs decrease sharply over time, while switching costs decrease rather smoothly. However, optical switching technologies, when available, will lead to a sharp reduction in switching costs.
- With packet technologies, the marginal costs of traffic are low, but distribution (i.e., local loop) costs remain high.
- With wireless technologies (wireless local loop, mobile networks), it is necessary to use bandwidth as efficiently as possible, as it is costly and limited. It might also be true for DSL technologies. Indeed, bandwidth available on a copper line goes well beyond 8 Mb/s and could be under-exploited today.

*Fibre in backbone networks*

The increasing demand for bandwidth will progressively transform backbone networks into optical networks. Within five years, network operators will introduce optical cross-connect. In a second step, they will install optical routers. However, optical routers will not be available before ten years. As for transmission, wavelength multiplexing[3] will provide extensive bandwidth at a very low marginal cost.

[3] With WDM techniques, many wavelengths are sent over a single fibre.

Therefore, it seems reasonable to say that when optical switching (either through optical cross-connect or optical routers) is available, transmission costs will become negligible compared to other costs (such as, information processing costs, storage costs, commercial costs, etc.). This will be true even for the transmission of video programs.

*Wireless technologies*

New wireless technologies make it possible to use higher frequencies which have not been allocated yet by regulators.[4] In very high frequencies (e.g., 26 GHz for wireless local loops, 60 GHz for short-range networks, infrared for very short range networks), difficult interference problems remain to be solved. For instance, very accurate pointing mechanisms are required because systems are sensitive to atmospheric conditions. In home networks, walls and ceilings can be difficult to deal with.

UMTS technology is designed to provide 2 Mb/s per base station. Theoretical limits are around 15 Gb/s per station. However, increase in bandwidth – e.g., bandwidth doubled or tripled compared to the bandwidth available today on UMTS networks – will not be provided by UMTS itself but by fourth or fifth mobile generation networks. It seems also likely that it will always be much more costly to provide high bandwidth with mobile technologies than with wireline technologies.

Finally, within the next ten years, fixed and mobile networks will converge to some extent. The convergence will probably take place with the fifth mobile generation. Backbone

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[4] However, in higher frequencies, higher power is required to transmit signals. Indeed, the power necessary to cover a zone increases with the square of frequency. Therefore, with these technologies, operators have to build networks with very small cells. Since, each cell covers a very small area, more base stations are needed, which increases total investment. On the other hand, signal reception is easier in high frequencies, as lower signal-to-noise ratios are possible with the same error rate. This tends to reduce transmission power.

networks will at that time use IP technology and provide controlled quality of service (for real-time services, for instance). They will also be able to manage mobility. Convergence will provide operators with the opportunity to benefit from scale economies and scope economies. In particular, network management costs will be reduced.

*Satellite technologies*

Even though satellite constellations like Iridium have been economic fiascos, satellite technology might still be the most efficient and less costly technology in some cases. In particular, low-orbit satellite technologies can provide global coverage for an entire country. Satellite constellations could therefore be useful and viable technologies for large countries when the wireline infrastructure is not widespread (e.g., in India or Canada).

*DSL technologies*

Today, ADSL[5] technology enables operators to upgrade most existing copper lines to provide 2 Mb/s downstream and 0.5 Mb/s upstream.[6] Moreover, the upgrading cost is low. It is difficult to assess whether the available bandwidth on DSL connections could improve, without reducing the distance between DSLAM[7] and end customers. According to some experts – but not all – the theoretical bandwidth available on copper lines is currently under exploited.

[5] ADSL stands for Asymmetric Digital Subscriber Line.

[6] In urban areas, operators provide even higher bandwidth (8 Mbit/s downstream).

[7] DSLAM stands for Digital Subscriber Line Access Multiplexer.

*Fibre in the loop*

Fibre optic local loops will provide customers – including, residential customers – with very high bandwidth connections. It should be possible to develop fibre loops (at least to the curb) within five years. However, the need for fibre loops will depend mainly on the customers' willingness to pay for bandwidth.

A candidate technology is the technology known as "metro WDM". The fibre optic local loop goes to end customers up to a certain point (for instance, up to the curb); VDSL connections are used to connect customers in the last few meters.

## 2.3. Networks

We identified the following trends in network technologies.

*Next Generation Networks*

Next Generation Networks (NGN) will be available within five to ten years. NGN represent the convergence into a single, unified, broadband network of multiple independent networks including voice, video and data networks. Thus, legacy networks will benefit from greatly enhanced functionalities inherent to the unification of disparate networks. NGN will provide network operators with the ability to develop services that will not be specific to a given platform. With NGN, interoperability between different infrastructures will also improve. Therefore, it will be possible to develop new services in a very short time, compared to the time it takes today to develop new services.

*Multicast Internet*

Within five years, there will be a multicast Internet, which will make it possible to *broadcast* programs (such as, sport programs) to large audiences on the Internet, without experiencing big congestion.

*Caches*

When the distance between information and users of information is large, congestion issues may arise. The need to solve congestion issues leads to the development of technical solutions such as caches and mirrors.

*Ad hoc networks*

Ad hoc networks have been designed first for military purposes. The idea is to create a "network" that randomly links nodes together. A "mobile ad hoc network" is an autonomous system of mobile routers wirelessly connected and forming an arbitrary graph. The routers are free to move randomly and organize themselves arbitrarily; the network's wireless topology may change rapidly and unpredictably. Ad hoc networks could operate in a stand alone mode, or could be connected to Internet. These networks are self-organized and self-managed. For instance, some persons equipped with bluetooth chips would have the ability to organize in a network instantaneously. Ad hoc networks can be a technical solution to link communication devices together – for instance, at home.

Ad hoc networks are one example of a more general trend that moves network intelligence from the core to the terminals (peer-to-peer networks, such as Gnutella, are another example).

*Computing grid*

The idea is to team up computing resources within an evolutive network. A given user can connect to the grid and benefit from the computing resources of the whole network (which may therefore be huge).[8]

The computing grid aims at enabling users to access computing power and resources as easily as with electrical power. The "computational power grid" is in a way analogous to the electric power grid. It allows coupling geographically distributed resources and offers a consistent and inexpensive access to resources irrespective of their physical location or access point. The Internet or dedicated networks can be used to interconnect a wide variety of geographically distributed computational resources and present them as a single, unified resource.

Computing grids may be interesting for research purpose. They may also create new business models. Indeed, the computing grid approach is pushed forward by some computer manufacturers. The idea could be to propose to a customer a discount for a network of computers if it agrees to give access to its computers from a computing grid when they are not used.

## 2.4. Computer Hardware

Computers will comply with Moore's Law until 2010 (in terms of processing power).[9] It is unclear whether incremental improvements will still be possible after 2010. Radical alternatives to conventional lithography-based VLSI technology could be:

[8] The project "SETI@Home" is one example.

[9] Moore's Law states that the density of transistors in a chip doubles every eighteen months.

- *Molecular computers*: computers based on macro-molecules could be available within ten years, but their availability will depend on the progress made in molecular engineering.
- *Bio computers*: biochips exploit the storage capabilities of oligonucleotides molecules and the massive parallelism involved in processes of DNA hybridization and ligation; DNA is also used as a basic building block for self-assembly of nanostructures.
- *Quantum computers*: quantum computers will be faster than existing computers. They will make parallel computing very easy. Quantum computers will be used to solve problems that are intractable today (e.g., meteorology and various NP-complete problems). They will probably still be in their infancy in 2010, though some prototype quantum computers might exist by then.

Notice that research in these three fields will probably not reach the marketplace before ten to fifteen years. Therefore, in the next ten years, Moore's Law will remain valid.

## 3. Trends in "software" (product) technologies

### 3.1. Software

The software industry could be a source of major innovations in the coming years. In particular, the production function of software could be transformed substantively, due to both the open source movement and to the development of new computer languages.

The open source movement is a striking example of the evolution of the software industry. Free software is usually "free", which means that it is priced at zero.[10] However, it is

[10] Note that, incidentally, some "free" software applications are charged a strictly positive price, even though the source code remains "opened".

only a consequence of a more fundamental characteristic: with free software, the source code is "opened" to outside developers and protected by particular types of copyright (from the GPL license known as copyleft to the BSD - Berkeley Software Distribution license).[11]

Therefore, the issues raised by the open source movement slightly differ from the copyright issues related to texts or images. Indeed, open source appears to be mainly a new and more efficient way to produce software. It does not seem to aim only at selling software at marginal cost (which is equal to zero).[12]

Open source software provides professional customers with better quality of service compared to proprietary software for the following reasons. First, since the source code can be accessed, it is possible to adapt the software to the very need of one company or one application. Therefore, open source developers can easily develop specific add-ons, for instance for a given customer. Second, open source software makes client companies less dependant upon software companies, as the source code is opened. It protects the client company from market aleas in the software industry (e.g., the software company may disappear). It also protects the client company from rent extraction strategies. Third, the open source way of developing software is claimed to increase quality of software: since the source code is opened to any developer who works on the project, global optimisation is realized in a more efficient way. Fourth, open source software improves quality of support, due to the new support focused business model mentioned above.

The new production function requires a new business model. In this new model, revenues are generated mainly by high-level support services to large customers (companies, etc.). Therefore, the general public tends to pay less for free software than it pays for

[11] See the GNU doctrine for more detail (http://www.gnu.org/philosophy/free-sw.html).

[12] The GNU doctrine states: " "Free software" is a matter of liberty, not price. To understand the concept, you should think of "free" as in "free speech" not as in "free beer".

proprietary software. However, it should be noted that: (i) free software address mainly professional needs; (ii) producers of proprietary software use demand segmentation techniques, that may have similar effects (for instance, a "light" version of the software may be delivered for free).

Open source software also requires a sophisticated segmentation of demand. Progressive *releases* may play that role. Some releases are delivered exclusively to main customers, who benefit from a tailor-made software in advance of their competitors. Public releases are less frequent. They are realized with well-tested and standard versions of the software. The incentives of the software company to provide public releases are: advertising, bug fixing, stimulating additional developments which will increase the value of the software, imposing the software as a standard (due to network externalities).

Free software are not always completely "free" or "opened". Copyleft rules are not used when they could slow down the adoption of free libraries. Elementary parts of software libraries are not always "polluting". A "polluting" piece of software transforms – from a legal point of view – any software that uses it into an open source software. Therefore, free software can compete with proprietary software on several market segments (operating systems, libraries, general applications, specific applications, etc.).

Some authors argue that open source software is a very specific phenomenon in the software industry. The proposed explanations for the development of the open source movement focus on signalling effects (see Lerner and Tirole, 2002): a developer decides to work on a given open source software project to acquire good reputation (i.e., it can work efficiently with other developers and accept his colleagues to read and correct his code). As salary depends on reputation, developers have incentives to participate to open source projects.

Our analysis leads us to think that open source could be more than what these authors suggest: fundamentally, open source seems to be a more efficient way to produce software. It must be noted that this movement was initiated by creators (software developers) who were looking for a more efficient way to produce content (software). One key question is therefore whether this production model could be applied in other creative areas: R&D, artistic creation (music, films, etc.), and more generally in fields where value creation depends heavily on individual inventions.

At the same time as free software develops, there is today also a tendency towards stronger protection for software through patents rather than copyright. How will this closed model compete with the open model of free software? There is no clear answer yet to this question.

Therefore, the potential of open source software remains highly uncertain. On the one hand, free software could have limited impact on the software industry and be limited to specific software applications. On the other hand, free software could well substantially transform the way software is developed and open source development methods might also spread outside the software industry.

### 3.2. Human-Computer Interaction

The progress made in human-computer interaction will determine, to a given extent, how technological advances could spread widely into the marketplace. Indeed, we think that the human-computer interfaces used today are inadequate to be handled by everybody. Therefore, these interfaces can be viewed as a bottleneck for the development of the information society.

The diffusion of human-computer environments is very slow. For instance, it is common to observe a ten year time lag between the invention of a human-computer device (e.g., the “mouse”) and its adoption as a common input device for computers. Diffusion is slow mainly because users learn very slowly. As a consequence, human-computer interfaces may give rise to lock-in effects, when one technology, although inefficient, is used widely and cannot be overcome by a more efficient technology. For instance, it has been stated that the QWERTY keyboard is not the most efficient keyboard.[13]

Since the delay between the invention of a new interface and its adoption by customers is very long and since they can be copied at low cost, human-computer environments can hardly represent a competitive advantage. For example, the computer environment used today (icons, mouse, windows) has been elaborated progressively by Xerox, Apple and Microsoft.

Research in human-computer interaction is characterized by rare, unpredictable and radical innovations (e.g., mouse or icons). Today, the most promising research projects focus on complex interfaces, which associate different "modes" in parallel. A mode is a means of interaction between humans and computers (mouse, voice, etc.). Current research analyses how the following modes could be complementary and progressively replace existing modes (keyboard, mouse, screen): voice (which requires voice recognition and synthesis); writing (on a screen); tactile screens, tablets, intelligent paper; glasses.

In the field of complex interfaces, the following research paths are currently investigated. "Improved reality" systems add virtual information to reality. For instance, relevant information could be displayed on glasses to help people make appropriate decisions. This could be useful for a tourist to find its way into a city or for a professional to repair a lift. Efforts are also made in terms of iconography, using metaphors.

Within ten years, a new mode or medium could appear and become widely used. This could be a device similar to web cams. Web cams have the advantage of being a non-intrusive device. They could be used to recognize gestures and lips movements, which would help to understand contextual information.

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[13] For instance, see David [1985] and Arthur [1989].

Voice recognition is still a difficult issue for researchers. The problem is that voice recognition has to be almost perfect to be useful. Indeed, if the machine does not understand the user, the user will be reluctant to use it at all. Since quality of service is difficult to measure or even to define, it is difficult to estimate when voice recognition could be readily available. Besides, there might be only a small distance between a technological failure and a technological success.

As for automatic translation, progress has been rather slow for the last twenty years. Two techniques are currently investigated: the interlingual method and the transfer approach. The former, which requires only translation to and from the interlingua (a sort of pivot language), has strong limitations. We do not know yet what could come out from the second research path, the transfer approach, according to which a major part of the translation system for a given pair of languages is specific to that pair. Therefore, it seems that natural languages are far too complex to be the appropriate medium for human-computer interaction in the next ten years.

Communication or interaction devices will probably diversify. Personal digital assistants will be able to communicate. Other devices could spread: improved reality glasses and e-books. One of the major challenges for research in human-computer interaction is certainly to produce a light, low-powered and affordable e-book. However, some difficulties remain. First, the screen has to be of sufficiently good quality so that reading on the screen is easy and not too tiresome. Second, it should be easy to enter information into the device: this could require writing recognition or voice recognition.

Our analysis therefore suggests that while the potential impact of human-computer interfaces and devices is huge, the probability of success of the various research paths explored today is still highly uncertain.

### 3.3. Signal compression

Compression technologies are of key importance for audio or video applications such as online music, interactive television, pay per view, etc.

There have been large improvements in signal compression technologies for the last few years. This step forward is due to the implementation of discrete cosinus transform (DCT) and block coding. The MPEG2 standard relies upon these two technical innovations.

It seems that large improvements in compression rates cannot be expected in the near future. For instance, the recent MPEG-7 standard – which came out in 2001 – does not increase compression rates. This standard, formally named "Multimedia Content Description Interface", rather addresses content indexation issues. More precisely, it makes it possible to convey context information within a signal through a separate channel. For instance, for films, it would be possible to insert scripts within video signals. Various promising applications of MPEG-7 for interactive television can be expected (for instance, one would have the ability to search for a given sequence with one actor or another). Work on the new MPEG-21 standard does not aim at increasing compression rates either but focuses on the interoperability of multimedia systems.

Current research that aims at improving compression rates seems less promising. It seems as if no real progress could be expected in the next five years. However, one should bear in mind that this analysis rules out any major disruption that could occur in the meantime.

For audio files, the AAC standard (« MP4 ») increases compression rates by a factor of two compared to MP3, for similar encoding and decoding times. However, it seems that this standard could not be substantially improved in the near future. As for pictures, the "jpeg2000" standard provides a gain around 30, but encoding time is multiplied by 100 and the time necessary to decode is multiplied by 10.

For video, one way to improve compression rates would be to use wavelets. Compression technologies based on wavelets provide gains around 30% but the needed computing capacity is multiplied by ten. Moreover, with wavelets, processing cannot be divided into small blocks, but has to be made on the whole picture. This is an issue, because processing cost is convex with the size of images – i.e., in the order of n.log(n). Therefore, there is a trade off between processing costs and compression rates. Finally, fractal coding is a very asymmetric compression technology, which means that encoding information takes a lot of time. Therefore, this technology – if ever available – will probably not used for real-time broadcasting.

To summarize, it seems that no major improvements in compression technologies should be expected in the next five years. Though video programs are available on xDSL networks now, one question remains: will it be possible to provide video to mobile users on 3G mobile (UMTS) networks at a sufficiently low cost?

### 3.4. Artificial Intelligence

Artificial intelligence (AI) is closely related to the field of human-computer interaction. One aim of research on AI is to improve the collaboration between human intelligence and artificial (i.e., computer) intelligence. In particular, much effort is devoted today to improve Internet search engines. As a consequence, it is widely expected that search engines will substantially improve over the next decade in the way they classify information and understand human requests.

Another field of research aims at developing clones, agents, alias or robots with artificial intelligence and capabilities. Within five to ten years, agents with some intelligence will be able to realize simple tasks, such as commerce transactions, search of information, negotiation, etc. However, it is clear that artificial intelligence will not catch up with human intelligence before a long time, except in case of an unexpected and drastic technological disruption.

Therefore, the ability of AI research to improve human-computer interaction or to produce autonomous and efficient agents is still uncertain, though important.

## 4. Conclusion

In this article, we described likely trends in information and communication technologies for the ten years to come. This analysis reveals three main uncertainties with regards to technological progress in information and communication markets. First, progress made in quantum computing could soon allow to crack current security systems, before the availability of quantum cryptography; hence, there may be a period with a lack of security. Second, open source software could either be the first sign of a revolution in the way contents are produced or be limited to very specific software. Third, human to machine interfaces and artificial intelligence appear as lasting bottlenecks for the development of the information society, and the possibility of breakthroughs is uncertain.

For the digital economy to develop smoothly and without too many difficulties, social tensions or business uncertainties, three conditions must be met : (1) no lasting gap of security, endangering consumers' privacy or business incentives to innovate; (2) new production process for content production, allowing at the same time large economies of scale to recoup fixed cost of conception and sufficient product variety for real mass customization; (3) efficient, friendly and low-cost interfaces with the virtual world, in order to build some continuum between reality and representations.

Without one of these technical breakthroughs, some elements of regulation or legislative framework would have to be changed.

If there is a lack of security in the virtual world, numerous applications will not take off as most users will be concerned by the lack of privacy (e.g., consumer data base in the case of e-commerce) or by the threat of fraud (e.g. payment through insecure networks). They will be even put off by the cost and user-unfriendliness of content protection (e.g., clumsy digital right management systems considering customers as potential thieves and denying them even fair use). Such a situation would call for a hardening of law and penalties towards hackers and "virtual trespassing", which would however result in making the virtual world an unfriendly world.

If progress made in content production is not sufficient, the new software applications and entertainment products needed for the virtual world will not appear. The processes that are sufficient for a broadcast society where all customers are fed with the same information are not sufficient in a world of pervasive networking, where everybody can access specific and customized products. The content production process must therefore develop new techniques: (a) for designing and writing meta-contents (i.e., general elements that can be freely used on a very large scale: software libraries, videogame engines, concepts of TV-programs, of books or movies, etc.); (b) for adapting these general elements to each culture and each customer segment; this can be done at low cost if some customers can be induced to participate in the production process (e.g., beta-testers or early adopters becoming co-designer of customized software, videogame skins or cultural versions). Without this technical evolution, the virtual world could become a world of content scarcity, overpaid talents and stars (cf. the recent evolution of the price and salaries of football players) and low quality information products.

If human-machine interfaces remain awkward and difficult to get accustomed to, if the gates to virtual environments are expensive and developed mainly for business purposes, if there is no efficient search engine, no possibility to easily ask questions using natural languages, the virtual world will remain a privilege of the few. This will be true even though it is necessary to give access to many if the fixed costs are to be recouped. The digital divide could be a matter of income (no computer, no home Internet access...) but more often it relates to a lack of acculturation when human-machine interfaces are not user-friendly and require specific training.

If the virtual world can be accessed only by privileged customers, the main regulation questions will revolve around universal service (e.g., universal broadband access) and cross subsidies towards rural and high-cost areas, low-income households (a sort of life line assistance for the virtual world).

This analysis underlines that, if technological progress often raises new regulation issues, the lack or delay of some technological innovations also presents new policy issues (and puts existing policies) in a new light.

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